AGROFORESTRY SYSTEMS AND PRACTICES IN NEPAL

(REVISED EDITION)

SWOYAMBHU MAN AMATYA
EDWIN CEDAMON
IAN NUBERG

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Front Cover:

A hillside farm in Kavre Palanchok district showing homesteads surrounded by mustard in bloom on terraces, fodder trees Dhudhilo (*Ficus nemoralis*) and patches of private forests (mainly pine trees) and community forest in the far background to the right side. Photo by: Edwin Cedamon

FOREWORD

Farmers in the hills of Nepal have practiced agroforestry for centuries. For much of this time, farmers grew trees to meet subsistence farming needs, but the nature and extent of these practices depended on the size of their land and the accessibility of fuelwood and fodder from community forests. Over the last decade, much has changed in the rural areas of the Middle Hills. Household livelihood expectations have changed, many families have individuals working in cities or outside Nepal which has increased household income and reduced labour availability. Throughout this period, the role of agroforestry in Nepalese farming system has remained important, but the need for improved agroforestry systems and better knowledge of the various agroforestry options and market possibilities has increased.

This book written by Dr Swoyambhu Man Amatya, Dr Edwin Cedamon and Dr Ian Nuberg makes a timely contribution to the agroforestry knowledge base in Nepal and is a testament to the knowledge of and passion for agroforestry that these three scientists have. It builds on earlier work by Dr Amatya and incorporates new knowledge and experienced gained over the past 5 years while they had been collaborating on the Enhancing livelihoods and food security from agroforestry and community forestry in Nepal (EnLiFT) project which was funded by the Australian Centre for International Agriculture Research (ACIAR). One of the objectives of the EnLiFT Project was to improve the capacity of household-based agroforestry systems to enhance livelihoods and food security. A survey of the impacts from the project's agroforestry interventions showed that average farm incomes increased by 57% from NRS 44,817 to NRS 70, 622 which brought an additional 14% of households above poverty line and enables and additional 16% households to achieve food security. Clearly these results demonstrate the great potential that improved agroforestry systems in Nepal.

The ten chapters in this book make a comprehensive presentation of the current knowledge base for agroforestry, from understanding the local context including local farming systems and socio-cultural aspects through to describing benefits, practices, regulatory environment and markets relevant to agroforestry systems. In doing so, it describes what is known, what some of the challenges are and what further research is needed to improve the functioning, profitability and governance of these important farming systems. The book will be a valuable resource for students, academics, forestry and agricultural extension officers and all those people around the world who have interest in agroforestry.

Tony Bartlett

Forestry Research Program Manager

Australian Centre for International Agricultural Research
Canberra, Australia

Australian Government

Australian Centre for International Agricultural Research

FOREWORD

The combined use of land for different crop types in agroforestry systems often leads to increased productivity and other added benefits as compared to a segregated use of land either for agriculture or for forestry. The multifunctional approach of agroforestry systems may consequently help solve or alleviate many problems associated with increasing human population densities, poverty and scarcity of land for food production and for goods and services derived from trees.

The 2018 edition of Agroforestry Systems and Practice in Nepal is an interesting and comprehensive update on agroforestry in Nepal. Authored by Dr Swoyambhu Man Amatya (Agriculture and Forestry University of Nepal) in cooperation with Drs Ian Nuberg and Edwin Cedamon (University of Adelaide, South Australia) this publication sets a standard for many policy and management issues in agroforestry.

Dr Amatya currently serves as coordinator of the unit for agroforestry in IUFRO (International Union of Forest Research Organizations). This position is a hot spot for international exchange of practical experience, views and ideas as well as of scientific agroforestry research. Readers of the book will benefit from this dynamic. I hope the book will influence agroforestry practices and serve as inspiration for further developments in Nepal and beyond.

Jens Peter Skovsgaard

Coordinator of IUFRO Division 1 Silviculture

Professor of Silviculture, Swedish University of Agricultural Sciences

IUFRO

Agriculture and Forestry University

Chitwan, Nepal

FOREWORD

Agroforestry has been practiced all over the world since time immemorial. Farmers have developed sustainable agroforestry systems that produce crops, trees, livestock, fish, medicinal and aromatic plants, and other related forest resources. In our country empirical evidence suggests that agroforestry can provide a sound ecological basis for increased crop and animal productivity, more dependable economic returns, and greater biodiversity. In view of these, agroforestry is increasingly becoming an important landscape feature of Nepal and the entire hill farming systems of the country.

Agroforestry practice in Nepal generally aims for meeting the present and future requirements of fuel wood, small timber, fodder, and Non-Timber Forest Products including Medicinal and Aromatic Plants, and for environmental services to include watershed functions, slope stabilization and erosion control, environmental protection, and microclimate amelioration.

With the opening of the Agriculture and Forestry University, agroforestry discipline has becoming more demanding. Since there are very few books, booklets and other references on Nepalese agroforestry systems, I am very happy to see the revised edition of the book written by Dr. Swoyambhu Man Amatya, Adjunct Professor of AFU and two eminent scientists, Dr. Edwin Cedamon and Dr. Ian Nuberg both from University of Adelaide, Australia.

I would like to congratulate the author team for their effort in revising and editing the book "Agroforestry Systems and Practices in Nepal" written by Dr. Amatya during early 1994. I am particularly happy that our little financial support was very productive, effective and useful. I hope that this revised version of the book provides in great extent, insights of Nepalese agroforestry to our researchers, students, policy makers, academicians and interested general public. I am sure this book would be an additional asset for us.

Mana Raj Kolakshayapati
Registrar
Agriculture and Forestry University, Nepal

Agriculture and Forestry University

Office of the Vice Chancellor

FOREWORD

ure and honor to write few words on the publication of Agroforestry book. I am happy to see the joint effort made by Nepalese and foreign scholars towards this direction by revising "Agroforestry Systems and Practices in Nepal" an old book written by Dr. Swoyambhu Man Amatya, a professional forester, in 1994. I would like to appreciate and congratulate all the concerned authors for bringing this publication in final shape.

Farming system in Nepal generaly depends on the various types of products that are obtained from forests. Rural people collect green biomass (fodder) as livestock feed and leaf litters from forests for animal bedding. They take livestock to forests for grazing throughout the year. As a result forests are degraded and receding from villages. This type of systems is being practiced in Nepal since time immemorial. In other words, forestry is an integral part of farming system in Nepal.

Our forefathers have been planting tree species for multiple uses such as food, shelter, medicine and spices in and around their farmland. Agroforestry practices are seen to improve livelihood through increasing the asset base for households, increasing productivity of both tree and agriculture crops, help conserve ecosystem and biodiversity, and improving agriculture landscapes including protection against environmental degradation.

As I understand a complete book on this subject matter has not been published so far. I am confident enough that this book will help a lot to students, academicians, researchers and general readers to understand the systems and obtain benefits through implementing appropriate practices in the field. I believed that this book will also guide policy making personnel of the Government of Nepal in taking decisions on developing agroforestry policy as one of the viable land use options.

This book is one of the best examples of developing synergy between national and international professionals. I would like to congratulate Dr. Amatya, Adjunct Professor of our university, Dr. Edwin Cedamon and Dr. Ian Nuberg, University of Adelaide, Australia for their tireless efforts in bringing out this revised edition.

Prof. Ishwari Prasad Dhakal, Ph.D
Vice - Chancellor

PREFACE

Agroforestry Systems and Practices in Nepal, a small book was prepared soon after I was back from Agroforestry training at Silsoe College, Cranfield University, Bedford, United Kingdom (UK). During the training I learned Agroforestry in much detail. The exposure visits at various Agroforestry research stations at UK and various parts of Spain were very productive in observing the beneficial combinations of trees and agriculture crops at same space and time. That training inspired me in writing the small book on Agroforestry in Nepalese context. It was published by the then Forest Research and Survey Centre, Ministry of Forests and Soil Conservation, Kathmandu in 1994.

There was a realization that Agroforestry could be a viable option of livelihood development especially in private farmlands of the country. Hence, various Universities in the country have initiated in teaching Agroforestry course at its Bachelor and Master level. Nonetheless, there was no comprehensive book on Agroforestry in the Nepalese context. The small book Agroforestry Systems and Practices in Nepal was not representing total Agroforestry scenarios of the country. I was tempted to revise that book but finding difficulty in collecting field data as no resources were available. I approached many related institutions within and outside the country but without success. But I did not leave my insight of revising the book. In this context, I am very thankful to Dr. Balram Bhatta, Dean, Agriculture and Forestry University who took the notice of my desire and on behalf of Agriculture and Forestry University, Rampur, Nepal provided a token of resources to carry out the field wok. I sincerely thank Dr. Bhatta and the concerned personnel of the Agriculture and Forestry University for their cooperation.

Agroforestry systems are, by definition, more complex than mono-cultural production systems, it is important for the student to understand the many interactions between the components of an agroforestry system: trees, crop plants, livestock, soil, water, climate, as well as the farming household. The knowledge of the principles of these interactions is essential for scientifically informed innovation of agroforestry systems that meet the developmental needs of the rural economy.

As our understanding of how Nepalese agroforestry systems continue to grow, there are still rooms for improvement to meet the demands of the rapidly changing Nepal economy and society. The success of agroforestry system identification for suitable sites, adequate and reliable information on options of different combination of cereal, fruit and tree crops and species selection are absolutely needed.

I was alone to write the book Agroforestry Systems and Practices in Nepal in the past but now I am very happy that my two other colleagues Dr. Ian Nuberg and Dr. Edwin Cedamon, both from the University of Adelaide, South Australia, have joined me in revising it.

The botanical name of plant keeps on changing. This is mainly because of the change in the nomenclature of the plant. For example, Loth sallo or Talispatra in Nepali is used to be scientifically called *Taxus bacata* now it is being recognized as *Taxux wallichiana*. Similar is the case with Jatamansi (*Nardostachys grandiflora*). Previously the botanical name of this species was *Nardostachys jatamans* now it is being known as *Nardostachys grandiflora*.The case is similar with Ipil-Ipil (*Leucaena leucocephala*). The plant now has its botanical name as *Leucaena latisiliqua*. Therefore, as far as possible, in this book, the latest botanical name of the plant have been spelled out in local name followed by scientific name in bracket following the Catalogue of Nepalese Flowering Plants published by National Herbarium and Plant Laboratories, Department of Plant Resources, Ministry of Forests and Soil Conservation, Government of Nepal in the year 2011. Similarly, the year cited in the book are both B.S (Bikram Sambat) and A.D depending on the individual publication. To convert BS to the 'Gregorian System', subtract roughly 57 years. For example, Baisak 2074 BS means April/May 2017.

This book has been revised as a foundation study for Agroforesty in Nepal. It has 10 chapters and covers almost all aspects of Agroforestry in line with the Bachelor and Master level curricula of Agriculture and Forestry University, Rampur, Nepal. We are aware the chapters are not balanced in terms of its content because these were developed based on the available information to the authors at the time of writing. However, we hope this book will be helpful to students, academicians, practitioners and other individuals interested and or eager to practice Agroforestry.

While revising the book we have consulted numerous books and journals, and we would like to acknowledge gratefully all those authors for that. While developing and editing the book care have been taken not to make any typographical error but there could be some and I must conface that it is mine. There could be a lot of scope for its improvement. I hope the suggestions and feedbacks obtained from readers will be incorporated in the next edition of the book.

Swoyambhu Man Amatya

Kathmandu, Jesth 18, 2074

(1st June 2018)

ACKNOWLEDGEMENT

The concept of revising the book wouldn't have been materialized if Dr. Balram Bhatta, Dean, Faculty of Forestry, Agriculture and Forestry University, Hetauda, haven't taken the necessary administrative process. We would thus like to thank him very much for his active initiative.

Appreciation also goes to the Australian Centre for International Agricultural Research (ACIAR) for their support to Dr. Cedamon's salary during his time spent in manuscript preparation, editing and desktop publishing.

Our thanks are due to Dr. Sindhu Dhungana, Chief REDD cell, Ministry of Forests and Soil Conservation, Mr. Yam Pokharel, Deputy Director General, Department of Forest Research and Survey, and Mr. Shiva Khanal, Research Officer of the same department for their support in providing documents and other related materials.

We sincerely thank Dr. Yam Malla, a distinguished eminent forester of Nepal, and former country representative, International Union for Conservation of Nature and Natural Resources (IUCN) and to Dr. T. P. Barakoti, the then Agroforestry Research Officer at Tribhuvan University/ International Development Research Centre (IDRC) Farm Foresry Project, and Agroforestry Research Scientist/ as well as Coordinator of Nepal Agricultural Research Council (NARC) for going through and providing invaluable inputs on this book. Dr. Barakoti is highly acknowledged as he provided valuable data and information for this book.

Similarly, we would like to thank Prof. Dr. Naba Raj Devkota, Director of Research and Extension, Agriculture and Forestry University, Rampur, Chitwan, Nepal for his invaluable feedback for this book. We would also like to thank Mr. Bharat Shrestha, District Forest Officer, Illam, Mr. Sudhir Koirala, Regional Forest Director, Far-Western Regional Forest Directorate, District Forest

Officers of Kailali and Baitadi Dr. Rajendra K. C. and Mr. Prabhat Sapkota respectively for their cooperation during our field visit in those areas.

Last but not the least we sincerely thank Dr. Bishwa Nath Oli, Secretary, Ministry of Forests and Environment, Government of Nepal, for thoroughly going through the book and providing valuable feedback.

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Chapter 1

COUNTRY BACKGROUND

Nepal is a small country (with regards to its geographical area of 147, 181 km[2]) in comparison with its neighbours, India in the South and China in the North. The altitude ranges from 70 metres above sea level in the South to 8,848 metres at the summit of Mount Everest, in the North. The climate ranges from sub-tropical in the low lands to alpine in the High Mountains.

The country can be divided into five physiographic zones based on altitude: Terai, Siwalik, Middle Mountain, High Mountain and High Himal. Terai is a flat and plain land inclining gently towards south of Nepal with average elevation from 70 to 300 metres. On its north lies Siwalik, the elevation between 300 m to 920 m (DFRS, 2008). The Middle Mountains are located at an altitude between 200 m and 3000[1] m between the Terai and the High Mountains. The High Mountain and High Himal fall in the northernmost part of the country on the border with China. The altitude in these regions is typically more than 2300 m.

Climatically, the country can be divided into three distinct seasons. Cold season from October to February, Hot and dry season from March to mid-June and Rainy season from Mid-June to the end of September. The average annual rainfall in Nepal is about 1,600 mm. The eastern region is wetter than the western region due to early and higher rainfall. Eighty percent of precipitation comes in the form of the summer monsoon rain prevailing in the country from June to September. Winter rains are more common in the western hills. Temperature varies with topographic variations in the country. In the Terai, winter temperature is between 22° -27° C while summer temperature exceeds 37°C. In the mid-hills, temperature is between 12° – 16° C and in higher up occasionally it snows.

The economy of the country is predominantly agrarian and characterised by low productivity. Nepal has a population of 26.5 million with the population density of 180 people per square

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[1]Based on the agricultural classification, less than 1000 m is low hill, 1000-1900 m is mid hill and above 1900 to 3000 m is high hill.
[2]Source: Ministry of Forest and Soil Conservation, 2010.

kilometre (CBS, 2016). Approximately 70% of the people are forest dependent[2] and 66% of the population live off a combination of agriculture and forest products (ACIAR Report 2014). The economic growth of the country in terms of Gross Domestic Product (GDP) was 3.5 % in the year 2010/2011 (CBS, 2011). Agriculture and Forestry are estimated to contribute about 33% of the GDP followed by non-agriculture sector such as industry, housing rent, and the real market (67%). The Human Development Index is 0.55 (UNDP, 2016).

According to the new constitution of Nepal (2072), the country is divided into seven (7) Pradesh (provinces). The Number of districts that each Pradesh (province) include is given in Table 1.

Table 1: Number of districts in each Pradesh (province) and forests area coverage.

Pradesh Number	Total number of districts	Districts included in Pradesh	Total land area (ha)	Forest area (ha)	Forest area (%)	% of forest in the total forest area
1	14	Taplejung, Panchthar, Illam, Sakhuwa sabha, Tehrathum, Dhankuta, Bhojpur, Khotang, Solukhumbu, Okhaldhunga, Udayapur, Jhapa, Morong and Sunsari	25,90,500	11,34,250	43.78	17.3
2	8	Saptari, Siraha, Dhanusha, Mahottari, Sarlahi, Rautahat, Bara and Parsa	9,66,100	2,63,630	27.29	4.4
3	13	Dolakha, Ramechap, Sindhuli, Kavrepalanchok, Sindhupalchok, Rasuwa, Nuwakot, Dhadhing, Chitawan, Makawanpur, Bhaktapur, Lalitpur and Kathmandu.	20,30,000	10,90,877	53.74	17.5
4	11	Gorkha, Lamjung, Tanahun, Kaski, Manag, Mustang, Parbat, Syanja, Myagdi, Baglung and Nawalparasi (Barda ghat East of Susta)	21,50,400	7,96,991	37.06	11.7
5	12	Nawalparasi (Bardaghat West of Susta), Rupandehi, Kapilbastu, Palpa, Arghakhanchi, Gulmi, Rukum (East side), Rolpa, Piyuthan, Dang, Banke and Bardiya	22,28,800	9,87,445	44.30	15.9
6	10	Rukum (West side). Salyan, Dolpa, Jumla, Mugu, Humla, Kalikot, Jajarkot, Dailekh and Surkhet.	27,98,400	11,90,631	42.55	16.1
7	9	Bajura, Bajhang, Doti, Acham, Darchula, Baitadi, Dadeldhura, Kanchanpur and Kailali.	19,53,900	11,46,106	58.66	16.9
Total	77		1,47,18,100	66,09,930	44.91	100

Source: Forest Research and Survey Department, 2016.

Latest forest resource assessment data reveal that out of the total land area of the country, forest including other wooded land comprises around 5.96 million hectares (44.74 %), 1.56 million hectares (12%) of grassland, 3.0 million (21%) of the farmland, about 1.06 million hectares (7%) of uncultivated inclusion. The data shows that the forest areas have increased nearly by 5.14 percent. (Table 2)

Table 2: Land use of Nepal

Categories	Area (Million hectares)	Percent
Forest*	5.96	40.36
Other Wooded Land *	0.64	4.38
Grass land **	1.77	12.0
Agriculture land **	3.09	21.0
Non-cultivated inclusions**	1.03	7.0
Water, streams, and river beds**	0.38	2.6
Urban and industrial areas**	2.62	17.8
Total	15.49	105.14

*Source: DFRS, 2016. ** Source: GoN/MoFSC, 2014.

Forest, range land, wetland, and agro-ecosystem are the major ecosystem groups of Nepal. A total of 118 ecosystems are found in Nepal. Of the five physiographic zones of the country, Middle Mountain has the maximum number of ecosystems (Table 3).

Table 3: Number of ecosystems in Nepal

Physiographic Zone	Ecosystems	
	Number	%
Terai	12	10.2
Siwalik	14	11.9
Middle Mountains	53	44.9
High Mountains	38	32.2
Other	1	0.8
Total	118	100

Source: GoN/MoFSC, 2014

INTRODUCTION TO AGROFORESTRY

Agroforestry is one of the alternatives for sustainable natural resource management promoted in the world over. As a land use system or practice of integrating trees or woody perennials, crops and animals in some spatial or temporal pattern, it has been practiced for centuries by farmers in many countries. The aim of agroforestry systems is to increase, diversify and sustain production of economic, environmental and social benefits.

DEFINITION OF AGROFORESTRY

Agroforestry is a land use system where agriculture and forestry disciplines are combined to provide multiple products (food, timber, fodder, fuel wood, leaf litter, medicine) related with agriculture and forestry in a given space and time. It is an age-old practice in Nepal and farmers have been practicing various combinations of tree and agriculture crops since time immemorial.

Agroforestry as a science has emerged almost four decades ago. Empirical evidences suggest that it can provide a sound ecological basis for increased crop and animal productivity, more dependable economic returns, and greater biodiversity. It has an important role in reducing vulnerability, increasing resilience of farming systems and buffering households against climate related risk in addition to providing livelihood security. Agroforestry has the potential to provide most or all the ecosystem services.

Scientists have defined Agroforestry in various forms. The World Agroforestry Centre (WAC) then International Centre for Research on Agroforestry (ICRAF) has defined Agroforestry as "a land use system that integrates trees with agricultural crops and / or animals, simultaneously or sequentially, to get higher productivity, more economic returns, and better social and ecological benefits on a sustained yield basis, than are obtainable from monoculture on the same unit of land, especially under conditions of low levels of technological inputs and on marginal sites" (ICRAF, 1982). Lundgren and Raintree (1982) have defined "Agroforestry as a collective name for land use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.)

are deliberately used on the same land management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence.

Definitions of agroforestry have gradually been refined in terms of the services it provides and combination pattern of both agriculture and forestry products. Gordon and Newman (1997), for example, have included both ecological and economic interactions between the different components in agroforestry systems. Nair (1989) has put more stress on soil conservation and erosion control aspects of agroforestry. The Declaration of 1st World Congress of Agroforestry held on Orlando, Florida, USA during 27 June to 02 July, 2004 mentions "Agroforestry as a science without borders, can tackle problems of biodiversity, rural poverty, deforestation, land degradation, genetic erosion, soil fertility decline, climate change, environment, food and nutritional security". Agroforestry is more than just an amalgam of agriculture and forestry. The inclusion of trees in farming systems and their management in rural landscape is aimed at enhancing productivity, profitability, diversity and ecosystems sustainability (World Agroforestry Centre, 2013).

Within this backdrop, agroforestry in the Nepalese context can be defined as a land use system where trees and agriculture crops are grown together, incorporating livestock, medicinal and aromatic plants, in a given space and time, to raise the productivity of each component without compromising the yield of others.

These definitions of agroforestry illustrate both complementary perspectives and diversity of agroforestry practices around the world.

The widely accepted definition of agroforestry, however, stresses two characteristics, common to all agroforestry system. They are:

- The deliberate growth of woody perennial on the same unit of land along with agricultural crops and/ or animals including medicinal and aromatic plants either in some form of spatial mixture or temporal sequence,

- A significant economic and/ or ecological interaction (both positive or negatives) between the woody and other components of the system.

Whatever may be the definition of agroforestry, evidence shows that agroforestry is a land use system which increases social, economic, and ecological benefits on a sustainable basis. It has both biological and socio-economic advantages. Some of them are:

Biological

- Increased space utilization
- Increased productivity
- Potential reduction in soil erosion
- Reduced risk of complete crop failure
- Physical support for herbaceous climbers
- Positive use of shade

Socio-economic

- Increased income opportunities
- Potential for improved human nutrients
- Crop diversity and reduced risk
- Reduced establishment costs
- Reduces pressure on forest and promotes livestock development.

HISTORICAL BACKGROUND OF AGROFORESTRY

The history of agroforestry is very old. It has been said to be initiated when human beings learnt the art of domesticating plant and animals in about 7000 BC. Raychaudhuri and Roy (1993) (quoted in Dagar, 2014) mention that some stray references occur in different texts of the Vedic literature of Indus valley civilization period on the origin of agroforestry. For example, the cultivation of date Palm (*Phoenix dactylifera*), Banana (*Musa paradisiaca*), Pomegranate (*Punica granatum*), Coconut (*Cocos nucifera*), Jujube (*Ziziphus mauritiana*), Amla (*Emblica officinalis*), Bel (*Aegle marmelos*), Lemon (*Citrus limon*), Rudraksha (*Elaeocarpus ganitrus*) and many other fruit trees and requirement of livestock in agriculture and cattle breeding may be traced in pre-historic era. King (1987) describes that agroforestry has been practiced since the beginning of agriculture as farming communities either settled into forested areas or encouraged useful trees around their fields. Traditional peoples such as the Hanunoo in the Philippines cleared forests for agricultural deliberately leaving some trees to prevent excessive heat from the sun on their crops. Trees were one of the important components for them which would provide food, medicine, construction timber and other essential items besides to their protective service functions. King (1987) has extensively covered the history of agroforestry in a book edited by Steppler and Nair (1987).

It should be noted that not all traditional agroforestry systems were carved from the forest. For example, Nuberg & Evans (1993) report that the forest gardens in the Uva Province of Sri Lanka are known to have evolved on previously treeless grasslands. The farmers brought their domestic trees with them and birds that followed brought the seeds of other native forest species

The first modern use of agroforestry can be traced to the Taungya system employed in the Teak (*Tectona grandis*) plantations of Burma at the end of the nineteenth century. To control weeds in the young plantations, farmers were allowed to grow their crops for the few years before tree canopies closes. The system was taken from Burma to Chittagong area in India in 1890 and to Bengal in 1896 (Raghavan, 1960) and since then it had believed to spread throughout Indian provinces. In Nepal Taungya system was introduced in Terai (Bara distict) during 1974/75.

However, the first formal recognition of agroforestry as field of study separate from agriculture or forestry occurred in the 1977 with the establishment of the International Council for Research in Agroforestry (ICRAF), now also known as the World Agroforestry Centre (WAC) based in Nairobi, Kenya. ICRAF now has regional centres in Bogor, Indonesia and India. WAC has been in the forefront in planning, coordinating in agroforestry on a world-wide basis. It has conducted various kinds of research that combined land management systems of agriculture and forestry.

As there was a felt need of conducting research in agroforestry, especially integrating animals with plantation trees, and intercropping agricultural crops in between trees crops. And to carry out these sort of research International Institute of Tropical Agriculture (IITA) was also established in Ibadan, Nigeria in 1979 (Nair, 1979).

The Center for International Forestry Research (CIFOR) is a non-profit scientific research organization working in the field of agroforestry. It is a network of 15 research centers around the world. CIFOR focus mainly on agricultural research and natural resource management especially on poverty reduction, food security and nutrition, and ecosystem services. Forests, Trees and Agroforestry research programs are conducted by specialized agencies such as World Agroforestry Centre (ICRAF), International Center for Tropical Agriculture (CIAT) and Biodiversity International works in five components: Smallholder production systems and markets, management and conservation of forest and tree resources, environmental services and landscape management, climate change adaptation and mitigation and impacts of trade and investment on forests and people.

National Agro-Forestry & Bamboo Mission (NABM) especially focusing on farmers' welfare is being implemented in India. This mission assist farmers/bamboo growers for nursery establishment, plantations in non-forest area, imparting training for preparation of nurseries and bamboo plantations, and establishing of bamboo markets.

India has been carrying out organized agroforestry research since the establishment of All India Coordinated Research Project in 1993. It has established the National Research Centre for Agroforestry (NRCA) in 1988. The NRCA has been mandated for agroforestry research and development throughout India. The agroforestry research conducted by the NRCA has contributed in many ways such as identifying suitable tree species for different agro-ecological zones of India for (i) biodiversity conservation; (ii) yields of goods and services to society; (iii) augmentation of the carbon storage in agro-ecosystem; (iv) enhancing the fertility of the soils; and (v) providing social and economic well-being to the people. To accelerate the pace of agroforestry development in India, The World Congress in Agroforestry with the theme 'Trees for Life' was organized at New Delhi in February 2014. One of the outcomes of the congress was the promulgation of Indian National Agroforestry Policy.

MAJOR AGROFORESTRY SYSTEMS IN SOUTH ASIA

The objectives of practicing agroforestry in all the countries of South Asia are the same i.e meeting household fuel wood requirement, fodder for livestock, grazing, conserving soil and water utilizing traditional agroforestry knowledge and technologies, learnt from their forefathers. However, depending on the countries, some of the practices is very diverse and tends to be complex.

Integration of crop production, grazing animals and forest areas into a mutually supportive system is the main features of agroforestry being practiced in Bhutan. Large ruminant plays a critical role by providing draught power, manure and livestock products for sale or home consumption in this country. Transhumance system mainly in the Dzongkhags of Haa, Thimphu, Paro, Gasa, Wangdi Phodrang, Bumthang and Trashigang is also prevalent in Bhutan where nomadic herders keep yaks and sheep as their sole source of livelihood.

Planting trees on homestead and along the vicinity of farmland boundaries is common in Bangladesh. There are various challenges in Agroforestry development in this country. One of them is inadequate policy support, followed by insufficient participation by the concerned farmers. It is mainly because farmers feel the insecurity of tenure once the trees are introduced on their farmland.

Agroforestry in India is more developed in comparison to other South Asian countries. Kumar and Sikka (2014) have provided a short overview of Agroforestry in the South Asia context from Vedic (4500 and 1800 BC) to the current era. India has already promulgated Agroforestry policy in the country. Both farm and forest-based Agroforestry systems are being practiced but the intensity and use differs along with the argo-ecological zones of the country. Silvo-pastoral practices are being practiced within village grazing grounds where villagers have their tenure rights whereas this system in forests involve lopping trees and grazing understory ground grasses.

In Maldives, trees and shrubs species Griricidia (*Gliricidia*), Sesbania

(*Sesbania*), *Erythrina variegata* are being used in agroforestry practices as fodder for livestock and to serve as wind breaks. Coconuts are extensively planted in and around homestead. Farmers are practicing trees as intercrops in uniform grid pattern as it provides flexibility in arranging the spacing between the trees and individual farmer can remove them when they feel it necessary.

In Sri-Lanka, agroforestry is one of the main sources of timber and food for the country. Two types of home garden systems prevail in Sri-Lanka; traditional and modern. In the traditional system, Jackfruit (*Artocarpus integra*) constitutes as an important component of most Sri-Lankan home gardens for house hold consumption whereas modern home gardens look at more cash generation through planting tree species that yield spices, beverages and sap. Sri-Lankan home gardens are considered the most complex and diverse in the world.

HISTORY OF AGROFORESTRY DEVELOPMENT IN NEPAL

Recorded history of planting trees goes back to as old as ***Padma Purana,*** a Hindu epic. It says ***"those people who plant trees near road side s/he would feel happy in heaven as much the number of years as the tree has fruits and leaves on it".***

Acharya, (2003) has listed that 80 plant species are used in socio-cultural festivals in Nepal. These plants are used in specific purposes. Their nature, however, varies from herb to big-sized trees.

Ingles (1994) states that the way forests are perceived and managed in Nepal depends a lot on the religious practices and beliefs of the people. He further argues that religious forests provide a refuge for many species, which may otherwise have been locally extinct. Acharya (2002) also states that some plant species such as Pipal (*Ficus religiosa*), Bar (*Ficus bengalensis*), Gular (*Ficus racemosa*), Pakhuri (*Ficus glaberrima*), Amp (*Magnifera indica*) and Amala (*Phyllanthus emblica*) are considered highly sacred by Hindu communities and they are worshipped and used for birth to death rituals. Similarly, the sticks of Paiyu (*Prunus cerasoides*) and Dhak (*Butea monosperma*) are used to perform the ceremony of "brata bandha"of young Nepalese boys. A culture called "bel bibaha" is practiced in the Newar community where a young girl marries with the fruits of tree species Bel (*Aegle marmelos*) before the onset of her menstruation. Sisters offer their brothers fruits of Okhar (*Juglans regia*) and Katus (*Castanopsis indica*) during the Tihar festival.

Huyan Tsang, a trader, has also touched upon the animal 'Yak" during his visit in Nepal sometimes in sixth century. Yak would need fodder and people should be having such provisions of feeding Yak. A sort of silvo-pastoral system might have been in operation during that period. During the period of King Jayasthiti Malla in 1379, a legal provision to develop forests on any private land uncultivated for five years or more was established (Acharya et.al.2015). This was adopted even after the unification of Nepal by Prithwi Narayan Shah and continued by Rana Prime Ministers (Acharya and Baral, 2016). Rana Prime Minister Juddha Samsher started a rule to plant at least a sapling before cutting a mature tree from one's private land. This can be considered a historical milestone of Private Forest development in Nepal.

In Nepal, agroforestry has not been taken up as an important subject of scientific study although farmers had been practicing them since time immemorial. However, in the mid eighty (1985) Farm Forestry Project funded by International Development Research Centre (IDRC), Canada was implemented in the Istitute of Agriculture and Animal Science (IAAS), Chitawan and in the Institute of Forestry, Hetauda. It is the first important event in the history of Agroforestry in Nepal. The pioneer research and promotion works on agroforestry were started in the IAAS field, and the on-farm sites: as alley inter-cropping of sumer crops (maize, soyabean, sesame, other) and winter crops (wheat, oat, mustard, others) were carried out in the established plantation of 3 to 4 years old multi-story alleys of *Eucalyptus camaldulensis*, *Madhuca latifolia* and *Leucaena latisiliqua*. The rows of trees were encouraging to provide fodder and fuelwood, and the yields of winter crops were found higher inside alleys than in open plots (Barakoti, 1989). Along with alley cropping, a number of research and studies were carried out by the acknowledged person (Dr. T.P. Barakoti) who served as a field research officer for five years. Multipurpose tree nursey, tree species elimination trial, home garden types of agri-silviculture and silvo-pastoral models with Multipurpose Tree Species were established and developed at various locations of Chitwan, Dhadhing, Lamjung, Makwanpur, Bara and Parsa districts. Trainings to farmers and staff were conducted to develop the skill and capacity in agroforestry. The farmers were encouraged and attracted towards agroforestry. Farm Forestry Project had also conducted seminars and workshops. Thus research and development work on agroforestry were intensively conducted along with feeding trials to gaots and buffaloes.

It was only in 1987 that scientific studies on this subject matter began (Amatya, 1994 a). It was mainly because the subject has not really been adopted by either agriculturalists or foresters. Agriculturists seem to think that trees are the domain of foresters, while foresters often feel that they should not be dealing with agriculture crops. Hence, the Forest Research and Survey Centre (FRSC), with the technical support from the then Nepal United Kingdom Forest Research Project decided to take up the agroforestry issues and established a Working Group on Fodder Trees, Forest Fodder and Leaf Litter under the coordination of Research Officer of FRSC in the year 1987 (FRIC, 1987). Since its establishment several informal and formal meetings and workshops were held, and the proceedings published. The papers presented in the series of workshops not only highlighted the importance of Agroforestry in the Nepalese context but also pointed out the research needs in Community Forestry (Amatya, 1994a).

Back then, the aim of developing agroforestry system in Nepal was to meet the present and future requirements of fuel wood, fodder, small timber and to protect the environment in and around house hold areas. Extensive use of tree fodders is a common practice in Nepal (Amatya, 1990). Wyatt-Simth (1982) reports that to sustain one hectare of agriculture land it need about 2.86 hectare of forests. This report indicates the importance of forests in sustaining farming systems in Nepalese context.

Historically, Taungya system of agroforestry was practised at Tamagadhi area of Bara district by the Forest Department in coordination with the then Sagarnath Forestry Development Project during early 1970s to protect the Sal (*Shorea robusta*) and its associate trees Saj (*Terminalia alata*), Haldu (*Adina cordifolia*) and Bot-Dhangero (*Anoguises latifolia*).The main objective of classical taungya system was to minimize the weeding cost using local labour. The essence of this system is that local villagers, especially landless poor are involved as Taungya planters. These landless farmers' cultivated crops underneath the remnant trees and in between the newly planted trees for up to three to four years. Taungya planters have planted tree species Masala (*Eucalyptus camaldulensis*), Sisau (*Dalbergia sissoo*) and Teak (*Tectona grandis*). In between trees, taungya planters planted maize, mustard, tobacco and other seasonal vegetables where they harvested the agriculture crops twice a year. Currently, this practice no longer exists in the country. It is mainly because of the resistance of farmers to settle in the areas permanently rather than practicing intercropping and government also could not provide new areas to Taungya settlers. Hence despite all the positive biophysical aspects of tree growth the practice was not sustained.

The Asia Pacific Agroforestry Network (APAN) funded by Food and Agriculture Organization of the United Nations was also instrumental in sharing agroforestry related information within and outside the country through knowledge documentation. Exchange visits were carried out among farmers practicing agroforestry within the country which helped them understand basic science of agroforestry and practice scientifically on their farmland. Farmers' exchange visits at national level were instrumental in understanding and identifying the important fodder trees and their lopping cycle.

Looking at the role of women in agroforestry, the Agroforestry Working Group (1.04.00) of the International Union of Forest Research Organizations (IUFRO) in collaboration with other Nepalese partner (Nepal Foresters' Association) organized a workshop entitled "Women in Agroforestry" in November 2013.

This workshop acknowledged the contributions of women in agroforestry and identified the emerging issues especially possibility of shading effect to agriculture crops from trees, lopping techniques of fodder trees, below ground interactions between planted crops that could be taken up in the future. Similarly, IUFRO's Agroforestry Working Group (1.04.00) had organized two days conference under the main theme "Agroforestry as one of the viable land use options" outside Kathmandu, in Makawanpur district, Hetauda in December 2016.

Delhi based office of the International Centre for Research in Agroforestry (ICRAF) is also working in developing agroforestry policy for Nepal in partnership with national agroforestry actors.

Nepalese Government is also very positive in developing Agroforestry in the country. The Fourteenth Plan (2013/14 -2015/16) pointed out that communities and private individuals will be encouraged to identify high value medicinal and aromatic plants, sustainable harvest, technology development, commercialization and marketing (NPC, 2013). Following the provisions in the plan, Government of Nepal has given due consideration in developing agroforestry. Consequently, several International and National Non-Government Organizations (I/NGOs) are also engaged in various agroforestry activities. Various National and International Organizations are taking up agroforestry activities to support livelihood conditions of rural population. For example Kathmandu based Food and Agriculture Organizations of the United Nations (FAO) in close cooperation with IUCN is piloting programes in Kaski and Parbat districts and helping formulate agroforesty policy for the country. Since 2013, the Government of Nepal and Australian Centre for International Agricultural Research (ACIAR) has implemented a five-year action research project titled "Enhancing livelihood and food security from agroofrestry and community forestry systems in Nepal" at two districts (Kavre and Lamgung) of middle mountain physiographic zones of Nepal through national and international partners.

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Chapter 2

CLASSIFICATIONS OF AGROFORESTRY SYSTEMS

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INTRODUCTION

Looking at the broad definition and concepts of agroforestry, various types of agroforestry combinations abound in all ecological and geographical regions of the world. Some of them appear very promising in terms of land use systems and integrating trees, crops and livestock. Some are innovative and aims at improving the existing systems.

It is desirable to understand briefly the concept of a system and its features. Definition of a system and its components are well described by Avila (1992). However, for our understanding, a system could be defined as a group of associated elements forming a unified team and working together for a common goal in a broad sense. Since different elements of the system are interrelated with each other, a change in one element causes change in one or more of the other elements. A system helps to understand in depth the important components to be considered, identifies the ways and means to implement them effectively, possibility of replicating the system in similar physiographic conditions. Additionally, an element of a system can itself be considered as a system. For example, the crop production activities of a farm constitute its cropping systems. In silvo-pastoral system, an animal is also an example of a living system, an element of the animal production system. Systems can be of any size or of different range and if the system under consideration is very complex, they can be studied in terms of sub-systems. A system may have many elements, but it should have the following essential ones.

- Boundary
- Structure
- Function
- State
- Hierarchy
- Type

Boundary

All system must have its boundaries and they must be well defined. However, they could be real or imaginary depending on the system into consideration. Apiculture sub-system, for example, may have imaginary boundary. It would be very difficult to define the trees as boundary because bees would be visiting different tree inflorescences.

Structure

Any system must have a structure of its own. Structure helps to understand the type of arrangement in a system. For example, home garden system of agroforestry provides the relationship between light and shade demanding species in vertical strata in a given space and time.

Function

Similarly, a system must have a function. Function of any system is related with inputs and their expected outputs. A function is a process where various kinds of inputs are applied, managed to obtain expected outputs within a given time frame to achieve set objectives/ goals.

State

It is the physical condition of a system in a specific time and space. The state changes as with the change in structure and functions of any system. Both external and internal factors can bring changes in the state of the system.

Hierarchy of systems

Any system has a hierarchy. This applies to agroforestry system as well. Hierarchy could be both interrelated and interdependent but follows a distinct norm which goes from lower to higher order.

Type

Basically, there are two types of systems: mechanistic and purposeful. In mechanistic, the behaviour of a system can only be predicted. In contrast to mechanistic, the purposeful system determines its objectives and means to achieve these objectives.

UNDERSTANDING AGROFORESTRY SYSTEM

It is essential to understand an agroforestry system and follow some common criteria so that action plans could be developed and implemented. One of the main purposes of classification is to provide a practical framework for the synthesis and analysis of information about existing systems and the development of new and promising ones. However, depending on the focus and emphasis of strategies for development of improved systems, the nature of a given framework will vary. Nonetheless, any classification scheme should include a logical way of grouping the major factors on which production of the system will depend how the system is managed (pointing out possibilities for management interventions to improve the system's efficiency); offer flexibility in regrouping information; and be easily understood and ease of handling (practical).

It is difficult to accommodate all complexities satisfactorily by a single classification. Hence there is a need for series of classifications which serve different purposes. In this regard, several attempts have been made to classify agroforestry systems by researchers (Combe and Budowski, 1979; King, 1979; Grainger, 1980; Vergara, 1981; Huxley, 1983; Torres, 1983). While some of them were based on only one criterion such as the role of components (King, 1979) or temporal arrangement of components (Vergara, 1981), others tried to integrate several of these criteria in hierarchical schemes in rather simple ways (Torres, 1983) or more complex ones (Combe and Budowski, 1979). In this respect, ICRAF, between 1982 and 1987 have carried out a global inventory of agroforestry systems and practices specifically in developing countries. Working with the inventory, Nair (1987) report that the information collected by ICRAF are very comprehensive and useful in developing a widely-applicable classification data base.

What would be the most obvious and easy to use criteria for classifying agroforestry systems? There is no easy answer for this question. Combe (1982) proposed 24 agroforestry systems, based on three kinds of association of trees (trees with crops, trees with pasture, and trees with crops and pastures), two major functions of the tree components (production and protection) and two spatial arrangements of tree (regular and irregular) and two types of temporal association (temporary and permanent). However, one of the easy ways to classify agroforestry system would be the arrangement of components, its role, the production or the outputs expected from the system, and social and economic considerations. Based on the above considerations, agroforestry systems can be classified into the following criteria.

Arrangement of components

This is the composition of the components. This component deals with the arrangements of trees in a given space and time. The arrangement varies significantly with respect to the defined objectives and expectation of end-product. Normally trees are planted at spacing of 2.5 m x 2.5 m to provide ample space for agriculture crops to be grown in between. The spacing also varies with the nature of agriculture crops whether they are light demanders and shade-tolerantones. A trial conducted in Adhabhar of Bara district with Timilo (*Ficus auriculata*) as tree component and ginger and turmeric as shade crops showed a perfect composition of components in terms of their yields.

Role of the components

Normally trees have three functions–productive, protective and regulatory. Whereas tree performs all three functions in a given space and time, its role depends on the set goals and objectives of the component in consideration. Normally, people tend to plant trees for their productive function (timber, fuel wood, medicine and food). The role of trees appears important in conserving soil and water especially in the hilly areas including terrace risers of land. Whereas in the flat land its role is more pronounced in breaking wind velocity and providing shelter to adjoining crops.

Economic components

This component refers to various kinds of inputs provided in managing a given agroforestry system such as tending operations including different grades of thinning. The inputs in terms of thinning provided could be high if trees are to be harvested for timber and it could be low if the objectives are to produce firewood. Hence, the application of this component could be low and high depending on the scale of management and production goals i.e. subsistence, intermediate and commercial.

Ecological components

This component is important especially if it has to deal with the prevailing environmental conditions. Ecology is the functions of climate and edaphic regimes. Hence, trees and agriculture crops thrive best in those sites where they favour the ecology of the site and components in considerations. Given the diverse climatic condition of Nepal, the agroforestry system varies, and suitability of the system depends on the ecological condition.

The classification of agroforestry system in Nepal is based mainly on the inter-relationship between forest, farmland and livestock (Figure 1).

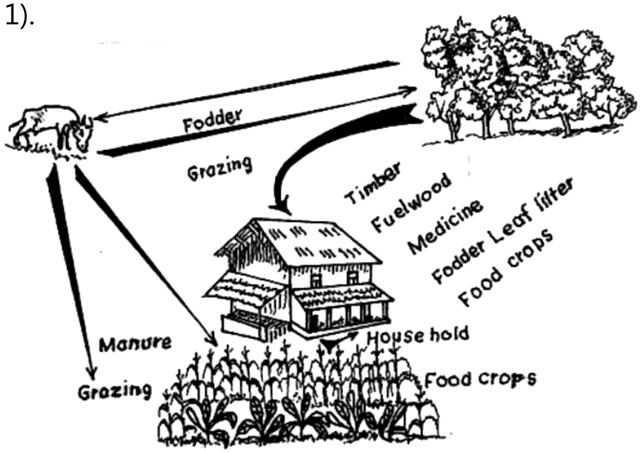

Figure 1. Inter-relationship between forest, farmland and livestock in Nepalese agroforestry system

BASIC CONCEPTS ON AGROFORESTRY SYSTEMS CLASSIFICATIONS

The previous chapter have defined that agroforestry as a deliberate integration of trees or woody perennials, with herbaceous crops and animals. The dominance of woody perennials is the major distinguishing characteristics of agroforestry from other land use systems. In addition, all agroforestry systems should have the following attributes:

Productivity

The main purpose of agroforestry is to increase the overall land (estate) productivity. Increase in productivity can be achieve in various ways such as increased outputs of tree products, improve yields of associated crops, reduced cropping systems input and labour efficiency.

Sustainability

In agroforestry system, conservation of the resource base mainly soils and water, is delivered by the beneficial effects of trees and woody perennials on soil and water. Therefore, agroforestry maintains fertility and achieve conservation goals.

Adoptability

Agroforestry is an old-age practice yet there may be a need to introduce improve agroforestry practices in other areas to improve productivity and sustainability goals of agroforestry systems. In this context, agroforestry systems should be easy to 'adopt' by farmers to suits their socio-economic and biophysical condition. The term 'adopt' means to accept a certain innovation which is different to the term 'adapt' which means to modify or change the system to suits farmers needs and circumstances (see Cedamon et. al. 2017).

CLASSIFICATION BASED ON VEGETATION STRUCTURE

Agroforestry systems can be easily distinguished from other land uses because of its vegetation structure. Because of this easily recognisable characteristic of agroforestry, classification based on structure had been widely used. Structure is the nature and arrangement of components of the system – trees/ woody perennials or shrubs, herbaceous plants, or fodder plants, and or animals. Herbaceous components are present in many agroforestry systems except, apiculture and silvofishery systems. Vegetation structure in agroforestry is generally defined based on distribution of trees or woody perennials and herbaceous plants on the horizontal space but a few practices are also defined based on the distribution of agroforestry components in the vertical space. Examples of agroforestry systems based on vegetation structures are provided in Figure 2.

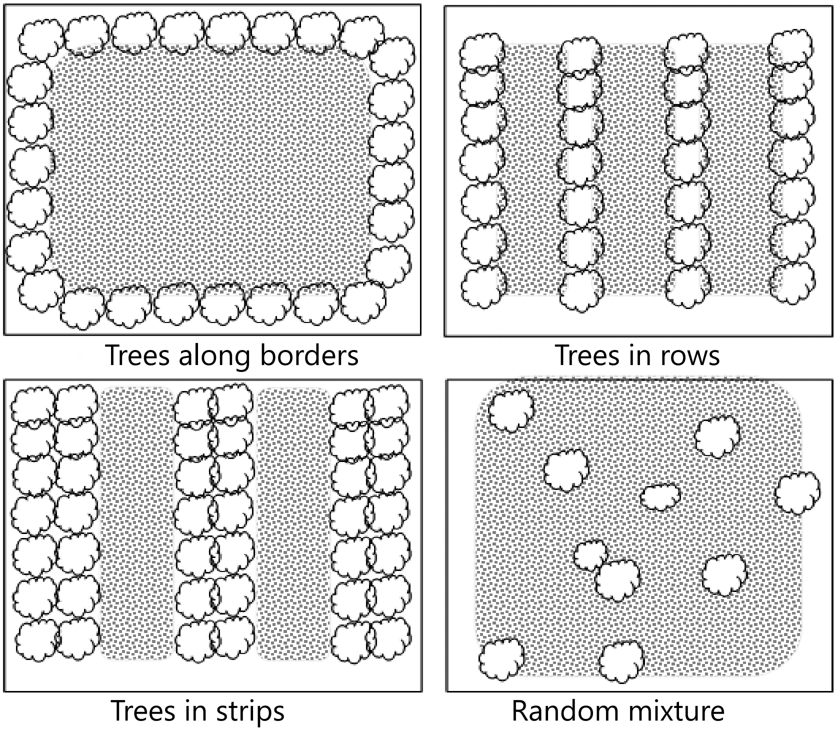

Figure 2: **Examples of agroforestry systems based on vegetation structure**

CLASSIFICATION BASED ON FUNCTION

Each component of an agroforestry system may have a specific function, like trees for timber production. However, the agroforestry system as a whole has a general function which can be used as a basis for classification of agroforestry practices. Examples of these systems based on functions are shelterbelt system, shade tree system (in tea, coffee and cardamom agroforestry), and silvopastoral system. It is to be noted that agroforestry systems enhance the productivity, diversity and sustainability of farming system. For example, Utis (*Alnus nepalensis*) and other legume tree fodders are nitrogen fixing trees that can help in improving soil fertility or replacing nutrients loss form harvested crops as well as controlling erosion. Example of agroforestry systems based on primary function includes: Biofuel agroforests, fodder bank, and home garden.

CLASSIFICATION BASED ON SOCIO-ECONOMIC ACTIVITIES

The production output of agroforestry system relative to the household demand can also be a basis for classifying agroforestry systems. Lundgreen and Raintree (1982) identified types of agroforestry systems based on socio-economic conditions of decision makers or landholders-subsistence, intermediate and commercial. Commercial agroforestry is generally concerned on the sale of all its outputs or products and labour can be hired or contracted and can be owned by private companies, government or established business individuals. In subsistence agroforestry, the products are generally consumed by the farmers or the production activity is generally dictated on its own demand. Farmers are generally in the low-income class and the primary function of land is to meet the basic needs of the household or landholder. Intermediate system lies in between subsistence and commercial systems. Generally, cash crops like ginger, turmeric and cardamom are the source of revenue while food crops are generally for domestic consumption only. In Nepal, agroforestry systems can be either subsistence or intermediate agroforestry systems. Atangana et. al. (2014) noted that while classification of agroforestry based on socio-economic activity may be helpful for development efforts, i.e. targeting agroforestry development program for improving subsistence and intermediate systems, he cautioned the limitation of this classification scheme because of difficulty of defining the standards for each criterion in a given location.

CLASSIFICATION BASED ON ECOLOGICAL CONDITIONS

Agroforestry is practiced in many corners of the world under various environmental and ecological conditions. On that basis, certain type of agroforestry practice can be more suitable in certain environmental and ecological conditions. Thus, there can be a set of agroforestry practices for arid and semi-arid lands, tropical lowlands, tropical high-lands, temperate areas and so on. It is to be noted that many agroforestry practices can be found in more than one agro-ecological zone and therefore agro-ecological zonation alone cannot be a satisfactory basis for classifying agroforestry practices (Nair 1993). However, knowledge on the agro-ecological condition of the region is important in designing agroforestry systems because presumably agroforestry systems will have similar structure in the same agro-ecological region.

FRAMEWORK FOR CLASSIFYING AGROFORESTRY SYSTEMS

These broad bases of classification of agroforestry systems however are interrelated and isolating them from one another is often difficult. It must be noted that arrangement of the components and their functions very much depends on the biological nature of the woody components included in the system. When the systems are very complex, they often can be studied in terms of sub-systems. Apiculture and aquaculture are some of the examples of agro-silvo sub-system. A system helps to understand in depth the important components to be considered, identifies the ways and means to implement them effectively, and possibility of replicating the system in similar physiographic conditions.

Based on the above approaches for classifying agroforestry systems and practices, the major agroforestry system and practices adopted from Nair (1987) is presented in Table 4 as a general guide for identifying and classifying agroforestry practices in Nepal.

Table 4. Approaches for classifying agroforestry systems (or practice) (Adapted from Nair 1987)

Categorisation of systems (based on their structure and function)			Grouping of systems (according to their spread and level of management)	
Structure (nature and arrangement of components particularly the woody components)		**Function of components (role/outputs of components particularly the woody components)**	**Agro-ecological and environmental adaptability**	**Socio-economic and management level**
Nature of components	**Arrangement of components**			
■ Agri-silviculture (crops and trees including shrubs) ■ Silvopastoral (pasture/animals and trees) ■ Agro-silvopastoral (crops, pasture/animals) ■ Silvofishery (trees with fish on ponds or mangroves) ■ Others (multi-purpose tree lots, apiculture with trees, trees with perennial crops)	***Arrangement in space (spatial)*** ■ Mixed-dense (e.g. home garden) ■ Mixed-sparse (e.g. tea gardens) ■ Strips (width of strip to be more than 1 tree) ■ Boundary (trees on edges of plots or fields) ***Arrangement in time (temporal)*** ■ Coincident ■ Concomittant ■ Overlapping ■ Sequential (separate) ■ Interpolated	***Productive function*** ■ Food ■ Fodder ■ Timber ■ Fuelwood ■ Other wood products ■ Other non-timber products (e.g. leaf litter) ***Protective function*** ■ Windbreak ■ Shelterbelt ■ Soil improvement ■ Soil conservation ■ Moisture conservation ■ Slope stabilization ■ Shade (for crops, animal and human)	***Systems in or for*** ■ Lowland humid tropics ■ Highland humid tropics ■ Lowland sub-humid tropics ■ Highland sub-humid tropics ■ Arid and semi-arid regions	***Based on level of technological input*** ■ Low input ■ Medium input ■ High input ***Based on cost/benefit relations*** ■ Commercial ■ Intermediate ■ Subsistence

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Chapter 3

FARMING SYSTEMS AND AGROFORESTRY PRACTICES

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The study of any farming systems within a larger system is known as an eco-zone system. Eco-zone system is based on the biophysical characteristics such as altitude, climate, topography, soil type, or vegetation. It can also be described based on specific farming and/or production systems which reflect to a large extent what is feasible in terms of the above agro-ecological determinants. Eco-zone study provides a logical basis for classifying farming systems for example, a general definition (e.g., systems with maize and cattle), will encompass a greater number of farms, while a more specific definition (e.g., systems with specific management and yield levels of maize) will contain a lesser number of farms.

Agroforestry farming system is a combination of agriculture and forest crops including livestock managed in spatial and temporal arrangements to satisfy mostly the household needs/objectives and other priorities, subject to the given biophysical and socioeconomic condition. A farming system can be described both structurally and functionally. Structurally, in a given farming system, each component could be observed in relation with the existing settings. For example, boundary, buildings, crops, animals located in a farm. However, the structure of a farm may not be permanent. It changes with respect to the agricultural crops grown and other components employed.

A farming system comprises different activities over the natural resources. The activities are: cropping systems and practices, livestock keeping, farm management, agro-based enterprises, rural livelihoods etc. The classification of the farming systems of developing countries like Nepal is based on the natural resource base: biodiversity (forest resources, plant resources, agro-biodiversity, and animal resources), water resources, rangeland/grazing areas, physiographic zones, altitude, landscape, biophysical condition, climate, farm size, land tenure, organization. Likewise, the other criteria are: patterns of farm activities and household livelihoods, field crops, livestock, trees, aquaculture, apiculture, processing, marketing, off-farm activities, account of the main technologies used, which determine the intensity of production, and integration of crops, socio-economy of farmers etc.

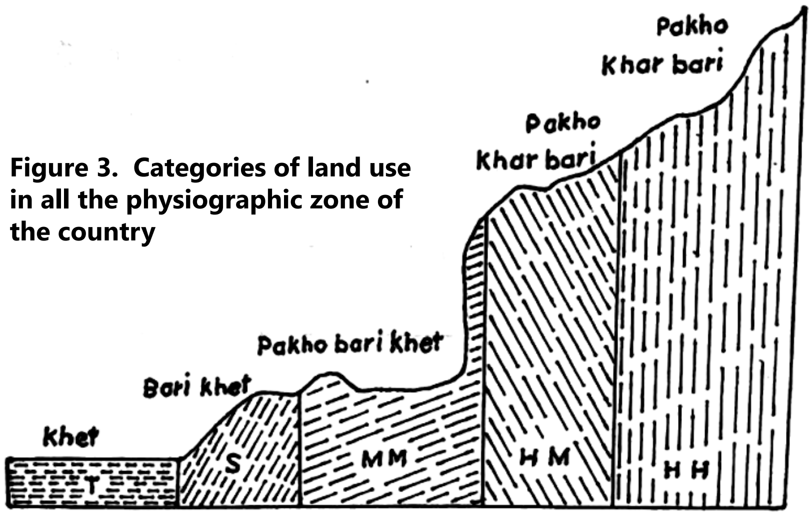
Nepalese farming systems include and represent the major farming systems of South Asia and East Asia. The broad farming systems identified in the region are lowland rice, upland rice, tree crop mixed, root-tuber crop, upland intensive mixed, highland extensive mixed, temperate mixed, pastoral, sparse (forest), urban farming system. The altitudinal variation has detrimental role in creating diversities in flora, fauna, climate, soil, ecosystems and hence in farming systems, farm animals, cropping systems, cropping patterns, among others.

Farming system depends on the type of land and its optimum utilization. Land is an essential resource for any crop to be grown and obtain any kind of production. Thus, land use system help identify and analyse how lands are being managed to maximise the production system of a given household. Analysis of land use system should have the following essential elements:

- Identifying household objectives and their priorities,
- The intensity of use of inputs (labour, seed, farm yard manure, chemical fertilizer,) per unit of area,
- Management level (frequency of management);
- Expected level of productivity and identification of new potentials;
- Use of the outputs and their mechanism (household consumption, market)

In the Nepalese context, the concept of land use system is fully understood, considered and acknowledged by rural farmers. Most farmers are aware about the level of productivity they would expect from land resources. However, farmers have been looking only to fulfil the household needs at subsistence level. There is hardly any computation on the intensity of use, and the management level each household are putting on it. This is mainly because in most of hill farming system, marketing the product is a problem. There are two reasons for it. One is the lack of inputs, mainly in terms of labour and prevailing marketing rules for forest products. Farmers distinguish various types of land as per their use. In the low land Terai, where paddy is widely grown, they are known as khet. The second category is the bari land where mainly maize and mustard are grown. Similarly, in the hills, farmers call pakho bari, meaning land without facility of irrigation where maize and millet are mainly grown. Khar bari is the land where thatch grass and fodder trees are normally planted. The categories of land use from Terai to the Mountain, in general, in all the physiographic zone of the country is provided in Figure 3.

Figure 3. Categories of land use in all the physiographic zone of the country



AGROFORESTRY SYSTEMS AND PRACTICES IN NEPAL

Based on a survey of agroforestry systems and practice in Eastern, Central and Far-western Nepal, 35 agroforestry practices within seven agroforestry systems are documented (Table 5). An agroforestry practice is defined by the combination of agroforestry components particularly species having unique biological and economics relationships requiring similar management strategies and techniques. An example of agroforestry practice is Utis– Cardamom agroforestry (Alnus-*Amomum sabulatum*) in Eastern and Central Nepal. A group of agroforestry practices for which major components are closely related economically, environmentally and socially are referred to as agroforestry system. The seven agroforestry systems in Nepal are (1) agrisilviculture, (2) silvopastoral, (3) agrosilvipastoral, (4) silvofishery, (5) home gardens, (6) woodlots and (7) shifting cultivation. These agroforestry systems are described below.

Agrisilviculture

Agrisilviculture system practiced widely in Nepal is generally defined by deliberate intercropping of trees and crops in a variety of spatial arrangement. The species of woody perennials and cash crops (both annual and perennial) vary between geographic location, i.e Terai and hills as well as East and Western Nepal. For example, in Eastern Nepal, Tea (*Camelia spp*) is most common in larger estates, while cardamom, vegetable and cereal crops are common in smallholdings except a few expceptions. The tree species in this agroforestry system also vary in altitudinal zones – e.g. Siris (*Albizia*) and Sisau (*Dalbergia sissoo*) as common woody crops in the Terai while Utis (*Alnus nepalensis*) and Loth Sallo (*Taxus wallichiana*) are common in higher elevation. The major product from the woody components in the Eastern and Central Nepal are timber and firewood. Random location of trees is the widely seen spatial arrangements of agrisilviculture systems while windbreaks and trees on terrace risers were also practiced. In Far western Nepal, Rittha (*Sapindus mukorossi*) and Chiuri (*Diploknema butyracea*) trees are common agroforestry species where interest for massive agroforestry planting of this species is emerging among landholders.

Agro-silvo-pastoral (crops, pasture/animals)

Under this system tree crops, pasture/ livestock are raised. This system is more prevalent in hill as compared in the low land and prevalent in those areas where there is a need or opportunity for intensive and efficient management. This system is practiced at subsistence level. This system promotes both agriculture and livestock in one space and time. Specially, goats are raised along with agricultural crops. The preference however is given for goat rearing meaning establishment of new fodder trees and protection of old ones. Farmers prefer Badahar (*Artocarpus lakoocha*), Ipil-Ipil (*Leucaena latisiliqua*), Bakaino (*Melia azadarach*), Kabro (*Ficus lacor*), Saj (*Terminalia alata*), Koiralo (*Bauhinia variegate*), Tanki (*B. purpurea*), Katus (*Castanopisus *indica*), Khanyu spp (*Ficus semicordata* var. *semicordata* and F. *semicordata* var. *montana*), Pakhuri (F*icus glaberrima*) as agroforestry/ fodder trees for their livestock specially goat.

Silvo-pastoral (pasture/animals and trees)

This system is characterised with intensive cultivation of fodder trees and grasses for animal use primarily goat and dairy buffalo and cattle. Fodder grasses and fodder trees in combination with timber trees occupying the upper stratum. Livestock are allowed to openly graze and some are tethered but generally, most animals are under 'cut-and-carry' system with enclosures and houses. This system is widely practiced in the mid-hills from Eastern to Far-western Nepal. Pasture productivity was studied by Devkota et al in 2008 in New Zealand by pruning Italian gray alder (*Alnus cordata*) planted to control soil erosion on hills, the study showed that the pruning of alder has the potential to improve the productivity of the under-storey pasture and its acceptability to sheep.

Devkota et al (2005) studied the effect of introduction of exotic legume grass such as stylo (*Stylosanthes guianensis*), molasses (*Melinis minutiflora*) and napier grass (*Pennisetum purpureum*) to reclaim degraded marginal forest through leasehold forestry activities along with the aim of promotion of improved buffalo and goats in the hills of Nepal. They have found that the introduction of exotic forage species was successful at low-medium altitudes.

Homegarden

While home gardens may be classified under agrisilvicultural systems, it is classified as a system in its own right in Nepalese context as it has a distinct system components and relationships relative to other systems. Conversely, while many agroforestry practices in Nepal have homesteads nearby like that found in agrisilviculture and agrosilvipastoral systems, these homesteads are not necessarily dwellings of decisions makers who have access to the agroforestry on a day-to-day basis. Home gardens are found across Terai and Midhills of Nepal characterised by a homestead with intensive cultivation of annual (cereals, vegetable and species, vegetables and spices), perennial crops (timber, poles,

Figure 4. A typical home garden system in Jhapa, Nepal

firewood, fodder and fruit trees), grasses and animals. The annual crops grown in home garden are the same across Nepal however the tree species vary with ecological zones. For example, Ficus and Citrus trees on terrace rises are common in Eastern Nepal, Ficus and Banana in Central Nepal, and Fusro (*Grevia optiva*), fodder tree in Western midhills of Nepal. There are namy species compositions in home garden systems. One single or two species do not representthe entire counry.

Woodlots

Small-scale woodlot is practiced in Eastern and Central Nepal to meet timber demand in rapidly growing urban and metropolitan areas. The famous species are Sallo (Pine), Chilaune (*Schima wallichii*), Utis (*Alnus nepalensis*), Sisau (*Dalbergia sissoo*), Teak (*Tectona grandis*), Kadam (*Neolanarckia cadamba*), Bakaino (*Melia azedarach*), Eucalyptus spp and Siris (*Albizia spp*) which are relatively faster growing species. Many farmers have started harvesting their trees giving them substantial returns. There is high transaction cost for marketing agroforestry trees has been an important challenge by tree farmers.

Shifting cultivation

In Nepal, shifting cultivation is practiced in the middle and high mountain physiographic zones of the country, often on very steep slopes. People tend to use forest land for crop production mainly maize, buck wheat, naked barley, potato and millet. They first clear the land and burn the area completely and take the advantage of pre-monsoon rain in sowing the crop. Rotation cycles vary depending on land location and population pressure but generally it is between three to five years in many places. Although this system provides a livelihood for a substantial number of people, it is wasteful and inefficient one. This practice also prevents regeneration of many valuable plant species and results in site deterioration. At present cleaing and burning is restricted in the government land. Shifting cultivation was common in Terai part of the country as well before 3-4 decades, particularly by the ethnic groups (Tharu and Danuwar) in Chitwan and some western districts of the country. It is not seen at present due to lack of land.

Table 5: Agroforestry systems and system units in Nepal

Agroforestry System or Practice	Description and arrangement of components	Agroecological zones
A. Agrisilviculture (crops and trees including shrubs)		
1. Siris (*Albizia*) – tea (*Camellia sinensis*)	Tea under Siris (*Albizia*) trees in random mix pattern	Terai in Eastern Nepal
2. Sisau (*Dalbergia sisso*) -tea	Tea under Sisau (*Dalbergia sisso*) trees in random mix pattern	Terai in Eastern Nepal
3. Utis (*Alnus nepalensis*) –tea	Tea under Utis (*Alnus nepalensis*) in random mix pattern	Midhills in Eastern Nepal
4. Betel nut (*Areca catechu*) – cardamom (mix)	Cardamom (*Elettaria cardamomum)* under Betel nuts (*Areca catechu*) planted in regular spacing of 3m x 4m	Terai in Eastern Nepal
5. Betel nut (*Areca catechu*) Bakaino (*Melia azedarach*), Siris (*Albizia*) Sisau (*Dalbergia sisso*) – crops	Betel nut and maize, rice, vegetable intercropping, Trees on borders	Terai in Eastern Nepal
6. Tea Utis (*Alnus nepalesnis*) - Loth salla (*Taxus wallichiana*) - Tea	Tea under Utis (*Alnus nepalesnis*) and Loth Sallo (*Taxus wallichiana*) in random mix patters	Midhills in Eastern Terai
7. Utis (*Alnus nepalensis*)-Cardamom (*Elettaria cardamomum*	Cardamom (*Elettaria cardamomum*) under Utis in mix random planting	Midhills in Eastern and Central Nepal
8. Utis (*Alnus nepalensis*)-Amriso	Amriso (*Thysanolaena latifolia*) under Utis at wider spacing (4m x 5m) or Utis in farm border for narrow lots	Midhills in Eastern and Central Nepal
9. Bhanj (*Quercus spp*) – cereal crops, lentils, vegetables	Cereal crops (maize, wheat, millet), lentils and vegetable grown on terraced bari under widely spaced naturally growing Quercus	Midhills in Farwestern Nepal
B. Agro-silvo-pastoral (crops, pasture/animals)		
10. Ritha (trees– cereal, lentils and vegetable	Cereal crops (maize, wheat, millet), lentils and vegetable grown on terraced bari under Naturally growing and widely spaced Rita (*Sapindus mukorossi*) trees	Midhills in Farwestern Nepal

11. Chiuri – cereal, lentils and vegetable	Cereal crops (maize, wheat, millet), lentils and vegetable grown on terraced bari under Naturally growing and widely spaced Chiuri trees	Midhills in Farwestern Nepal
12. Utis-chilaune-fodder trees – maize	Maize as alley crop; naturally growing Utis (Alnus nepalensis), Chilaune (*Schima wallichii*) and fodder on terrace risers	Midhills in Eastern and Central Nepal
13. Utis-chilaune-fodder trees– tea	Tea as alley crop; naturally growing Utis (*Alnus nepalensis*), Chilaune (*Schima wallichii*) and fodder on terrace risers	Midhills in Eastern Nepal
14. Utis-chilaune-fodder trees – cardamom	Cardamom as alley crop; naturally growing Utis (*Alnus nepalensis*), Chilaune (*Schima wallichii*) and fodder on terrace risers	Midhills in Eastern Nepal
15. Utis-chilaune-fodder trees – amriso	Amriso (*Thysanolaena latifolia*) as alley crop; naturally growing Utis (*Alnus nepalensis*), Chilaune (*Schima wallichii*) and fodder on terrace risers	Midhills in Eastern and Central Nepal
16. Utis-chilaune-foddertrees– ginger	Amriso (*Thysanolaena latifolia*) as alley crop; naturally growing Utis (*Alnus nepalensis*), Chilaune (*Schima wallichii*) and fodder on terrace risers	Midhills in Eastern and Central Nepal
17. Multi-purpose trees on terrace risers – cereal crops – fodder grasses - animal (cut and carry)	Alley cropping of cereals on terraces, multipurpose trees and forage grasses on terrace risers, and cut-carry system for animals (goat, cow, buffalo)	Midhills Central Nepal
18. Multi-purposetrees–fodder grasses	Amriso (*Thysanolaena latifolia*) for grass and broom), fodder grasses and multipurpose trees in mix random plantings	Midhills Central Nepal
19. Fodder trees– banana – animal (goat – cut and carry)	Banana on terraces; fodder trees on terrace risers and goat (cut-and-carry system)	Midhills Central Nepal
20. Foddertrees–banana-ginger -animal (goat – cut and carry)	Banana and ginger on terraces; fodder trees on terrace risers and goat (cut-and-carry system)	Midhills Central Nepal
C. Silvopastoral (pasture/animals and trees)		
21. Foddertrees–ginger-animal (goat – cut and carry)	Ginger on terraces; fodder trees on terrace risers and goat (cut-and-carry system)	Midhills Central Nepal

22. Foddertrees–amriso-animal (goat – cut and carry)	Amriso (*Thysanolaena latifolia*) on terraces; fodder trees on terrace risers and goat (cut-and-carry system)	Midhills Central Nepal
23. Fosro(Grevia) trees - cereals (maize, rice, wheat, millet), lentil and vegetables), goat and cattle (cut and carry system)	Cereal crops (maize, wheat, millet), lentils and vegetable grown on terraced bari under naturally growing and widely spaced Fosro trees; goat, cattle and buffalo in cut and carry system	Midhills Farwestern Nepal
24. Betel nut – goat grazing	Tethered goats grazing under mature Betel nuts (*Areca catechu*)	Terai Eastern Nepal
25. Timber trees – bamboo-forage grasses	Tethered and free-range goats grazing under multi-storey systems: Upper storey – timber trees-Haldu (*Adina cardifolia*), Bakaino (*Melia azedarach*), Gutel, (*Trewia nudiflora*), Siris (*Albizia*); middle storey -bamboo; ground cover–forage grasses	Terai Eastern Nepal
26. Fodder trees -fodder grasses- animals (goat)	Tethered and free-range goats grazingopen grazing and cut and carry system	All Midhills
27. Trees – apiculture	Bees kept in homestead feeding on farm trees and community forest	Midhill Central Nepal
28. Small woodlots – grasses – animals (tethered and cut-and-carry system)	Naturally grown fodder grasses under woodlots; animals are tethered and cut-and-carry system	Midhills Far-western Nepal
D. Silvofishery (trees with fish on ponds or mangroves)		
29. Multi-purpose trees-fish, Central Nepal	Multipurpose (fodder and firewood) planted on border or dikes of fish ponds (mainly tilapia)	Midhill Central Nepal
30. Timber trees – banana on borders of banana of fish pond	Fishpond with multi-storey system on dike and borders: Teak (*Tectona grandis*) and Sisau (*Dalbergia sisoo*)trees in upper storey, Banana in themiddle storey and grasses as ground cover	Terai Farwestern Nepal

E. Home garden		
31. Homestead – multistorey system – cereal, vegetables, spices, and animals	A homestead with small compartment of multistorey system: ■ Upper stratum: betel nut with betel leaf, pepper species), coconut, Bakaino (MPTS) ■ Mid stratrum: banana, fruits (banana, guava, citrus), eskos, black pepper ■ Lower stratum: grasses, vegetables (mustard, colocassia, corn, turmeric ginger) ■ Animal shed for cow, goat or buffalo	Terai Eastern Nepal
32. Multipurpose trees, fodder trees and fruit trees on terrace risers-crops (maize, vegetables, and vines) on alleys-homestead (house and animal shed)	A homestead with intensive cultivation of cereal (maize, wheat, rice or millet), vegetables, spices on terraces or alleys, and multu-purpose trees (timber, fruits, fodder,firewood) and grasses on terrace risers, and animals in cut-and-carry system	All Terai and Midhills
33. Teak, Sisau - fruit trees-vegetables, homestead and animals (cut and carry system)	Homestead with teak, Sisau, fruit trees (mango, guava, papaya); vegetable patch and animals on cut-and carry system	Terai Farwestern Nepal
F. Woodlots		
34. Small-scale woodlot	Eastern Nepal: Kadam (*Neolamarckia cadamba*) Teak (*Tectona grnadis*), Sisau (*Dalbergia sissoo*), Molato (*Plantago malato*, Utis (*Alnus nepalensis*), Sallo (*Pine*), Siris (*Albizia*), Central Nepal: Sallo (*Pine*), Utis (*Alnus nepalensis*) Chilaune (*Schima wallichii*), Sal (*Shorea robusta-Castanopsis spp.*), Siris (*Albizia)*.	Eastern and Central Nepal (midhills and Terai)

G.	Shifting cultivation		
35.	Shifting cultivation	Clearing and burning of fallowed lands and or public forests then planting of cereals (maize and millet) and vegetables in 3-5 years cultivation	Eastern Nepal and central Nepal

SPECIFIC EXAMPLES OF AGROFORESTRY PRACTICES IN NEPAL

Upland Intensive Mixed Farming System

This farming system is found in the upland of low to mid hills with varied slope. This is the most widespread and heterogeneous farming system in Nepal and is characterized by the cultivation of a wide range of crops, based on geographic and agro-climatic conditions, terracing etc. Livestock production is an important component of almost all farm families which contribute manure, draught power, and cash. Off-farm work is an important source of income for many poor households.

This approach of combining trees, agricultural crops has been able to sustain both livestock (3 goats, 1 buffalo and 1 cow) and fulfilling the demand of firewood, fodder and small timber for household consumption. Underneath of trees some seasonal vegetables such as Rayo, (broad leaved mustard) radish, cucurbeats, different varieties of beans, potato are grown and sufficient for sustaining family members of 4 person. A diagrammatic figure of this kind of system is provided in Figure 5.

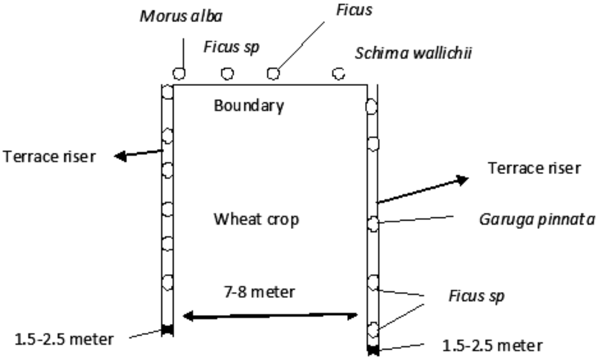


Figure 5. Upland intensive farming system

Tree Crop Mixed Farming System

This farming system is adapted mainly in the hill landscapes with poor soils where paddy cannot be produced. Tree crops are grown as agri-silvopastoral system under the smallholder land-use systems. Main users of the tree products are the smallholders who grow food and cash crops, keep various livestock, and supplement their livelihoods with off-farm income. Farmer' seems to have adopted the different cropping patterns as per the physiographic conditions of the country and there are many cropping patters in the country. For example, a study conducted by Amatya et al (2014) in Lamjung and Kavre districts of Nepal showed that three cropping patterns have been in operations.

1. Paddy-Mustard-Maize
2. Paddy-Paddy-Vegetable
3. Paddy-Potato-Maize

Highland Extensive Mixed Farming System

This farming system is found in high altitude and steep slopes. It often lies above the Upland Intensive Mixed Farming System with poor resources and lower population density. Extensive forested areas occur in this type farming system, some of which have little human settlement. The farming system can be subdivided into shifting cultivation and rangeland. Both types produce livestock, crops and forest products. This system provides the principal base for a number of tribal (indigenous) groups (Figure 6).

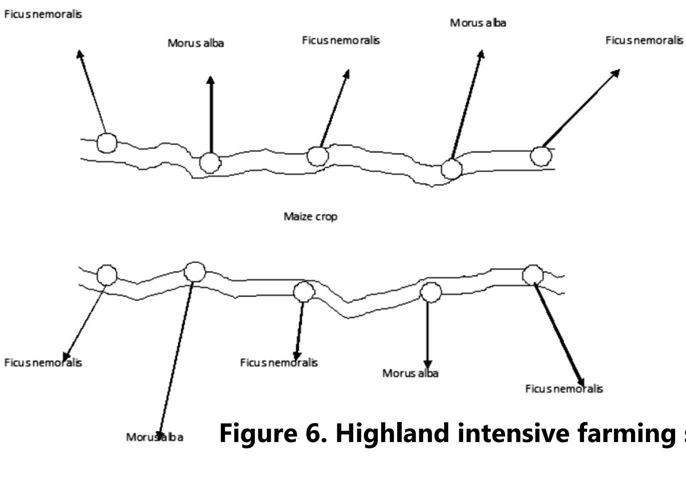


Figure 6. Highland intensive farming system

Temperate Mixed Farming System

This farming system is found in moist and dry sub-humid agro-ecological zones. Major crops are wheat and maize with smaller areas of rice, soybeans, sweet potato depending on temperature and water availability.

Root-Tuber Farming System

This farming system is found in plain and hill landscapes, also in the mixed cropping practice in almost all types of lands. It is one of the dominant farming systems in Terai Regions of the the country. Cultivation of the root food crops (sweet potato and yam), vegetables and fruits, and also livestock is common.

Specific Farming System Based on Commercial/ Plantation/ Industrial Crops

There are some crops which are grown for selling, income generation and export. These special crops or commodities are grown in the geographically suitable altitude and domains as appropriate and have specific farming system. Short descriptions of those are as follows.

Tea farming

The combination of tea and tree crop is one of the important faming systems in Nepal (Figure 7).

Figure 7. Tea plantation under Siris trees, Jhapa, Nepa

It is mostly developed in the Eastern part of the country. .Tea is grown commercially where the climate is moist with high humidity, long monsoon. In this system teas are planted along with two tree species of Siris (*Albizia procera* and *A. lebbek*) depending on the altitude. Normaly Seto Siris (*Albizia procera*) are planted along with tea crop at low where as Kalo siris (*Albizia lebbek*) at high altitude. But shading trees are not planted in the high hills where orthodox tea is grown as in Kanyam of Illam district.

Cardamom farming (under trees)

This is one of the potential agroforestry systems in hills of Nepal. The practice of planting cardamom under Utis (Alnus nepalensis) is an old one (Figure 8).

Figure 8. Intercropping Cardamom with Alnus nepalensis, Kavre district, Nepal

It has been more than 42 years farmers have practicing this system. Mechi and Koshi hill mainly Taplejung and Illam districts are very famous in cardamom farming. Cardamom (*Amomum subulatum*) is the major shade loving plant species which grows better under shade and moist areas along side of stream, waterfalls, tree covers and shrubs.

Alley Cropping

This is an agroforestry system where fast growing, nitrogen fixing shrubs are planted as hedgerows, and food crops are inter-planted between these hedgerows. This system was developed at the International Institute of Tropical Agriculture (ITTA) in Ibadan during 1984 AD. The essence of the system is that small trees or shrubs are planted and pruned frequently to prevent them from producing too much shade and are grown in relatively compact rows (between 2 and 4 m, never more than 6 m apart). Crops are grown in the space- the 'alley' - between the rows of trees. The clippings are laid down as mulch around trees and crops, gradually decomposing and becoming incorporated into the soil as organic matter. They have found that the yields of some crops are higher between the mulched rows than in comparable fields that are not being alley cropped. The IITA found that yields from maize were three times greater after four years of mulching with *Leucaena latisiliqua* clippings (IITA, 1986).

In the mid hills of Nepal (Naldung and Hinguwapati, Kavre Palanchok district) this practice is common with Ipil-Ipil (*Leucaena spp*) as the hedge crop. Alley or hedge-cropping was first introduced in Nepal to farmers in Bahunepati in Sindhupalanchok district (Arens, 1984; Baidya, 1990). In this method Ipil-Ipil (*Leucaena)* was sown 2-4 m apart in rows along the contour in farmers' field and the resulting hedge cut periodically to 15-30 cm above ground level to provide fodder and green manure. Ipil-Ipil (*Leucaena spp*) was planted at one metre spacing along terrace risers. This method was very successful and contributed expansion of livestock significantly in that area.

However, recently planting of Iipil- Ipil (*Leucaena latisiliqua*), Bhatmase (*Flemingia spp*), Mendula (*Tephrosia candida*) species as hedge along with maize or millet depending on the season are being common in middle hills of Nepal. In some cases, turmeric and ginger are planted under Albizia/Alnus and other species. The distance between trees varies depending on the tree introduced or planted. Normally, it is between 1.2 m to 1.5 m. Figure 9 below provides a glimpse of this system being practiced at Kavre district.

Figure 9. Alley cropping in Kavre

Most research is focused on obtaining the right species combination, but the question as to which crops respond best to which tree species also varies according to site conditions. Fast growing tree species such as Ipil-Ipil (*Leucaena latisiliqua*), Griricidia (*Gliricidia sepium*), and Gamari (*Gmelina arborea*) have been used in various research efforts. Other species that can be used for alley cropping include Calliandra (*Calliandra calothyrsus*) and Sesbania (*Sesbania grandiflora*) but these also have high moisture requirements. Therefore, they should be tried in vegetable gardens that are irrigated during the dry season. Acidic soils are also not suitable for alley cropping with the species that have been suggested above. Diverse crops such as millet, cowpeas, yams can be grown in the alleys to mitigate these problems.

In addition to the increased complexity of matching compatible crop and tree species to specific site conditions, several other problems may limit the widespread adoption of alley cropping. A major consideration to farmers who are considering various intercropping schemes is the amount of arable land that the trees will take up. Farmers tend to favour methods that will take as little land out of crop production as possible. Alley cropping requires close placement of tree rows, which can substantially reduce the amount of land left for the crop rows. Where land scarcity is a problem, therefore alley cropping is probably not the best method to adopt particularly in the narrow terrace land in the hills.

However, in some districts of Nepal such as in Mustang district people share available land for agriculture, horticulture and trees for timber and mainly for firewood where Willow (*Salix species*), Bhote pipal (*Populus species*), Blue pine (*Pinus wallichiana*) and Dhupi (*Juniperus species*) are planted around Apple (*Malus domestica*) orchard and crop fields. Individual on an average grows 30 to 80 trees and shrubs along with fruit orchard (186 apple trees on an average). The crops grown as understory included potato, naked barley, buckwheat, maize, oat, bean and vegetables. Most individuals grow oat (*Avena sativa*) Ryegrass and white clover for their livestock. Tree species also act as wind break for fruits from strong wind during early stage of fruit development.

Besides the above-mentioned systems some of the newly developed system in the country is as follows.

Apiculture

Apiculture sub-system is one of the old traditional practices and recently developed innovative agroforestry systems where forests and agricultural crops are utilized by honey bees. This system is also increasingly getting importance in the terai area where various types of trees and agronomic and horticultural crops such mustard, pumkin and other flowering vegetables as are grown together or in the vicinity of the forest.

This system has been in practice in hill districts as well. For example, in Jeta Taksar area of Lamjung district (500 m) more than 20 households are practicing this system. In this system, bees play a crucial role in collecting honey from different types of inflorescences. Bees are kept in hives and honey is normally harvested twice a year. First in the month of April/ May and the next is during November/ December. Honey yield is more in the month of April/May in comparison to that harvested in November/December. One of the reasons for high yield of honey in summer is the availability of various kinds of inflorescences mostly citrus fruits in and around the apiculture centre. Out of various flowering trees, inflorescence of Chiuri (*Diploknema butyracea*), Sal (*Shorea robusta)*, Chilaune (*Schima wallichii*), Katus (*Castanopisus indica*) and Sajiwan (*Moringa oleifera*) are considered better for honey production. During winter season a very less number of trees would flower hence some alternatives that produces inflorescences should be adapted for more honey yield.

The income from harvesting honey depends on the time of harvest and the number of bee hives and the species used in making bee hives. The price of beehives varies as per the material used. For making beehives the suitable species is Tooni (*Cedrela toona*). As Tooni (*Cedrela toona*) is available only in forests and getting scare people are switching to Utis (*Alnus nepalensis*) trees for making bee hives, which are easily available in and around villages. For the smooth functioning and sustainability of this system one of the requirements is that surrounding forest/ trees outside forests, shrubs and herbs both wild and domesticated should flower at least during summer and winter period and they should be within 5-7 kilometers radius where beehive has to be established.

Sericulture

This system has been recently developed in the hills but now increasingly becoming important where Kimbu (*Morus alba*) comes naturally. This system utilizes the insect *Bombyx mori* for the production of silk. Farmers lop Kimbu (*Morus alba*) three times a year from October, March/April, June/July to feed the silkworms. Farmers plant Kimbu (*Morus alba*) on the terrace risers and pollard them and used cutting for propagating the plant (Figure 10).

Figure 10. Morus alba for sericulture, Kavre

Trees in and around farmland

In this system agriculture crops are grown in between trees. Normally trees are planted on the edges of the farm. Combination of tree, shrubs and crop species generally varies as per the physiographic reasons, namely the Tarai, Hills and the Mountains. Micro-climatic variations owing to the variations in altitude, north and south face and slope provide different local specific systems. For example, *Ficus species*, Rato siris (*Albizia julibrissin*), Kalo siris (*Albizia lebeck*) and Bakaino (*Melia azaderacth*) are planted in the hills whereas Sisau (*Dalbergia sissoo*) is one of the favourable tree species in the Terai. Underneath Sisauo, the agriculture crops, normally gown are maize, mustard and sugarcane.

Due to the hilly topography, majority of farmers grow trees in rain fed terraces or on degraded land along with agricultural crops. The predominant tree species are: *Ficus spp.*, Sisau (*Dalbergia sissoo*), Koiralo (*Bauhinia spp*). Badahar (*Artocarpus lakoocha*), Cassia (*Cassia siamea*), Sesbania (*Sesbania aculeate*), Kalo siris (*Albizia lebbeck*) in the Terai region and Utis (*Alnus nepalensis*) and varieties of *Ficus* species in the hill areas.

The preference of planting agroforestry tree species also varies as per the locality and their use. For example in Nalma of Lamjung district, some of the preferred fodder trees are Badahar (*Artocarpus lakoocha*), Kabro (*Ficus lacor*) and Ginderi (*Premna latifolia*), Dabdabe (*Garuga pinnata*), Khasreto (*Ficus hipsida*), Ipil-Ipil (*Leucaena latisiliqua*), Nimaro *(Ficus roxburghii*), Khasro Khanyo (*Ficus semicordata var. semicordata*), Bhatmase (*Flemingia spp*) Terprosia, Dumri (*Ficus racemosa*) and Kimbu (*Morus alba*) and Bakaino (*Melia azadarach*). This practice appears to work well where adequate fallow land is available, site is dry but work force (labor) is scarce specially working in the agriculture fields.

Intercropping with horticultural crops

This type of agroforestry system is more prevalent in the Terai regions where horticulture crops such as Mango (*Mangifera indica*) and Litchi (Litchi chinensis) are intercropped with agronomic crops. The spacing for mango varies from 5 to 6 metres between and within depending on the horticultural crops introduced. An example of intercropping is Mango-sugarcane in Sarlahi district is provided in Figure 11.

Figure 11. Intercroping Mango trees with sugarcane (Sarlahi district)

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Chapter 4

BENEFITS AND SERVICES OF AGROFORESTRY

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FUNCTIONS OF TREES IN AGROFORESTRY

Forests perform three main functions: production, protection and regulation. All the three functions are equally important for sustaining both animal and human lives. The success of agroforestry system mainly depends on identification of suitable sites, adequate and reliable information on options of different combination of cereal, fruit and tree crops and species selection.

In any given agroforestry system, all these functions are inter-related and overlapped but depending on the objectives of agroforestry systems one tend to dominate others. Among the various important production functions identified, a few these have been described in detail.

Agroforestry's contribution to improve soil fertility has been widely recognized. Leaf litters enrich the soil fertility by providing organic matters. Trees leaves control the speed of the raindrops and allow them to go down to the land surface slowly. Tree roots help water to infiltrate into lower part of the soil surface. After the soil is saturated, plants growing on it can utilize the excess water. The excess water is leached to the inner part of soil and supports to originate natural well and streams in the lower areas. It also makes the water table high. Such natural conditions will be favorable for growth of plants and micro-organisms in the soil (Pandey, 2007).

Productive function of trees

The production functions of trees include a number of economic goods and services. The goods are timber, posts and poles for construction purposes including housing and furniture. Wood production in agroforestry can be quite different than under industrial forestry regimes because of its small scale production. Similarly, Non-Timber Forest Products such as fodder, leaf litter, bedding material for animals, grasses, charcoal, essential oils, resins, gums, honey, medicinal herbs, fruits, seeds, all comes from forests.

Protective function of trees

The protective functions of forest include protecting soil from degradation due to rain, wind and radiation while protecting the flora and fauna from overexploitation. Trees also help muffle urban noise. Through their foliage, craggy bark and abundant litter, trees and forests decrease the speed of water dispersion and favour infiltration of rainwater. The capacity of trees to retain other precipitations such as mist is also important.

Similarly, forest offers a habitat to flora and fauna through the functioning of the forest ecological processes. Apart from direct physical and biological protective functions, forests in general have gained increasingly important recreational functions so much so that mountain ecosystem are among the fragile ecosystems targeted by United Nations Conference on Environment and Development (UNCED) Agenda 2. In high mountains forests protect settlements against avalanches, falling rocks and landslides.

The protective functions of mountain forests and their relation to climate change are increasingly becoming important. This subject has been largely studied worldwide. Although it is beyond the scope of this book a glimpse of protective function of trees has been provided in the following section.

Regulatory function of trees

The regulative functions of forest include absorption, storage and release of carbon, oxygen, water, nutrients, radiant and thermal energy. One of the important functions of trees/ forest is to maintain the hydrological cycle (Figure 12).

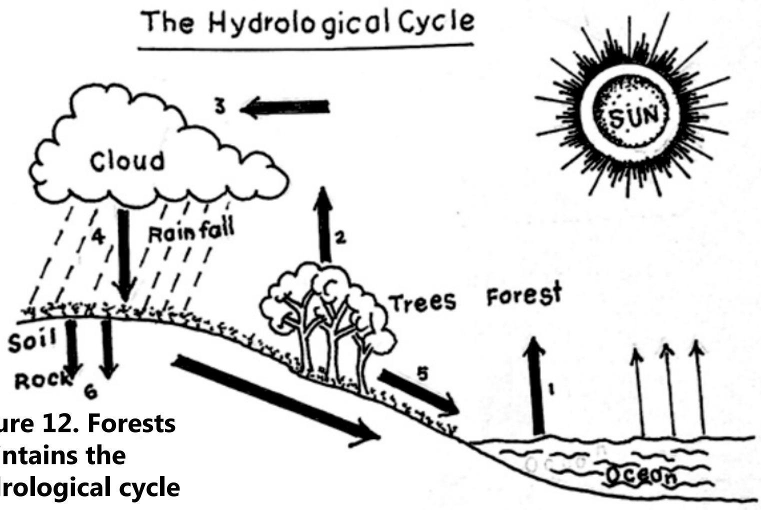

Figure 12. Forests maintains the hydrological cycle

Within the regulatory functions of trees, a new dimension has come up and is collectively known as Climate Change. Sustainable agroforestry practices can increase the ability of farm to sequester atmospheric carbon while enhancing other ecosystem services, such as improved soil and water quality.

Trees have significant role in reducing global warming, mitigate climate change and sequester atmospheric carbon. Global warming refers to an increase in average global temperatures. Natural events and human activities are believed to be contributing to an increase in average global temperatures. Global warming is caused primarily by increases in "greenhouse" gases such as Carbon Dioxide (CO2). There are six main greenhouse gases that are contributing the global warming. They are carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O), plus three fluorinated industrial gases: Hydrofluorocarbons (HFCs), Perfluoro carbons (PFCs) and Sulphur hexafluoride (SF6). Water vapor is also considered a greenhouse gas. These gases have significant effect to raise temperature.

Rise of temperatures will have a significant impact upon crop yields, and this is where tree could help in providing shade through appropriate agoforestry techniques. Trees, plants and crops absorb carbon dioxide (CO2) from the atmosphere through the process of photosynthesis, and store as carbon in biomass (tree trunks, branches, foliage and roots) and soils. The sink of carbon sequestration in forests and wood products helps to offset sources of carbon dioxide to the atmosphere, such as deforestation, forest fires, and fossil fuel emissions.

Microclimate improvement

In agroforestry systems, microclimate amelioration results primarily from the use of trees for shade, live fences or windbreaks and shelterbelts. The presence of trees reduces heat and light. Atmospheric temperature, humidity, movement of air, soil temperature and soil moisture are changed due to agroforestry systems. The smaller temperature fluctuations under shade are attributed to reduced radiation load on the crops during the day and to reduced heat loss during the night. A reduction in vapour pressure deficit causes a reduction in transpiration and hence reduced water stress for intercrops. Microclimate amelioration also reduced the disease and pest pressure by facilitating biological control agent

Water conservation

The presence of trees has positive effect on water budget of the soil and crops growing between or beneath them. A mulch or litter layer increases the infiltration of rain water and simultaneously reduces evaporation from the soil. Mulch is important, especially on sandy soils, for trees to grow, as it maintains soil moisture during the dry season where water supply for the crops is a problem.

Weed control

Shade of trees suppresses light-demanding weeds. It has been reported that weed yield is positively correlated with available radiation (Patra, 2013). Apart from shading, weeds suppression is also determined by factors such as land-use history, weather and mulch quality and crop competitiveness. Shade also reduces dry-season fire risks.

Competition for nutrients

Any agroforestry system is assessed mainly by the yield of crop components both tree and agriculture crops and reduction of production mainly of agriculture crops receives more attention than those of the associated tree species. The effect of nutrient competition is more severe for the crop components than for trees, because the crop root system is usually confined to the soil horizons that are also available to the roots of trees but trees can exploit soil volume beyond the reach of the crop.

Competition for water

Competition for water is likely to occur in most agroforestry systems at certain periods except in areas with well distributed rainfall or continuous supply of ground water. It plays a major role in the productivity of agroforestry systems despite the use of drought-tolerant and drought-adapted plants, especially in dry areas.

Microclimatic modification for pests/diseases

Bacterial and fungal diseases may increase in shaded, more humid environments in an agroforestry system. Trees and crops can be a host of each other's insect pests and diseases.

DYNAMICS, INTERACTIONS AND PRODUCTIVITY IN AGROFORESTRY SYSTEMS

Tree Crop Interaction in Agroforestry

When trees and crops are planted in the same place and at the same time, they interact with each other. The interaction is two ways: above ground interaction for light and below ground interaction for nutrient. The success of an agroforestry system relies heavily on component interactions and their nature. Between the two components, the nature of interactions can be described based on observable net effect of one component on another in a given system. The deciding factor of the nature of interaction is the ability of different components to capture the essential growth components such as nutrients, light, moisture from one another.

The interaction depends on the surface area covered, root system of the species and the type of trees and agriculture crops involved in a specific time and space. In case of Nepal, there is a gap on the literature on the above and below ground tree crop interaction although some studies have been conducted by Barakoti et al during 1998 and 1999 and Barakoti and Amatya in 2004. Literature however, mentions that there are mainly three types of interaction between tree and agriculture crops (including MAPs and NTFPs). They are:

- Complementary
- Supplementary
- Competitive

Complementary

Tree crop interaction is said to be complimentary with each other if all components (trees, agriculture crops, medicinal and aromatic plants and livestock) help develop by creating favorable conditions for their respective growths. In this case all the components of the agroforestry system produce optimal yield in comparison to monoculture. For complementary interaction the species should be chosen so that they do little harm with other components in question. For example, agriculture crops wouldn't flourish on the same piece of land at the same time if trees selected have the habit of having surface rooting system (as in the case of *Ficus spp*.) and the agriculture crops selected are shallow rooted ones. But they would complement with each other if the case is just opposite. Similarly, the planting distance also plays a crucial role in nullifying competition between planted crops. However, there are substantial opportunities for temporal complementarities if species make their major demands on available resources at different times, thereby reducing the possibility of competition. Barakoti et al. (1999) found positive effect on wheat and negative effect on maize in alley cropping of mixed tree species (*Artocarpus lakoocha*, *Bauhinia purpurea*, *Eucalyptus camaldulensis*, *Leucaena latisiliqua*, *Madhuca latifolia*) in Tarai condition where intercropping was encouraging in the on-farm condition (Barakoti, 1990).

Puri and Bangarwa (1992) reported that in Haryana, India a spacing of 3m from trees affected wheat yield but beyond 7m there were no impact. Species like Babul (*Acacia nilotica*) affected wheat yield and prolonged maturity, while Sisau (*Dalbergia sissoo*) had less effect.

In Pakistan Seto Siris (*Albizia procera*) Masala (*Eucalyptus camaldulensis*) Ipil-Ipil (*Leucaena latisiliqua*) and Kimbu (*Morus alba*) had no effect on wheat yield beyond 2 m (Akbar et al, 1990)

Supplementary

If the two components interact in such a way that the yield of one component exceeds the yield corresponding to its sole crop without affecting the yield of other component, the interaction is known to be supplementary in nature. In Dhankuta district, Nepal, farmers' plant trees especially Utis (*Alnus nepalensis*) that fix atmospheric nitrogen and species that conserves soil and water are given priority (Baral and Amatya, 2000).

Competitive

If trees and agriculture plants are grown in the same piece of land at the same time, there would be general tendency that they interact and such interaction in said to be competitive if they interact in such a way that the increase in the yield of one component leads to decrease in the yield of other component. The intensity of competition would be highest when requirements are similar, and the growth and development proceed synchronously for both the components.

POSITIVE AND NEGATIVE INTERACTION

Trees are the most important of all components in agroforestry systems. Based on components, interaction types may be 'tree crop interactions' (TCI) and 'tree-animal interactions' (TAI). These interactions could be positive (beneficial) or negative (harmful).

These positive or negative interactions can be direct or indirect or both. Some of the features of these interactions are discussed below:

Positive interactions

It is believed that leguminous trees such as Ipil- Ipil (*Leucaena spp)*. Siris (*Albizia spp*), Acacia spp and Koiralo (*Bauhinia spp*) have a positive influence on adjacent crop. Farmers in the eastern hills classify trees grown in cropping land into *Rukh*o (unfertile) for negatively affecting species and *Malilo* (fertile) for positively affecting species on the succeeding crop. They also categorize nutritious fodder as *Posilo*. Some of the features of positive interactions can be summarized as follows:

Increased productivity

One of the important features of positive tree crop interaction is the increase in productivity. In positive interaction, in almost all the cases, the overall productivity of an agroforestry system is generally greater than that of an annual system. Increased productivity is the outcome of the capture of more growth resources, e.g. light and water or due to improved soil fertility.

Improved soil fertility

The potential for micro-site enrichment by some trees is an extremely important aspect of agroforestry. Alley cropping using fast growing, nitrogen fixing trees can substantially increase the soil fertility. A major feature of this system is the capacity of trees to produce a large quantity of biomass for green manure. However, they need regular pruning to prevent shading to the intercrops.

Nutrient cycling

In agroforestry systems, trees provide additional nutrient inputs through biological nitrogen fixation and deep nutrient capture. Deep nutrient capture is the uptake of nutrients by tree roots acting as a 'safety net' from depths where agriculture crop roots are not active. Similarly, taking up of nutrients from weathered minerals in deeper layer by tree roots is called as 'nutrient pumping 'or 'nutrient mining'. These nutrients are considered as additional inputs in agroforestry systems because such nutrients would otherwise leach down as far as the crop root zone is concerned. They become an input upon being transferred to the soil via tree litter decomposition (Figure 13).

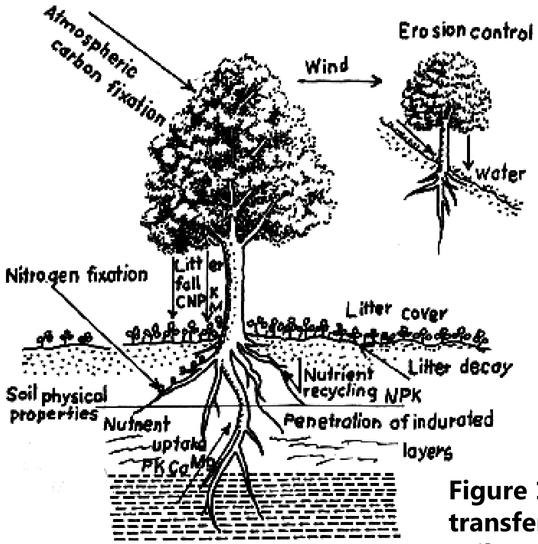

Figure 13. Nutrients transfer through tree soil

Soil conservation

Contour hedgerows are highly effective in controlling soil erosion. The woody hedgerows provide a semi permeable barrier to surface movement of water, whereas litter mulch from trees reduces the impact of rain drops on the soil and minimizes splash and sheet erosion.

Negative interaction

The most important negative interactions can be observed in between animals and plants. Low quality tree fodder with toxic compounds can adversely affect livestock production. Mechanical damage of trees or deterioration of soil properties through compaction by the animals may have a negative impact on the woody perennial component. Many tree fodder species contain secondary compounds that reduce the feed value. For example, Ipil-Ipil (*Leucaena spp*) contains mimosine which affects hair fall in livestock if they are fed regularly only with Ipil-Ipil (*Leucaena spp*). The presence of high levels of phenolic compounds (tannins) or strong odours found in the leaves of species such as Cassia (*Cassia siamea*) and Gliricidia (*Gliricidia sepium*) may reduce palatability or acceptability of the fodder. Some of the harmful compounds reported from the tree fodders are cyanogenic glucosides in *Acacia* species and robinin in *Robinia*.

Competition for light

Plants need light for its growth and optimal yield. Almost all plants compete for light. There are trees that demand strong light for it growth. Sisau (*Dalbergia sissoo*) is a strong light demander and hence the combination of crops underneath should not be light demander one. It must be shade bearers one. Investigations on light interception and competition in agroforestry systems are generally scarce.

Allelopathic interaction

Allelopathy refers to the inhibition of growth of one plant by chemical compounds (allele chemicals) that are released into the soil from neighboring plants. The effects of these chemicals are dependent mainly upon the concentration as well as the combination in which one or more of these substances is released into the environment. The organic compounds released this way are often phyto- toxins. Such toxic chemicals may be injurious to microbes and even to the seedlings of those plants releasing them. The effects of the chemicals may result in complete inhibition of growth or retarded growth. When the toxic exudates of the adult trees of some species suppress and eventually kill their seedlings, then the phenomenon is called auto allelopathy. Allelopathic compounds are released in to the environment by volatilization, leaching from living or dead tissues, exudations from roots and decay of plant tissues. These chemicals effect negatively in the growth of plants.

In India, wheat and mustard yield reduction adjacent to rows of Masala (*Eucalyptus tereticornis*) were correlated with reductions in soil water (Malik and Sharma, 1990 quoted in Young 1997). Hauser (1993 b) reports that Bhatmase (*Flemingia congesta*) and Gamari (*Gmelina arborea*) has small allelopathy effect.

Factors affecting interactions

The interactive relations among agroforestry components are affected by many factors. In the first stage, it is the locality factor (rainfall, temperature and humidity) followed by edaphic (physical, biological and chemical properties of soil) one which nearly decides the choice of tree and agriculture species. However, in the second stage, density and age of trees may affect interactions in the components. However, many of these factors at the second stage could be manipulated for better production selecting appropriate management system.

Management options to neutralize negative interactions

The magnitude of interactive effects between trees and other components of agroforestry systems depends on the characteristics of the species, their planting density, and spatial arrangement and management of the trees. Manipulating densities and arrangements is probably the most powerful method for capitalizing on beneficial effects of trees while reducing the negative interactions between them. However, the effect on different parameters is different depending on the distance from the tree. However, in some cases, for example, when trees are used as supports for crop plants (mostly vines), the planting density of the trees is determined by the planting density of the crops.

Management options to achieve increased growth of components in agroforestry systems are microclimate amelioration, fertilization, application of mulch or manure, irrigation, soil tillage. Similarly, management options for decreased growth include pruning, pollarding, reducing shading, application of herbicide and grazing or browsing.

Choice of tree species is crucial about shading effects, root competition or provision of useful products for the farmer. As trees generally have a long lifetime, a good choice is a far-reaching decision, which has effects in the longer term.

AGROFORESTRY FOR SOIL AND WATER CONSERVATION

Agroforestry practices can be used to control soil erosion via three mechanisms: barrier, cover and binding approaches. The barrier approach checks run-off and soil removal by means of barriers. These may be earth structures, vegetative strips, or hedgerows.

The cover approach is to check raindrop impact and run-off through the maintenance of a soil cover formed of living and dead plant material. Techniques include mulching, cover crops, minimum tillage and general tree canopy cover. As a rule of thumb, maintenance of ground cover of 60%, by a combination of living and dead plant material, is necessary to control soil erosion. The attitudes of scientists and agricultural development workers to soil conservation have changed greatly over the many decades that it has been formally studied and promoted. These changes are largely due to farmers' resistance in adopting many of the recommended soil conservation strategies; but they were also due to scientists learning more about soil in the process. For example, in the beginning they were interested in simply "Soil Conservation". Then that water was having more impact on yields than any soil that was saved so the terminology changed to "Soil and Water Conservation" (SWC).

Then in the 1980s it was realised that the actual fertility of the soil was an equally important issue as the mere amount of soil saved; so the terminology evolved to "Soil Restoration" or "Soil Rehabilitation". Consequently, land husbandry efforts have been shifting away from structural technologies (eg terraces, bunds and ditches) toward vegetative or agronomic technologies (eg hedgerows, green manure and cover crops, and dispersed shade). Whereas earlier SWC technologies were often too expensive for farmers, these latter vegetative approaches can often pay for themselves within the first year of their application. This makes their adoption much more successful.

Tree roots bind soil and also help in improving aeration and water permeability. Regular cropping in the same unit of land removes the natural soil cover and nutrients which declines agriculture crop productivity. Adaptations of Agroforestry techniques, to some extent, help ensure farmers to keep their farmland fertile and productive through various means.

Leaf litter from the trees add organic matter to the soil and act as a mulch to retain soil moisture and help prevent soil erosion. Leguminous trees such as Tanki, Koiralo (*Bauhinia spp*) *Acacia*, and, *Sesbania* improve soil fertility directly by nitrogen fixation. Different strata of both agriculture and forest crops provides good ground cover which help reduce eroding surface soil. Home garden agroforestry system is better example of this binding approach which contains an intensive mix of crops of all types (tree, shrub, herb including vegetables).

SYSTEMS FOR IMPROVING SOIL PRODUCTIVITY AND LAND SUSTAINABILITY

Soil productivity can be defined as the capacity of land resources to support plant growth, including agriculture crops, trees and pastures on a sustained basis in a board sense. In a narrow sense, it is the capacity of soil to support plant growth, under the given climatic and other environmental conditions. Under natural ecosystem, soil productivity is maintained by a constant interaction between soil and plant communities with internal recycling of nutrients.

The use of land for any purposes will change this equilibrium. To sustain production, there should be ways and means to restore soil fertility if not maintain the existing one. The decline of fertility in any agroforestry system is checked by a range of practices, green manuring, compost and animal manure to restore organic matter and add nutrients to some extent along with adopting various farming and planting techniques.

Effects of trees on soils

Farmers' normally believe soils that develops underneath trees may be fertile, well-structured and has good water holding capacity and stores nutrients and plants trees along with various agricultural crops. The effects of trees on soils can only be found when research is carried out in this aspect. The evidence of the effects of trees on soils can be obtained from comparing soil beneath tree canopies and within the orbit of the root system with soils in surrounding area beyond the influence of tree. It has been reported that in India, in the sub-humid natural and cultivated soils, seven tree species including Casuirina (*Casuarina equisetifolia*), Masala (*Eucalyptus spp*), Teak (*Tectona grandis*) and Bans (*Bamboo spp*.) have been studied to examine the effects trees on soil.

Soils under trees compared with soil beyond have higher C, N, P and K. Similar study conducted by Aggarwal et al (1993) with Prosopis cineraria in the arid part of India also showed that C, N, P and K are higher (Quoted in Young (1997). There are five processes by which trees effects positively and improve soils (Table 6).

Table 6. Processes which trees effects positively and improve soils

Processes which increase additions to the soil	Processes which reduces losses from the soil	Processes which effect soil physical conditions	Processes which affect soil chemical conditions	Soil Biological processes and effects
Maintenance of soil organic matter	Protection of erosion	Maintenance of soil physical properties	Reduction of acidity or its rate	Production of high quality leaf litter
Nitrogen fixation	Nutrient retrieval and recycling	Penetration of compact layers by roots	Reduction of salinity and sodicity.	Improved activity of soil fauna
Nutrient uptake	Reduction in the rate of organic matter decomposition	Modification of extremes of soil temperature	Reduction of soil toxicities	Improvement of nitrogen mineralization
Atmospheric inputs	Reduction of water loss from evapotranspiration			Increased availability of Phosphorus
Increased water infiltration	Increased water storage capacity			Root nodulation
Water retrieval				Exudation of growth promoting substances

Source: Young (1997)

Adverse effects of trees on Soils

Trees are not always beneficial to soils, they have some adverse effects as well. The effects are either directly or through competing with herbaceous plants for soil resources. There are mainly three types of effects of trees on soils: They are:

- Allelopathy
- Acidification
- Removal of organic matter and nutrients

Acidification

Many plants produce organic acids. Where plant litter accumulates on or is incorporated to the soil, these acids (including acetic acid, oxalic acid, and other acids) are liberated.

This is especially acute in soils under coniferous trees such as pine, spruce, and fir which return fewer base cations to the soil than do most deciduous trees.

THE ROLE OF TREE ROOTS IN AGROFORESTRY

The role of tree roots in agroforestry is immense in a sense that it is the prime means of which water and nutrients are taken up from the soil. Roots typically form 20-50 % of plant biomass (Young, 1997). According to Young (1997), most agroroestry research into roots initiated only from 1990s and the first substantial review on roots were cariried out by Schroth (1995) and van Noordwijk et al (1996) followed by schwab et al (2015). Young (1997) has pointed out five main functions of roots in agroforestry. They are:

- To provide physical support for the tree;
- To take up water and other nutrients from different soil horizons for tree growth;
- To enrich soil with organic matter through root shedding;
- To reduce leaching losses through capturing water and nutrients from soil solutions; and
- to assist in the binding of soil properties into structural aggregates through root exudates.

Tree root system consists of structural roots, of medium to large diameter, fine or feeder roots (1-2 mm in diameter) very fine root hairs and mycorrhizae symbiotic association with soil fungi.

Coarse roots are relatively permanent in nature where as many of the fine roots die back and regrow annually in seasonal climatic conditions recorded.

Nutrient cycling and nutrient-use efficiency

Nutrients are available to plants by weathering from primary and secondary soil minerals, atmospheric inputs in the form of rain and dust, fixation of nitrogen from the air, mineralization of nutrients from organic forms and additions from sources external to the system (Table 7).

Table 7. Soil type and its implications for agroforestry systems.

Soil type	Soil properties	Implications for agroforestry systems
Oxisols Ultisols	Low base status	Low nutrient availability and plant production. Shallow rooting system. More root competition between trees and annual crops.
Spodosols	Very sandy	Shallow rooting system. Low plant production
Alfisols Mollisols	Fertile	Good root development. Nutrient pumping from deeper base is high.
Andisols	Fertile	Potential for nutrient cycling from deeper soil layers.
Aridisols	Moderate fertility Moisture stress	Deep roots hence good potential for nutrient pumping from deep un weathered soil

Source: Young (1997)

CARBON SEQUESTRATION IN AGROFORESTRY SYSTEMS

Trees in agroforestry system can sequester carbon. Nath and Aziz (2013) conducted a survey of home garden in ecologically critical area of Cox bazaar in Bangladesh. They report that villager allocates 70% of their homestead area for homestead agroforests. Supari (*Areca catechu*) is the dominant species with average density of 4000 plants/ha. Carbon sequestration in homestead agroforestry can be considered permanent as complete biomass removal does not occur, which has been one of the key concerns in carbon sequestration projects within the Clean Development Mechanism

(CDM) of the Kyoto Protocol. The role of these agroforests as a means of livelihood improvement and storage of atmospheric Carbon deserve to get Carbon credits from appropriate carbon financing mechanism.

WATERSHED SERVICES OF AGROFORESTRY

In recent years, there has been increasing interest in the market-based valuation of forest known as Payments for Environmental Services (PES), in which beneficiaries of ecosystem services provide economic incentives (voluntary or mandated by law) to the providers of the services including park authorities and local communities. It is a market-based mechanism. Until before 2000, Nepal had no experience of PES in a protected area context. There has been low level of awareness on the issues such as environmental goods and services and possible benefits to be obtained and its equitable sharing. The major stakeholders (local people, local institutions, beneficiaries of ecosystem services, and policy makers) lack awareness of ecosystem services and their value.

It was only in the year 2003 when pilot case studies on PES have been carried out in Nepal with the support from donor agencies such as International Centre for Integrated Mountain Development (ICIMOD) and World Agroforestry Centre to compensate and reward upstream community of some watershed in Nepal. These studies indicated that it is possible to develop and implement PES mechanism over common property resources if people have user rights over such resources. The possibilities of having PES in privately owned forests have not yet assessed.

In Nepal payments for ecosystem services (PES) so far mainly work as an incentive-based mechanism to conserve water resources. Some of the PES schemes which are operational in Nepal include Kulekhani Hydropower PES, Dhulikhel Drinking Water Supply and rewarding Buffer Zone Committees (WTLCP, 2012). Western Terai Landscape Complex Project (WTLCP) has also piloted PES in Kailali and Kanchanpur districts to promote effective conservation. In this project, Community Forest User Group (CFUGs) are the seller of water services, while irrigation users are the service buyers. The amount generated from selling of services is used for service enhancement, forest conservation, monitoring and public audit (WTLCP, 2012). A glimpse of PES pilot projects in Nepal is presented in Table 8.

Table 8. PES pilot projects in Nepal

Site/ District	Environment service	Buyer	Seller
Kanchanpur	Water	Sitaram Irrigation User Committee (58 households irrigating 66 ha land)	Baijanath CFUG (285 households managing 195 ha forest from last 10 years)
Kanchanpur	Water	Brahmadev Irrigation User Committee (202 households irrigating 220 ha land)	Siddhanath CFUG (302 households managing 585 ha from last 15 years)
Kailali	Flood control	Geta VDC, Kailali	Chetna women CFUG (47 households managing 59.02 ha forest), Sahid Sanghari CFUG (254 households managing 44.96 ha forest) and Panchawati women CFUG (86 households managing 23.4 ha forest)

ICIMOD and Forest Action carried out a PES feasibility study in Shivapuri-Nagarjun National park, which lies to the north of Kathmandu. The national park is well recognized for its rich biodiversity and watershed services. It provides up to one third of the piped water supply in the Kathmandu Valley. Water from the catchment is also used for generating hydroelectricity, irrigating paddy fields, bottled water, and the soft drink industry.

Another study by ICIMOD's at Sundarijal catchment near Kathmandu valley has estimated that there is ample potential of providing such services by Community Forests (ICIMOD, 2011).

Similarly, a study carried out by Khatri (2011) revealed that PES in Kulekhani has provided a mechanism for transferring hydroelectricity revenue to the local communities to support rural development. The Kulekhani experience demonstrates that a PES scheme can be issued at the community level and is not necessarily constrained by individual choices and land tenure issues. The long tradition of forest management at the community level is certainly a major strength in this type of implementation.

Bhatta et al (2014) report that payment for ecosystem services (PESs) is part of a new and more direct conservation and management paradigm which recognizes (1) the need to bridge the interests of communities connected by ecosystems, (2) the costs of securing and maintaining the provision of different ecosystem services and (3) that those who benefit from these services need to pay for these costs. PES is a possible instrument to finance ecosystem management in Nepal.

Paudyal (2017) report that Community-Based Forestry (CBF) is now a popular approach for landscape restoration, forest management, biodiversity conservation and support for rural livelihoods in Nepal yet the role of CBF in providing ecosystem services (ES) from restored forest landscapes is limited in Nepal. He report that Nepal's forest policy and practices are still dominated by a narrowly conceived notion of forest management that hardly accommodates the holistic concept of ES.

Studies reveals that there is ample scope for developing a PES scheme for other parks/ protected areas and within Community Forest areas of the country. The development of a regulatory framework, public awareness building and clarification of the roles and responsibilities of multiple stakeholders is necessary for its promotion.

AGROFORESTRY FOR CARBON BIOMASS

The use of biomass as a forest management tool is a relatively new concept in Nepal. Computation of biomass is necessary to estimates of present stocking and potential productions. Additionally, biomass information is necessary in order to manage the forest scientifically. Biomass could be in different forms. They may be in the form of timber, bark, leaf, fodder and root. The importance of these forms depends on the use of trees and their products in question. In Nepal, biomass products, in general, were used to be measured in terms of weight rather than volume. Nonetheless, researchers have found easy way to estimate the biomass rather than weighing each component separately.

It is on trial basis, yet in the Terai Arc Landscape programme, World Wildlife Fund (WWF) has already created a renewable energy carbon project based on 7,500 individual household biogas units. The amount of carbon absorbed is based on calculating the "reduction of greenhouse gases emissions that would otherwise be produced from the breakdown of livestock and human waste and from the burning of fossil fuels and fire wood that would occur in the absence of biogas stoves" (WTLCP, 2012). So far two bio-gas projects are registered as Clean Development Mechanism project in Nepal (WTLCP, 2012). It has been reported that from these two projects annual carbon revenue was around USD 60,000. This amount meets around 50 % of the current annual expenditure of Biogas Support Programme, including subsidy (WTLCP, 2012). Although study of carbon in private forests has not yet been carried out, Oli and Shrestha (2009) report that stock status of forest carbon in Nepal in 2005 was 897 million tons and Community Forest annually sequestrates 1.8 tons of carbon per hectare per year on average indicating Nepal's huge potential for forest-based carbon and possibility of its crediting.

Nepal's annual mitigation potential from Reduced Emission form Deforestation and the Forest Degradation (REDD) are 15.97 million tons of Carbon dioxide (CO_2) and 4.4 million tons of CO_2 respectively (ICIMOD, 2009). This suggests that Nepal has good potential for attracting REDD+ funding. The country has already become a signatory party to the United Nations Framework Convention on Climate Change (UNFCCC). The Readiness Preparation Proposal (R-PP) was approved in 2010. Currently eight national and international agencies are piloting in climate change and REDD+ activities in the country. The pilot projects/ programmes have provided some early lessons such as need of appropriate data collection, establishment of Forest Carbon Fund, capacity enhancement of FUG and to raise awareness especially of marginalized and disadvantaged groups including women. Based on the watershed REDD+ pilot programme has been initiated in

Chitwan, Gorkha and Dolakha districts and FUGs were provided some financial support. The pilot REDD+ activities implemented by various national and international agencies as reported by Mandal (2011) is presented in Table 9.

Table 9. The REDD + initiatives in Nepal

Types of programme	Institution involved in the programme	Remarks
Support to user Group for sequestering forest carbon.	ICIMOD, FECOFUN, ANSAB	Experiment based on watershed in three districts
Poverty alleviation through REDD.	WWF, Nepal	Experiment based on landscape at the western districts
Local level capacity building about REDD	RECOFTC	Local level in the district
Adaptive programme on climate change through forest management	SDC, Finnish Ministry of Foreign Affairs	Forest Users Group
Capacity enhancement programme for indigenous, janajati communities	Federation of Indigenous communities of Nepal	Specially aimed at raising the awareness among the indigenous communities.
Capacity development of Collaborative Forest Users Group	SNV	Collaborative Forest Users Group of Banke district.

Source: Hamro Ban. Annual Report, DoF, 2010/11

BIODIVERSITY AND LANDSCAPE CONSERVATION THROUGH AGROFORESTRY

Biodiversity is an important consideration in maintaining natural environmental balance in a particular habitat. This becomes particularly important in areas, where due to the encroachment of natural forests, biodiversity is depleting causing a potential loss in the natural habitat (Kharal et al 2008). Biodiversity in the farmland becomes an important considerationin such a situation. Kharal et al (2008) shows that tree species biodiversity in the rural farmland of study area are lower in comparison to the similar areas of countries like India, Bangladesh and

Sri Lanka. The lower biodiversity status is mainly due to the wide distribution of two dominating tree species of Sisau (*Dalbergia sissoo*) and Bakaino (*Melia azederach*).They have also found that tree species biodiversity in the farm land has been affected by the socioeconomic situation of the area.

Similarly, on-farm tree growing is potentially important for livelihood strategies and forest conservation and varies greatly according to local contexts. A study conducted by Oli et al (2015) suggests that on farm trees are very important to farmers. The study carried out in the middle hills of Nepal showed that farmers had on average 65 trees per hectare. Trees on farmland contributed on average 43 % of households' firewood and fodder consumption.

In this context, tropical forest conversion to pasture, which drive greenhouse gas emissions, soil degradation, and biodiversity loss, remains a pressing socio-ecological challenge (Mcneely at all, 2006). This problem has spurred increased interest in the potential of small-scale agroforestry systems to couple sustainable agriculture with biodiversity conservation, particularly in rapidly developing areas of the tropics (Mcneely at all, 2006). Agroforestry systems have the potential to maintain higher levels of biodiversity and greater biomass than lower diversity crop or pasture systems in addition to providing natural resources (i.e. food, medicine, timber, fuelwood). There is more chance of enhancing soil quality and supporting increased agriculture productivity if there are more plant diversities in a given space. Study conducted at three common land use types maintained by small-scale farmers in the Pearl Lagoon Basin, Nicaragua showed that higher surface soil % C, % N, and pH relative to neighboring to secondary forest, while maintaining comparable plant diversity. The finding of the study suggest that small, diversified agroforestry systems may be a viable strategy for promoting both social and ecological functions in eastern Nicaragua and other rapidly developing areas of the tropics (Mcneely at all, 2006).

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Chapter 5

ECONOMIC AND MARKET CONSIDERATIONS OF AGROFORESTRY

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PRINCIPLES OF ECONOMIC ANALYSIS

Agroforestry as an investment project is unique because of the multiplicity of products produced or become available at various points in time of the investor’s management horizon. Unlike any other agrarian-based investment project, agroforestry has generally long gestation period because of the presence of trees in the system. This characteristic makes a choice of discount rate a vital matter. It also requires estimates of furture benefits, which are extremely uncertain due to the length of time involved. Within the timeframe of the management horizon, multiple outputs are produced jointly by several components of the system which often make financial analysis a tedious task. Benefits from agroforestry that are often hard to quantify within the auspices of financial analysis are wildlife habitat, climate regulation function, soil and water conservation, and improvement of biodiversity.

Empirical evidence suggests that financial returns generated from agroforestry system are generally much higher than return from continuous unfertilized food crops around the developing world Acharya et al (2009).

FOREST BASED INCOME AND EMPLOYMENT

Generating income and employment from trade and enterprise operation based on forest products and services constitute their pathway to link forest with food security. Management of timber, non-timber forest products and ecosystem services can generate significant contribution to the household and national economy. In this regard, in Nepalese hills, goats are considered as an important part to food security in comparison to another type of animals because goats are easy to raise, require low maintenance, and easy to sell.

ENHANCED FOREST-FARM INTERFACE

Forests are an integral part of the agricultural system in Nepal. They provide fodder, leaf litter for mulching and animal bedding, conserve soil and water, retain soil fertility, and preserve water sources. They also support livestock and thereby providing manure and draft power, among others.

The most important concept of evaluating agroforestry systems, in terms of economic efficiency, is to compare them to each other or to the monoculture agricultural or forestry systems that they replace. There are many ways to evaluate agroforestry systems. The biological efficiency of agroforestry systems can be assessed by measuring how much biomass is produced per unit of area or time. The planting and caring for a crop of trees use resources, such as land, people, materials (tools, fertilizers, plants, etc.), and perhaps machines, with the intention of producing timber, fuel wood, fodder for future. Financial appraisal specifically measures (or estimates) the value of the resources used with the anticipated benefits produced.

In financial analysis, the most important concept one should know is discounting. Discounting is the process of determining the present values of any expected future costs or benefits. It uses discount rate which represents the rate at which financial amounts in the future are converted to their present values. Discount rate represents the time preference for money or the rate of return required by the investor.

The difference between the costs and the benefits shows how much more or less money is likely to be earned than spent over the lifetime of the project. By setting out costs and returns for each year, in a cash flow table, financial analysis shows how much funding is going to be needed annually. Below are examples of cost and benefits of an agroforestry project. Neither all the costs nor all the benefits apply to every project and some are less significant than others. The ones that are not significant can be ignored; local knowledge and judgement will indicate which costs and benefits are important (Table 10).

Table 10. Costs and Benifits sheet in a typical agroforestry model

	Direct	Indirect
Costs	■ site clearance ■ site preparation ■ plants ■ planting ■ maintenance ■ protection ■ harvesting and access ■ marketing ■ land	■ Competition with agricultural crops for: – light – soil nutrients – water ■ Harboring of agricultural pests and disease ■ Production of toxic substances
Benefits	■ <u>Woods:</u> firewood and charcoal, posts and poles, pulp wood and chips, sawn timber ■ <u>Other tree products:</u> forage, fodder, resin, gum, latex tannin, dye, fruit, nut, oil, leaves and shoots, medicine, bark, fiber	■ Atmospheric nitrogen fixing ■ Grazing ■ Green manure ■ Nutrient recycling ■ Shelter and shadefor people, livestock and crops such as coffee and cocoa ■ Control of soil erosion ■ Harboring useful predators and prey animals, nectar for honey, ■ Amelioration of environment

The costs of agroforestry project will include variable cost e.g. site preparation, seedlings, planting and maintenance, overhead cost, e.g. law compliance, capital cost e.g. land purchase, equipment and lastly opportunity cost. The benefits will include any revenue from the agroforestry prject and return from synergies with other enterprise i.e. complimentary projects. In this context Amatya (1996) has tried to calculate the financial returns in the Nepali agroforestry model when Taungya based agroforestry was in pratice.

METHODS AND TOOLS FOR ECONOMIC ASSESSMENT

The economic evaluation of agroforestry systems is complicated by the long periods of time covered by one 'cropping" rotation also complicated by the fact that bulk of returns generally occur at the very end of the cycle. So the methods used to assess the profitability of an agroforestry system and to compare agroforestry options are based on discounting principles. Discount rates are based on the theory that the value of NPR whether it be a benefit or cost is greater today than the same amount of benefit or costs next year or any time in the future.

Tree crops are long-term investments and there needs to be a way of assessing the current value which considers the time and risk. The risks involved with tree crops are disease, fire, accidental damage, and that there will be a suitable market at the time of harvest.

Discount rate

Discount rates are the opposite of interest rates. To calculate how much one has to pay back at the end of the period the following formula is used:

$Vn = Vo * (1+i)n$

Vo = money value in year 0 (the present)

Vn = money value in year 'n'

i = discount rate expressed as decimal

The selection of discount rate used in the calculation of Net Present Value (NPV) is very important and changes the results quite significantly. Most evaluations will use discount rates between 5 to 10% which broadly represent the range of average interest rates that banks and other financial institutions apply. If a farmer were borrowing money from a commercial money lender to establish agroforestry system, then the discount rate used in NPV calculations should be at least the same as the interest rate imposed by the lender. This may often be in the range of 15 to 25%.

If the agroforestry project were part of a regional development project and provided significant environmental benefits (eg soil conservation) then the agency promoting development may use lower discount rates (3 to 5 %) in their calculations. Using lower discount rates favours projects with long term benefits.

Discounted Cash Flow (DFC) Modeling Approach to Financial Analysis

DCF analysis involved basically of setting-up a cash flow table over the investment horizon. The cash flow table lists what operations may be needed for growing the various crops or livestock and what kinds of cost and or benefit can be expected as a result.

The financial viability of any investment projects is judged based on the net present value (NPV), land expectation value (LEV), internal rate of return (IRR), and payback period. NPV measures the worth of an investment project or the amount that a particular project would contribute to the wealth of the household or a firm. If the NPV is positive for a given discount rate (required rate of return) it is predicted that the project will add to the household's wealth and the project is said to be financial viable or acceptable. The formula for calculating NPV is

$$NPV= \sum_{t=1}^{n} \frac{R_t}{(1+i)^t}$$

Where is the net cash flow, t is time in years, i is the discount rate. For computational purposed, this formula can be expanded to

$$NPV= \sum_{t=1}^{n} \frac{B_t}{(1+i)^t} - \sum_{t=1}^{n} \frac{C_t}{(1+i)^t} \quad \text{or}$$

PV= $\sum$ Present value (PV)of benefits – $\sum$ Present value (PV) of costs

Where PV = $\frac{A_t}{(1+i)^t}$, A is the amount, i and t as defined earlier.

The project with the cash flow in Table 11 has an NPV of NRs 2359 at end of year 5 at a discount rate of 10% using the formulae presented above.

NPV is a good tool for comparing two agroforestry systems over a similar time span. The selection of discount rate used in the

Table 11. Elements of cost and benefits of an agroforestry project

Year	0	1	2	3	4	5
Costs (NRs 1000)	10	7.5	4	5	4	4
Revenues		7.5	7.5	7.5	7.5	7.5
Present value of costs C_t/(1+i)^t	10	4.5	3.3	3.0	2.7	2.5
Present value of revenue B_t/(1+i)^t	0	6.8	6.2	5.6	5.1	4.7
Net discounted revenue	-10	2.3	2.9	2.6	2.4	2.2

calculation of NPV is very important and changes the results quite significantly.

However, it does not take into account the relative magnitude of costs and benefits. Also in some cases the production cycles of two agroforestry systems may be quite different and so NPV may not be the best tool to use. Hence, other tools used for analysis are

- Benefit-Cost (B/C) Ratio
- Internal Rate of Return (IRR)
- Annual Equivalent Value (AEV) and
- Valuation of Inputs and Outputs

Land expectation value (LEV) is an alternative measure to NPV to compare projects of varying time span. This approach assumes an infinite rotation. If the agroforestry project were part of a regional development project and provided significant environmental benefits (eg soil conservation) then the agency promoting development may use lower discount rates (3 to 5 %) in their calculations. Using lower discount rates favours projects with long term benefits.

Benefit-Cost (B/C) Ratio

B/C ratios are an alternative way of providing information for decision making when there is a constraint on costs. They are often used in agricultural development programs where there may be several projects among which funds are to be allocated.

B/C ratios are useful in calculating budget allocations. Table 12 presents the Income/Expenditure Ratio up to 20 years.

Table 12. Income/ Expenditure Ratio

Interest rate %	Rotation length in years							
	3	4	5	6	8	10	15	20
2	1.06	1.08	1.10	1.13	1.17	1.22	1.35	1.49
3	1.09	1.13	1.16	1.19	1.27	1.34	1.56	1.81
4	1.12	1.17	1.22	1.27	1.37	1.48	1.80	2.19
5	1.16	1.22	1.28	1.34	1.48	1.63	2.08	2.65
6	1.19	1.26	1.34	1.42	1.59	1.79	2.40	3.21
8	1.26	1.36	1.47	1.59	1.85	2.16	3.17	4.66
10	1.33	1.46	1.61	1.77	2.14	2.59	4.18	6.73
12	1.40	1.57	1.76	1.97	2.48	3.11	5.47	9.65
14	1.48	1.69	1.93	2.19	2.85	3.71	7.14	13.7
16	1.56	1.81	2.10	2.44	3.28	4.41	9.27	19.5
18	1.64	1.94	2.29	2.70	3.76	5.23	12.0	
20	1.73	2.07	2.49	2.99	4.30	6.19	15.4	
22	1.82	2.22	2.70	3.30	4.91	7.30	19.7	
24	1.91	2.36	2.93	3.64	5.59	8.59		
26	2.00	2.52	3.18	4.00	6.35	10.1		
28	2.10	2.68	3.44	4.40	7.21	11.8		
30	2.20	2.86	3.71	4.83	8.16	13.8		

Internal Rate of Return

The Internal Rate of Return (IRR) is the discount rate (i) when NPV = 0 or B/C=1. This method is good for comparing agroforestry systems when discount rate is not specified. However it ignores timing and relative magnitude of costs and returns of the different agroforestry options.

Annual Equivalent Value (AEV) Method

It is the cost per year of owning and operating an asset over its entire lifespan. It is often used as a decision making tool in capital budgeting when comparing investment projects of unequal life spans. For example if project A has an expected lifetime of 7 years, and project B has an expected lifetime of 11 years it would be improper to simply compare the net present values (NPVs) of the two projects, unless neither project could be repeated.

The method for handling the choice of the mutually exclusive projects with different life can become quite cumbersome if the projects' lives are very long. But one can calculate the annual equivalent value (AEV) of cash flows of each projectand select the project that has lower annual equivalent cost.

Valuation of Inputs and Outputs

In a financial analysis, the valuation process is fairly straight forward and market prices are used for all inputs and outputs. But it is necessary to calculate the use and non-use values associated with forests. In case of Consumptive Uses the following items can be dealt with.

- commercial/ industrial market goods (fuel, timber, pulpwood, poles, fruits, animals, fodder, medicines, etc.)
- indigenous nonmarket goods and services (fuel, animals, skins, poles, fruits, nuts, etc.)

Similarly, in case of non-consumptive uses recreation (jungle cruises, wildlife photography, trekking, etc.), science/education (forest studies of various kinds) can be taken into account.

Indirect use values associated with watershed protection (protection of downstream areas) soil protection/fertility improvements (maintenance of soil fertility, esp. important in tropical regions), gas exchange and carbon storage (improvement of air quality, reduction of greenhouse gasses), habitat and protection of biodiversity and species (potential drug sources, source of germplasm for future domesticated plants and animals), soil productivity on converted forest land (space and soil productivity for agricultural/horticultural crops and livestock) can be taken into account.

There are non-use or existence values of forest. They are the value of forest or natural resource complex purely for its existence and without any intention to use the resource in the future. In other words, the value of forest exits which would be available in perpetuity. Many are willing to contribute money, time, or other resources to assist in preserving special endangered species and ecosystems. These economically manifested existence values may be based upon religious, spiritual, cultural, or other values held by individuals or social groups within a society. Although such values are difficult to measure, they should be recognized in valuing the contributions of forests to human welfare.

EXAMPLE OF AN AGROFORESTRY DISCOUNTED CASH FLOW MODEL

The financial analysis functions and other features of Microsoft Excel is widely used in estimating net annual cash flows and to generate financial performance indicators –NPV, IRR, and payback period as well as conduct sensitivity and break-even analysis. An example of the financial analysis of a one-hectare cardamom agroforestry investment project is provided below to show the basic structure of a DCF model and the methods for calculation of the various financial indicators.

The cardamom agroforestry project is assumed to be planted on existing middle age Utis (*Alnus nepaulensis*) stand with a canopy cover of about 50-60%. The cardamom investment project is treated as a complimentary project to Utis Woodlot and is dependent upon the service of the shade trees and to a lesser extent on nutrition, i.e. soil organic matter and microbial activities from the existing trees. The capital outlay includes planting materials, plantation establishment and drying and storage shed. The operating costs include labour costs on plantation maintenance, harvesting and drying. The revenue of the project is generated through sale of dried raw cardamom on the farmgate and sale of extra 'cardamom slips'in which the cost of collection of slips is undertaken as a maintenance activity. The investment horizon is 10 years and the analysis using a 'real' discount rate. A zero opportunity cost of the land assumed as the land is already used for forestry purpose and cardamom plantation is the only next best alternative use of the land. The DCF model consists of five blocks namely- physical parameters, financial parameters, cashflow table, financial measures table and break even and sensitivity analysis (Figure 14 a,b,c) below.

Figure 14a. Parameters for discounted cash flow model

Financial Analysis of a 1-hectare Cardamom Agroforestry Project

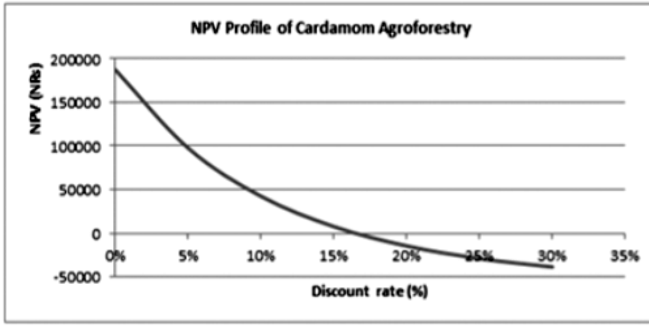
Physical Parameters	
Planting density (plants per hectare)	2500
Replanting rate (%)	20%
Cardamom yield per plant/clump in Year 2(kg)	0.1
Cardamom yield per plant/clump in Year 3 (kg)	0.15
Cardamom yield per plant/clump on ward Year 4 (kg)	0.25
Labour requirement for site preparation (person-days per hectare)	10
Labour requirement for planting (person-days-per 1000 plants)	5
Frequency of weeding and plant tending per year (cycles)	2
Labour requirement of weeding and plant tending per cycle (person days per 1000 plants)	2
Labour requirement for harvesting (person days/ton)	60
Fuelwood requirement for drying (m^3/ton of cardamom)	1.5
Labour requirement of post harvest processing and drying (person-days/ton of cardamom)	15
Floor area of dryier - made of light materials and brick (m^2)	30
Cardamom slips extractable at end of year 10 (slips per clump)	10
Mulching requirement (Bhari per plant per year)	0.2
Financial Parameters	
Cost	
Cost of planting material inclding freight on board (NRs)	10
Daily wage rate at villages (NRs per person-day)	200
Fuelwood price at villages (NRs per m^3)	3000
Sundry tools (NRs per year)	5000
Price of mulch (NRs per Bhari)	20
Cost of drying and storage shed (NRs per m^2)	1000
Revenue	
Farm gate price of cardamom (NRs per kg)	80
Farm gate price of slips (NRs per kg)	5
Discount rate (real) (%)	10%
Annual depreciation rate of shed (%)	5%
Repair and maintenance cost of shed (% of construction cost)	5%

Figure 14b. Example of a DCF model tableau

Year	0	1	2	3	4	5	6	7	8	9	10
Capital Outlay											
Planting stock (NRs)	25,000										
Site preparation (NRs)	2,000										
Planting + basal mulching (NRs)	12,500										
Drying and storage shed (NRs)			30,000								
Total Capital Outlay (NRs)	39,500		30,000								
Capital Inflows											
Resell value of Shed (NRs)											18417
Value of extratable slips (NRs)											125000
Total Capital Inflows (NRs)	-39,500	0	-30,000	0	0	0	0	0	0	0	143,417
Operating Costs											
Plantation maintenance - weeding and tending (NRs)		2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
Replanting cost (NRs)		5000									
Plantation maintenance - mulching and earthing (NRs)		10000	10000	10000	10000	10000	10000	10000	10000	10000	10000
Harvesting cardamom pods (NRs)		0	3000	4500	7500	7500	7500	7500	7500	7500	7500
Post-harvest processing (NRs)		0	750	1125	1875	1875	1875	1875	1875	1875	1875
Repair and maintenance of shed						1,500	1,500	1,500	1,500	1,500	1,500
Sundry tools		5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
Fuelwood cost for post-harvest processing (NRs)			1125	1688	2813	2813	2813	2813	2813	2813	2813
Total Operationg Cost		22500	22375	24813	29688	31188	31188	31188	31188	31188	31188
Revenue											
Cardamom revenue (NRs)		0	20000	30000	50000	50000	50000	50000	50000	50000	50000
Total Revenue (NRs)		0	20000	30000	50000	50000	50000	50000	50000	50000	50000
Total Annual Operating Surplus/net cash income		-22500	-2375	5188	20313	18813	18813	18813	18813	18813	18813
Net Gross Revenue (NRs)	-39,500	-22,500	-32,375	5,188	20,313	18,813	18,813	18,813	18,813	18,813	162,230
Project Balance (NRs)	-39,500	-59,955	-86,711	-82,813	-68,940	-57,259	-46,639	-36,986	-28,209	-20,231	42,316

Figure 14c. Example of DCF model outputs

NPV	42316
IRR	16%
Payback Period (years)	10



Discount rate versus NPV

		0%	5%	10%	15%	20%	25%	30%
NPV	42316	187417	97501	42316	7636	-14602	-29102	-38681

Sensitivity Analysis

Parameters	20% increase	Current	20% decrease	Change on NPV
Farm Gate Price of Cardamom (NRs/kg)	100	80	60	
NPV	97804	42316	-13173	55489
Daily Wage Rate (NRs/ person-day)	240	200	160	
NPV	30020	42316	54611	12296
Yield at full bearing (kg/ plant from 4 years)	0.3	0.25	0.2	
NPV	69977	42316	14654	27661

Break-even Analysis

Parameters	Value
Farm Gate Price (NRs)	65
Daily Wage Rate (NRs)	338
Yield at full bearing (Kg)	0.17

Pudasaini (2015) has analyzed agro forestry practices in 40 pro-poor leasehold forest group of four district of Nepal and found that economic contribution of leasehold forest was Rs.14, 941/ hhs/yr/ (including internal product consumption and market sale). Its contribution in food security was 2.5 month/hhs/yr. Silvo pastoral was major agroforestry system practiced and livestock rearing (mainly goat) was extra sources of income for majority of poor households. Badahar (*Artocarpus lakoocha*), Grass species (*Stylosanthes guianensis,* molasses and bamboo), *Ficus species*, Ipil-Ipil (*Leucena latisiliqua*), Bakaino (*Melia azadirach*) are the most preferred agroforestry species for these communities. Financial analysis of these combinations would be of interest to farmers and communities.

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Chapter 6

SOCIO-CULTURAL ASPECTS OF AGROFORESTRY

Chapter 6

SOCIO-CULTURAL ASPECTS OF AGROFORESTRY

SCOPE OF AGROFORESTRY IN THE COUNTRY

There is a tremendous scope of expanding agroforestry in the country especially in the middle hills. One of the limiting factors for developing agroforestry is the small area of land holding. Interaction with officials of Municipality in Baitadi district, far western development region of the country, suggests that there are plenty of under utilized land in that district as people have left them in search of new and better environment and employment opportunities. This underutilized land could be pooled together from individual owners and appropriate agroforestry models/ entrepreneurs that are commercially viable could be initiated.

NON-TIMBER FOREST PRODUCTS IN AGROFORESTRY

Non-Timber Forest Products (NTFPs) are those products produced from forest which are essentially not a timber. They cover various products originating from forest such as grass, fibers, fruits, leaves, bark, exudates, animal products including soil and minerals. Although the term Non-Timber Forest Products provides almost the same meaning, in India, it is known as "Minor Forest Products" (MFP). The word MFP covers all forest products other than timber. Acknowledging the economic importance of NTFP or MFP the World Forestry Congress held in Dehra Dun in 1954 recommended them being called "Economic Forest Produce other than Wood".

Nepal is very rich in plant species. Of the estimated total 7000 vascular plants, more than 700 have been recorded having medicinal and aromatic value. The first edition of the handbook on Medicinal Plants of Nepal by Watanabe, et al (2005) has attempted to describe 108 plants (DPR, 2005). IUCN published a National register of medicinal and aromatic plants in 2004.

This register deals with 187 species of plants of Nepal. Later on Watanabe, et al in 2013 published the supplement of the same handbook which includes 150 plant species.

A recent study carried out by Magar (2014) suggests that NTFPs have great potential of contributing in national economy, but it has not been able to harness these resources in a sustainable way because of the problems of policy followed by institution.

According to World Health Organization, the majority of the world's human population especially in developing countries depends on traditional medicine (WHO, 2002). Medicinal and aromatic plants of Nepal provide the primary health care to majority of Nepalese population. This is followed by generating additional income mostly in the mountain areas. The livelihood of the majority of mountain populations depends on collection and trading NTFPs. It has been estimated that the revenue generated from Medicinal and Aromatic plants including NTFPs cover 16 % of the income generated by the forest-based products. Mostly all medicinal and NTFPs are exported to India. Of all the total number of species, the top five species Jatamansi (*Nardostachys grandiflora*), Chiraito (*Swertia chirayata*), Kutki (*Neopicrorhiza scrophulariiflora*), Timur (*Zanthoxylum armatum*) and Ritha (*Sapindus mukorossi*) exported to India make up more than 52 % of the total value (Watanabe, et al.2013).

DOMESTICATION OF NTFPS

Domestication is the process of cultivating wild plants for human consumption. The process is recent one as many of NTFPs including Medicinal and Aromatic Plants (MAPs) increasingly receded in and around forest premises.

Over-and unscientific harvesting of many MAPs in Nepal has caused a rapid depletion of many species including Chiraito (*Swertia chirayita*) and Satuwa (*Paris polyphylla*). Actually, the concept of MAP domestication is not much clear among many Nepalese people. Domestication have been seen sometimes failure as well. It is mainly because of the lack in understanding of the elements of domesticating NTFPs including MAPs. In order to address the domestication techniques, a study was undertaken from February 2014-July 2015 in two sites Ramche (2000 m) and Shypru (2300 m) of Rasuwa district of Nepal. The study revealed that domestication is technical, economic, environmental and social issues. On technical front, it is essential to know about the silviculture characteristics of the species. On economic front, the financial return it provides and on environmental front it should not be invasive and socially acceptable (Amatya, et al. 2016).

However, currently many projects are trying to demonstrate domesticating NTFPs/ MAP species. High Value Agriculture Project in Hill and Mountain Areas (HVAP) is establishing demonstration plots of Timur (*Zanthoxylum armatum*) in its working area (Salyan and Surkhet) districts through Agro-Herbo Forestry Model. Mulato (*Brachiaria ruziziensis*) and agricultural crops (Maize, Ginger or Turmeric) are planted alleys between the tree rows. It is expected that Timur trees would yield fruits (after 3-5 years of planting) the other crops would provide some additional benefits to the concerned farmer. Timur is prominently found in the middle hills of Nepal and are being cultivated both in private and in leased land. The unit cost of production of timur in the project area is estimated at NRs 47 per Kg for commercial cultivation and at NRs 40 per Kg for wild collection.

HVAP is being implemented by Ministry of Agricultural Development (MoAD) and is financed by International Fund for Agricultural Development (IFAD). NTFP agroforestry system is practicing in the project study area - Dharapani VDC of Surkhet district in the Surkhet-Jajarkot road corridor of HVAP where most of the women are engaged in the production of Timur (*Zanthoxylum armatum*) fruits.

Timur (*Zanthoxylum armatum*), an aroma bearing fruit, is one of the seven products selected for Value Chain by HVAP. The promotion of Timur value chain is mainly focused in two road corridors - Surkhet –Dailekha and Surkhet – Jajarkot including some parts of Salyan. Of the Timur growing area, as it is believed that this has potential to enhance the household income thereby contributing on the poverty reduction of the involved actors particularly in Timur value chain.

The recent study conducted at Dharapani Village Development Committee of Surkhet district by HVAP project indicates that women are involved in various steps of product management and marketing of Timur and are considered the domain of women; however, study reveal the fact that their involvement is mostly confined to the small retail village level trade only (HVAP, 2017).

THE ROLE OF WOMEN IN AGROFORESTRY

When we think of the rural women, the first image that comes to our mind is of poor women in the rural area carrying loads of fuel wood, working in household, farm, looking after the livestock and many different forestry activities (Shiva and Aalok, 2014). Throughout the developing world, women make significant contribution to agroforestry. Many women farmers have been using some of these agroforestry practices, though unconsciously, in their traditional farming methods while other women farmers are not even aware of any of these systems and the immense benefits it offer (Shiva and Aalok 2014).

A large share of Nepalese population, approximately 70%, is forest dependent. Womens in Nepal have developed a strong bond with the environment in general and with forest resources, in particular. Women in Nepal, especially of rural districts, are more inclined to household affairs such as collection of fire wood for cooking and heating, fodder and animal bedding for livestock, and search for food (wild yam, wild mushroom). These household operations drag a significant amount of time available to them. It has been estimated that 78% of the fuel collection in Nepal is done by women. In 1980, the Expert Group on Women and Forest Industries of the UN Economic and Social Commission for Asia and the Pacific reported that as much as two-thirds of the time collecting fuel-wood was spent by women (ESCAP, 1980).

Women also use forest products for purposes like basket-making, ropes making, straw mats and other such annual supplies for the livelihood needs. In the absence of other viable options of alternative energy, women in Nepal are forced to burn animal dung for heating and cooking purposes.

Amatya and Cedamon (2014) report that in Lamjung district of Nepal, women are engaged in practicing silvo-fishery system where trees Ipil-Ipil (*Leucaena latisiliqua*) and Koiralo (*Bauhinia variegata*) and other fruit species such as Banana (*Musa paradisiaca*) and Papaya (*Carica papaya*), and herbaceous species Napier grass (Pennisettum purpureum), and Stylo (*Stylosanthes guanensis*) are planted on the terrace risers.

Another activity where Nepalese women are involved is in transferring forest biomass to the agriculture field where, minor tree products such as leaves, leaf litter and ground grass of different types are collected and transferred in the farmers' homestead (Figure 15).

Figure 15. Biomass transfer from forest to farm (Kavre Palanchok district, Nepal)

Normally biomass transfer from pit to agriculture field is through doko (a basket made of bamboo in Nepali language). These substances generally known as farm yard manure, acts as natural fertilizers that would improve soil productivity and ultimately produce higher agriculture crop yield.

It has been claimed that if women had access to the same resources (e.g., education, farm inputs and labour) as men, food production would be boosted by 10-20%. Despite the key role that woman play, their contribution to agriculture is largely ignored by policy makers.

Similarly, women are involved in sericulture, a type of agroforestry system where insect *Bombyx mori* are feed leaves of Kimbu (*Morus alba*) tree in Nepali for the production of silk. For this, women raise Kimbu trees on their farmland, manage them, harvest fodder from these trees, regularly and feed to insect for silkworm production.

It is women who keep a close watch on forests and detect any minor change in them, but their contributions have largely been ignored. Therefore, a two days workshop entitled "Women in Agroforestry" was organized in Kathmandu on November 2013 in an attempt to look at their role in agroforestry under the auspicious of International Union of Forestry Research Organizations (IUFRO), Ministry of Forest and Soil Conservation, Government of Nepal and Nepal Foresters' Association, Kathmandu. Many tree products that benefit women are collected from wild populations in forests, woodlands/ rangelands, park lands or on farms. With the increase in population, some of the products are becoming scarce and women have to walk longer distances. The workshop examined various aspects of agroforestry and the role of women. The proceedings are available in IUFRO website (www.IUFRO.org).

There are several case to prove that the participation of women is essential for the success of agroforestry project. The important role of women in economic development is well depicted by Boserup (1970) in (Shiva and Aalok, 2014). She has explained central positions of women in the household economy of their societies. Following are the reasons why women should be involved in Agroforestry program.

- Women play a key role in most agricultural production systems.
- Women contribute to protection and management agroforestry species on the farm land.
- Women suffer more from environmental degradation and better know how about environmental concerned.

- In practice women are main managers of environmental and natural resources because they are more involved in utilization of natural resources.
- Women are more responsible for care and share in harvesting of field crops and collection of forage and fodder.

Thus, women are involved in almost all types of agroforestry practices in Nepal but they need to refresh on their existing knowledge on multiple use trees, planting techniques, pruning and lopping of these trees and appropriate pruning tools. In this context, Bajracharya (2014) has identified important areas of action research in all the regions of Nepal. They should include:

- Selection of tree species from among some three-dozen indigenous and one-dozen successful exotics vis-à-vis their silvicultural characteristics and local suitability;
- Choice of shrubs and herbs of economic value for commercial and general purposes, such as, medicine, essential oil, fibres, floss, food, etc.;
- Planting out of two-dozen known fodder trees and grasses according local preferences;
- Adoption of proven cereals, fruits, and crops;
- Development of soil and water conservation techniques to suit slow soil, aspect, and microclimatic conditions;
- Generation of additional income and employment opportunities through agri-slivi-pastoral systems.

WOMEN IN BIOMASS TRANSFER

At least sixteen (16) nutrients are needed for plants to grow, flower and make seeds. If crops are grown continuously in the same field, scarcity of these elements starts occurring. To replace such elements in the soil, fertilizer from an outside source should be added. Plant nutrients could be made available in the soil through biomass transfer. One of options is biomass transfer in the form of different components (fodder ruminants, leaf litter, ground grass, among others) plays a crucial role in restoring soil productivity. Biomass transfer is a process where minor tree products such as leaves, leaf litter and ground grass of different types are collected and transferred in the farmers' homestead. This is a regular phenomenon in the Nepalese hills (Figure 16).

Figure 16. Farm yard manure (black spots on the photo) on agriculture field (Kavre Palanchok district)

The forest biomass is normally transferred from natural forest especially for fodder and animal bedding. Used animal bedding and left-over fodder are normally kept for few days to weeks in a pit to develop compost. These composts are then taken to the farm/fields as manure. Farmers' opinion about biomass transfer is to act as fertilizers and help produce higher agriculture yields.

The number of such manure requiring in a given field depends on the size and the soil type. There are no scientific trails on this aspect. However, farmers prefer to collect Chilaune (*Schima wallichii*), Katus (*Castanopsis*) and Khasru (*Quercus*) species from natural forest where as on the farm they would collect leaves of Ipil-pil (*Lauceana latisiliqua*) and Phaledo (*Erythirina arborescence*).

AGROFORESTRY FOR FOOD SECURITY

Food security is a condition related to the perpetual availability of food for everyone living in this planet. And this principle applies to Nepalese citizens. There are three pillars that determine food security: food availability, food access, and food use. World Summit on Food Security in 2009 stated that there are four pillars of food security. They are: availability, access, utilization, and stability. Food should be available throughout the year and to all human beings but the ability to obtain food over time is not the same. It can be transitory, seasonal, or chronic. Agroforestry discipline can boost in securing food supply to some extent. Karki et al (2018) reported that there are three pathways through which private and community forestry could contribute to food security of forest dependent local communities in Nepalese hills. These include: i) Direct food: fruits, vegetables, root crops, honey; ii) enhanced farm forest interface: Community Forest can support to livestock and crop production through fodder, grass, mulch, manure, watershed protection, soil conservation, and protection of biodiversity; iii) forest-based income and employment through timber, NTFP, ecotourism and Payment for Ecosystem Services (PES) and Reducing Emission from Deforestation and Forest Degradation (REDD+).

Reviewing the contribution of agroforestry and community forestry to food security and livelihoods of rural people in Middle Hills of Nepal, Pandit et. al (2012) suggest that most agroforestry species are naturally grown on the edges and farm boundaries along with upland crops and on the walls of gullies and barren lands called Kharbari, where some kinds of thatch grasses are naturally grown.

Direct food supply from private and community forest

Given the rich ecological and biological diversity in Nepal, there is ample opportunity that trees provide a wide range of wild fruits, vegetables, mushroom, honey, fishes, insects, animal products and root crops particularly the Tarul, Githa, Vyakur (*Dioscorea spp*). The availability of these diverse wild foods varies with the ecological zones of the country. Historically, there is a rich culture of managing, harvesting, consuming and even selling these products often in the local market. Wild foods are tasty, nutritious, valuable during difficult times, and particularly help meet the food and nutritional needs of the forest dependent poor. Hundreds of such food items are harvested and utilized especially by the poor.

Food security situation of Nepal can be enhanced through several ways. Some of them can be grouped as

1. Reforming existing legislative framework
2. Improving labour availability
3. Providing knowledge and technologies

Reforming existing legislative framework

Forest Act 1993 and Forest Regulations 1994 have placed provisions of private forests, but these Acts and Regulations have not touched upon the practical constraints that private tree planters are facing such as: Payment of Value Added Tax (VAT). Private forest developers have to pay 13 % VAT on their products sold. The private land tree registration has been affected by conflicting sectoral and cross-sectoral policies and laws. Any forest-based industry to be operated at local level should conduct either IEE or EIA based on several criteria. However, these laws and Regulations remain silent for the product harvested from private lands. Some of these rules appear to be complicated especially for rural population located in remote villages, coupled with.

- Unavailability of Quality Tree Seeds/ Seedlings
- Unavailability of technical input from the state for private tree growers
- Problems of harvesting issues of forest products in the absence of land registration certificate
- Absence of suitable business plan resulted in the failure of forest –based enterprises run by CFUG and private tree growers

Improving labour availability

The lack of labour is increasingly becoming difficult in Nepal and in particular to rural villages mainly for agriculture and related business. A study conducted by Asian Development

Bank, Department for International Development, and International Labour Organization showed that about 77% of Nepal's population owned land in 2003/04 although the size of landholdings varied significantly across regions, ethnicity/caste. However, high migration rates within and out of the country may hinder its promotion. About 8% of adult men take jobs away from their usual place of residence (i.e., are "short-term migrants") for their main economic activity.

Providing knowledge and technologies

Limited scientific knowledge is one of the critical constraints for developing forest, farm and security of produced food.

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Chapter 7

POLICIES AND REGULATIONS RELATING TO AGROFORESTRY

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The Constitution of Nepal (2015), through its directive principles pursues a policy to promote and protect rights of individuals, their property and recognized the role of private sector. Forest Policy (2015) and Forestry Sector Strategy (2016) have acknowledged the role of private forests and emphasized the private, public and community partnership in developing forest entrepreneurship of which private forestry is an integral part.The GoN has classified forests into two main categories for the purpose of their management: National Forests (NF) and Private Forests (PF). The ownership and control of NF lies with the government and that of PF with the individual private tree owner.

The Private Forests (PF) Nationalization Act was promulgated in the year 1957 (AD). One of the objectives of this act was to nationalize privately owned forests of the county. The act provisioned a limitation on PF ownership. It allowed private individual to own a maximum of 25 ropani (1.3 ha) of PF in the hills or 5 bighas (3.4 ha) in the Terai. This limitation led to negative impacts on planting trees on private lands. Farmers virtually stopped planting trees on their land. One of the reasons that farmers stopped planting trees on private lands was the fear that the government would further limit the area of PFs. This scenario continued until 1993 (AD). The Forest Act 1993 and Regulations 1995 are the legal instruments to translate the policy vision into practice. However, there is no rule or regulations specifically set out for agroforestry as such. Nepalese people are allowed to collect one head load fodder, firewood, leaf litter and other forest products from the government managed forests throughout the year under this act.

Recent amendment to the Forest Regulations 1995 in 2015 has provisioned more simple and farmers friendly processes for the development of private forests. Farmers can harvest trees species such as Sisau (*Dalbergia sissoo*), Teak (*Tectona grandis*), Tooni

(*Toona ciliata*), Masala (*Eucalyptus species*), Kadam (*Neolamarckia cadamba*) and Aamp (*Mangifera indica*) grown on their private land sale and transport as they wish (GoN, 2015). However, it is necessary for individual farmer to visit the concerned Forest Office only once to register and endorse the stock and obtain permit for transporting the harvested timber.

Similarly, in a bid to promote private forestry in the country. Private Forest Development Directives came into operation in the year 2011. The directives provide a list of 26 tree species suitable for planting on private land. The directives have recommended these trees to be planted mainly into two ecological zones (hill, and Terai and Inner Terai) (Table 13).

Table 13. List of recommended tree species

Serial number	Trees recommended for private plantation in the Hill region	Trees recommended for private plantation in the Terai/ Inner Terai Region
1	Alnus nepalensis (Utis)	Dalbergia sissoo (Sisau)
2	Neolamarckia cadamba (Kadam)	Eucalyptus spp (Masala)
3	Albizia spp (Siris)	Neolamarckia cadamba (Kadam)
4	Populus species (Lahare pipal)	Bombax ceiba (Simal)/Ceiba pentandra (Kapok)
5	Eucalyptus spp (Masala)	Melia azedarach (Bakaino)
6	Melia azedarach (Bakaino)	Albizia spp(Siris)
7	Michelia champaca (Champ)	Dendrocalamus spp (Bans)
8	Morus alba (Kimbu)	Populus species (Lahare pipal)
9	Bombax ceiba (Simal)	Tectona grandis (Teak)
10	Pinus patula (Pate salla/ American salla)	Leucaena latisiliqua (Ipil-Ipil)
11	Gmelina arborea (Gamari)	Acacia arabica (Babul)
12	Castanopsis indica (Dhalekatus)	Azadirachta indica(Neem)
13	Engelhardia spicata (Mahuwa)	Acer oblongum (Phirphire)
14	Pinus roxburghii (Khotesalla)	Syzygium cumini (Jaamun)
15	Pinus wallichina (Gobresallo)	Syzygium jambos (GulabJaamun)
16	Schima wallichii (Chilaune)	Acacia catechu (Khayer)
17	Abies spectablilis (Talispatra)	Garuga pinnata (Dabdabe)

Serial number	Trees recommended for private plantation in the Hill region	Trees recommended for private plantation in the Terai/ Inner Terai Region
18	Cedrus deodara (Devdar)	Bauhinia purpurea(Tanki)
19	Quercus semecarpifolia (Khasru)	Shorea robusta (Sal)
20	Shorea robusta(Sal)	Pterocarpus marsupium (Bijayasal)
21	Taxus contorta (Lauthsallo)	Gmelina arborea (Gamari)
22	Abies pindrow (Thingresallao)	Phyllanthus emblica (Amala)
23	Artocarpus lakoocha (Badahar)	Artocarpus integra (Katahar)
24	Magifera indica (Amnp)	Artocarpus lakoocha (Badahar)
25	Choerospondias axillaris(Lapsi)	Magifera indica (Amnp)
26	Juglans regia (Okhar)	Michelia champaca (Chap)

Source: Private Forest Development Directives (2011).

Leasehold forestry for the poor is a participatory model of forest management designed to reclaim the degraded forests and improve livelihoods of the poor and marginalized households. In this model small plots of national forest land are provided to the group of poor households for a period of forty years with the purpose of operating agro-forestry practices (GoN, 1993). The group protects, manages and utilizes the products of the leasehold forests as specified in the operational plan (GoN, 1995). Leasehold forestry has been piloted in the shifting cultivation areas of Palpa district with the technical support of Food and Agriculture Organization (FAO) since 2010 (Kandel, 2014). He repots that silvo-pastoral agro-forestry model has brought major changes in the livelihoods of the people and ameliorate the environment vigorously in terms of Livelihood improvement of pro-poor population of the country.

CONCEPT OF PAYING MORE ATTENTION IN PRIVATE FOREST VS COMMUNITY FOREST

The 1993 Forest Act has provided special provision in handing over the National Forest to the local communities through Community Forestry Users Groups (CFUG). One of the essences of CF is the ownership of the forest products and the income thus raised by selling the forest products. There are set rules and regulations which have to be followed up by the local communities for managing forest areas in a sustainable way. Community Forestry has been very successful in protecting forests, mostly in denuded hill slopes and barren land. Community forestry guideline amended in the year 2008 so as to make it more relevant in terms of the existing policies, acts and regulations. CFUGs are enjoying full benefit by using timber, fuel wood, fodder, litter, NTFPs and other environmental services within the group. The CFUG may sell the forest products, within or outside the group, obtained by managing the community forests according to the approved operational plan.Similarly, Community Forestry Directives has allowed to plan tea, coffee, small cardamom (*Sukumel*) and big cardamom (*Alachi*) as cash crops in community forests.

Communication with the member of Community Forestry User Group and individual in Illam district reveals that the concept that private individual normally pay more attention to look after and manage tree crop in private forests than in community forests, although he or she may be the member of Forest Users Groups and even in executive committee is not always true. While individual having private forest engage themselves in looking after their own forests they rely on CF for obtaining different forest products which otherwise would be difficult to obtain. There is always a positive interaction between the CG User Groups and individual having private forests.

Agroforestry has significant role towards its contribution in uplifting economic condition and enhancing food security as well as biodiversity conservation in pro-poor households as lease hold forests. Pudasaini (2015) has analyzed agro forestry practices in forty pro-poor leasehold forest group of four district of Nepal and found that silvo pastoral was major agroforestry system practiced and livestock rearing (mainly goat) was extra sources of income for majority of poor households. Badahar (Artocarpus lakoocha), Grass species (Stylosanthes guianensis, molasses and bamboo), Ficus species, Ipil-Ipil (Leucena latisiliqua) and Bakaino (Melia Azadirach) are the most preferred agroforestry species for these communities.

Recent amendment on the Forest Regulations 2051 (BS) has made the process more simple and private forest friendly. For the

23-tree species, listed below, which are mostly grown in private land, farmers can directly harvest. However, it is necessary for individual farmer growing these species to visit the concerned forest office only once so as to register and endorse the stock and take the transportation permit (GON, 2015). The list of such planted is species has been provided in Table (14).

Table 14. Amended list of tree species as per the Forest Regulations 2051 (BS)

Serial number	Nepali name	Scientific name
1	Aamp	*Mangifera indica*
2	Litchi	*Litchi chinensis*
3	Katahar	*Artocarpus heterophyllus*
4	Amba	*Psidium gauva*
5	Haluwabed	*Diospyrus virginiana*
6	Imili	*Tamarindus indica*
7	Lahare Pipal	*Populas deltoides*
8	Goldmohar	*Delonix regia*
9	Birendraphul	*Jackaranda mimosifalia*
10	Kapok	*Ceiba pentandra*
11	Bakaino	*Melia azederach*
12	Neem	*Azadirachta indica*
13	Babul	*Acacia nilotika*
14	Masala	*Eucalyptus species*
15	Sissoo (planted)	*Dalbergia sissoo*
16	Ipil Ipil	*Leucaena latisiliqua*
17	Kadam	*Neolamarckiacadamba*
18	Teak	*Tectona grandis*
19	Cassia siamea	*Cassia siamea*
20	Kabhro	*Ficus lacor*
21	Lapsi	*Corespondis auxalaris*
22	Mallato	*Macaranga pustulata*
23	Tooni	*Toona ciliata*

Additionally, farmers are utilizing the principle of agroforestry in the production of MAP in different agro ecological regions such as *Citronella winterians* under *Dalbergia sissoo* and *Poplar* species in the Terai region. In Rasuwa district Nepal Agroforestry Foundation (NAF) is promoting Chiraito (*Swertia chirata*) and Satuwa (*Asparagus racemosus*) in the farmers' field.

However, restrictions imposed by government notifications have been the major constraints in planting and raising high value tree species on private land. For example, the Government has banned harvest, transport and export of Chap (*Michelia champaka*), Sal (*Shorea robusta*), Satisal (*Dalbergia latifolia*) and Vijayasal (*Pterocarpus marsupium*). Similarly, for commercial transportation and export of two non-timber forest products such as Panchaule (*Dactylorhiza hatagiera*) and Okhar (*Juglans regia*) has also been banned (Government notification, Nepal Gazette, 2001).

TIMBER SUPPLY MECHANISM

Amatya and Lamsal (2017) have reviewed the staus of private forests in Nepal. They have observed that middle man or contractor plays the vital role in procuring timber from private forests (Figure 17).

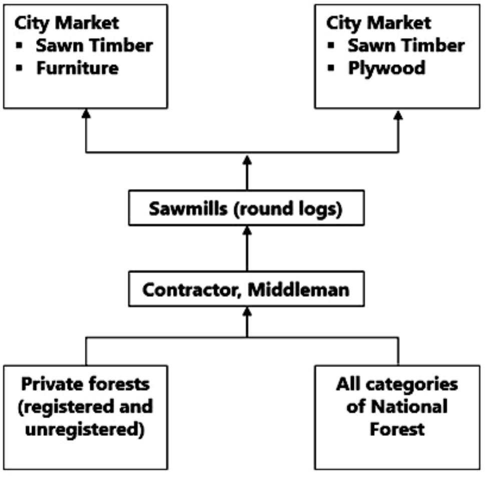

Figure 17. Timber supply mechanism adopted from Amatya et al (2015)

It is thecontractor who does all jobs to them. Generally, mill owner contact the local contractor. They are local agent but without any institutional identity. Pandit et al (2014) have analysed the barriers in the value chain of private forests in detail. Amatya et al (2015) has observed that there are more than fourteen steps that private tree owners have to fulfill before stepping up for harvesting and selling of trees planted on their registered private land. And almost all saw mills and forest-based entrepreneurs procure round logs from private forests (both registered and unregistered).

Cumbersome regulatory procedures, additional tax burden (local bodies, donation to various clubs in route to destination) and high transaction costs for harvesting and trade are considered the major constraints of the private forestry development in Nepal. A glimpse of the steps involved for selling and distribution process of private forest product is presented below (Figure 18).

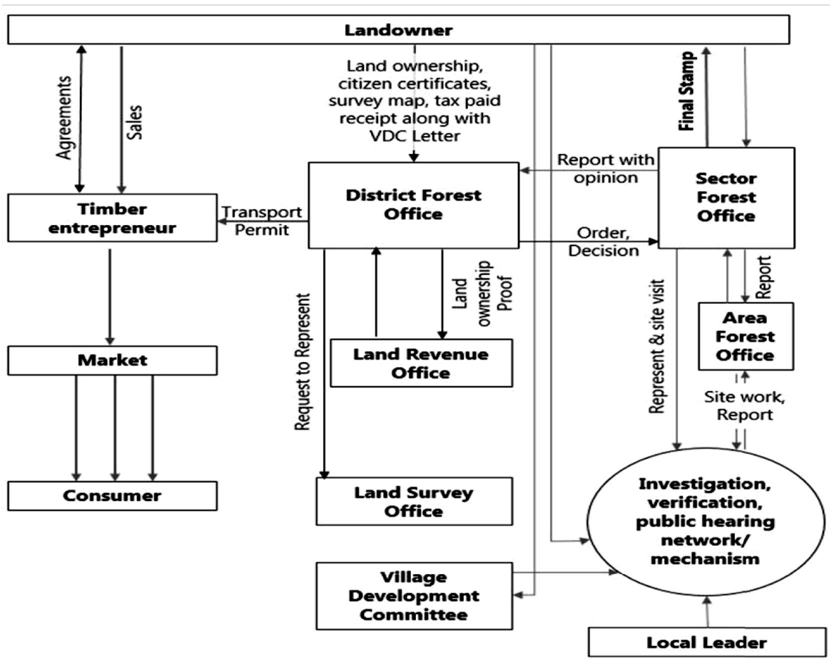

Figure 18. Selling and distribution process of timber from private forests. Adopted from Amatya et al (2015)

There is no separate policy for agroforestry in Nepal. There are conflicting sectoral and cross-sectoral policies, Acts and Regulations. Initial Environmental Examination or Environmental Impact Assessment based on several criteria has serious implication in developing private forestry in Nepal. However, the National Agroforestry Policy formulation process has been initiated in Nepal.

POLICIES RELATED WITH HERB AND NTFP DEVELOPMENT

Government of Nepal has formulated Herb and NTFP Development Policy, 2005 to develop herbs and NTFPs in the country. Some of them are directly related with private and community level. Poor, landless and marginalized people will be encouraged to cultivate medicinal and NTFPs/ MAPs on those lands which are not suitable for agriculture purposes, marginal lands, and lands without ownership. It further states that people living below poverty line will be encouraged to cultivate medicinal and NTFPs providing proper training on cultivation technique and following demonstration and rising awareness. For this special priority are given to women coming from rural areas. One of the important clauses in this working policy is to encourage farmers to cultivate medicinal and NTFPs on agriculture land under intercropping system. For this appropriate technical know-how and counselling services are provided to them.

The Government of Nepal has prioritized 30 important medicinal plants for research and management (Table 15).

Number	Scientific name	Local/common name
1	*Aconitum heterophyllum*	Atis
2	*Aconitum spicatum*	Bikh
3	*Acorus calamus*	Bojho
4	* *Asparagus racemosus*	Satawari/ Kurilo
5	*Azadirachta indica*	Neem
6	*Bergenia ciliate*	Pakhanved
7	* *Cinnamomum glaucescens*	Sugandhakokila
8	*Cinnamomum tamala*	Tejpat
9	*Cordyceps sinensis*	Yarsagumba
10	**Dactylorhiza hatagirea*	Panchaule
11	*Dioscorea deltoides*	Bhyaakur
12	*Gaultheria fragmantissima*	Dhasingre
13	*Juglans regia*	Okhar
14	*Lichens*	Jhyau
15	*Morchella spp.*	Guchchi chyaau
16	**Nardostachys grandiflora*	Jatamansi
17	**Neopicrorhiza scrophulariiflora*	Kutki
18	*Phyllanthus emblica*	Amala
19	**Piper longum*	Pipala
20	*Podophyllum hexandrum*	Laghupatra
21	**Rauvolfia serpentina*	Sarpagandha
22	*Rheum austral*	Padamchal
23	*Rubia manjith*	Majito
24	*Sapindus mukorossi*	Ritha
25	**Swertia chirayata*	Chiraito
26	*Tagetes minuta*	Jangali Sayapatri
27	**Taxus wallichiana*	Lauth Salla
28	**Tinospora sinensis*	Gurjo
29	**Valeriana jatamansi*	Sugandhawal
30	**Zanthoxylum aromatum*	Timur

Source: DPR (2011).

Among the above NTFPs, the 12 plants having asterisk (*) have been selected for agro-technology (DPR, 2011).

The development of NWFP's is one of the priority programs of the Ministry of Forests and Soil Conservation. It has recently introduced a special program of promoting NWFP's in 25 hill districts of the country so as to alleviate the rural poverty.

REGULATORY CONSTRAINTS IN DEVELOPING NTFPS

There are some of the regulatory constraints and are largely silent in conserving, managing and utilizing valuable wild edible products. For example, collection of species such as Yarsagumba (*Cordyceps sinensis*), Jatamansi (*Nardostachys grandiflora*), Kutki (*Neopicrorhiza scrophulariiflora*), Sarpagandha (*Rauvolfia serpentina*) Lauth sallo (*Taxus wallichiana*) and Sugandhawal (*Valeriana jatamansi*) are officially valid only when the collector(s) had obtained permission from Department of Forests, District Forest Offices, to collect them. Additionally, these species are banned for export outside the country without processing. Panch aule (*Dactylorhiza hatagirea*) is banned for its collection, processing, transport and export outside the country. Whereas Bhaykur (*Dioscorea deltoidea*) is known as an endangered species.

Because of these marketing difficulties as Pandit and Kumar (2010) report many farmers still are hesitant to grow such products in their farmlands. Moreover, the royalty system of the Government also discourages private individuals in growing NTFPs on their farm lands as there is no distinction between the royalty for NTFPs collected in the wild and grown in private land.

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Chapter 8

MANAGEMENT PRACTICES OF AGROFORESTRY

Chapter 8

MANAGEMENT PRACTICES OF AGROFORESTRY

Farmers' in Nepal are practicing various kinds of agroforestry systems depending on their own knowledge of tree and its silviculture. They might not know the meaning of the word "silviculture" but in actual practice thay are following some sort of silvilutrure practice such as pollarding and thinning.

Farmers' plant various types of ficus species especially for fodder. In Palpa distrtict farmers' plant extensively Dabdabe tree (*Garuga pinnata*) at the edge of farmland through stem cutting. They plant Khasro Khanyu (*Ficus semicordata*) wildlings on their farmland and start lopping this species in winter once they reach 4 to 5 years of age.

Dabdabe (*Garuga pinnata*) is a tree mainly use for fodder. They cut branches of stem (1.5-2 m) long with approximate diameter of 5-6 cm and directly plant in the field during monsoon period in close spacing (1m). These trees serve as live fence, and fodder bank. Farmers also know the techniques of looping this tree. They normally lop in winter period when the trees are leafless. However they are ignorant about the lopping cycle and fodder yield per cycle.

Once trees are planted on field their management is very essential to obtain maximum productivity both of tree and agriculture crops planted underneath. Farmers are very much aware about shading effect of tree on agriculture crops. Hence they cut branches of trees without considering the harmful effect of cut on trees. Therefore, in managing agroforestry tree species important management operations, known as tending operations are necessary to follow.

TENDING OPERATIONS

Tending operations are very important especially in agroforestry as it involves both forest and agriculture crops in the same space and in time. These operations include weeding, cleaning, thinning, and climber cutting.

Pruning

Pruning is done especially to improve the quality of wood for a given agroforestry system. Normally pruning prescriptions follow the removal of all branches up to a height of two metres, or up to a height of two thirds of the total height of the tree, whichever is less.

Pollarding

Pollarding is normally carried out at some height above the ground so that it produces a crown of new shoots from buds below the cut. A special advantage is that the new shoots are out of reach of cattle. Pollarding is done at 1 m. to 1.2 m. height. The following species have good pollarding ability (Table 16)

Table 16. Pollarding ability of important tree species

Local name	Scientific name
Sisau	*Dalbergia sissoo*
Dabdabe	*Garuga pinnata*
Kangiyo	*Grevillea robusta*
Bhimal/Shyal phosro	*Grewia optiva*
Kimbu	*Morus alba*
Bange kath/ Bhote pipal	*Populus ciliata*
Khasru	*Quercus semecarpifolia*
Bains	*Salix babylonica*
Saj	*Terminalia alata*

Weeding

Weeding is an important tending operation. Especially in plantations, weeding has to be carried out at least twice a year: once immediately after plantations and next in winter period. Results have shown that weeding has a remarkable effect on the height and diameter growth especially in case of *Eucalyptus* species.

Thinning

In agroforestry thinning is known as partial cuttings of planted trees. They are designed to improve future growth by regulating stand density. Thinning grades are differentiated on the basis of the crown classes removed. In a low-grade thinning, removals are confined to over topped trees or those dead or nearly dead. The timing of each thinning of tree species varies depending on its growth and underneath crops. For example, a close-planted, fast-growing stand of Sisau (*Dalbergia sissoo*) may have its first thinning at age 4, while a slower growing stand will have the thinning delayed until age 6.

Thinning guidelines have been developed by the Department of Forests for commercial forest plantations, natural forests, and community forests, aiming at Sisau (*Dalbergia sissoo*), Masala (*Eucalyptus spp*), Teak (*Tectona grandis*) and two types of pine species (*Pinus roxburghii*, and *Pinus patula*) in early 1960s (DoF, 1960)

As agroforestry species Sisau (*Dalbergia sissoo*) can be thinnedis to produce timber with intermediate yield of fuelwood and posts. Similarly, *Eucalutptus* can be thinned to produce, firewood and quality transmission poles.

Harvesting age

Farmers' tend to harvest trees as and when necessary. Harvesting age of trees varies depending on the objectives of plantation. In Terai belts of the country people in general harvest trees especially for firewood. The minimum harvestable age of some agroforestry trees (both indigenous and exotic) is provided in Table 17.

Table 17. Harvesting age of some agroforestry trees

Local name	Scientific name	Exotic	Indigenous	Minimum harvesting age (years)
Gliricidia	*Gliricidia sepium*	*		2
Ipil-Ipil	*Leucaena latisiliqua,*	*		2
Acacia	*Acacia auriculiformis,*	*		3
Cassia	*Cassia siamea,*	*		2
Masala	*Eucalyptus camaldulensis*	*		4
Masala	*Eucalyptusteriticornis*	*		4
Masala	*Eucalyptus alba*	*		5
Gamari	*Gmelina arborea*		*	3
Sisau	*Dalbergia sissoo*		*	14

Fodder production

Fodder production is one of the importat functions of tree species in Nepalese farming system. Farmers plant different kind of tree species so as to obting green foliage especially in the lean period. Barakoti (1990) has done sutudy on examing the Dry Matter content of different agroforestry tree species (Table 18).

Table 18. Dry Matter content of different agroforestry tree species

Fodder tree species	Dry Matter (Range)	Dry Matter (Mean)	Dry Matter yield (kg/ha)
Tanki	20-40	28	133
Khanyu	25-44	34	2146
Nebaro	24-36	30	599
Patmiro	25-35	28	756
Bhimal	22-45	32	942
Bhimal	22-45	32	942

Already there is a momentum of planting trees as shelterbelts along the farm boundaries. Sisau (*Dalbergia sissoo*), *Cassia siamea*, and *Indigofera* spp are being planted as windbreaks and shelter belts in Terai districts of Nepal.

SELECTION OF AGROFORESTRY SPECIES

It is logical to assume that if agricultural crops are to be grown in conjunction with forest crops, and if forestry is to be the dominant land use form, then from the inception of the plantation, the tree species that are used should preferably be chosen because they display silvicultural characteristics that would permit them to compete effectively with the agricultural crops.

So far, no specific criteria have been set exclusively for selecting agroforestry species. For example, a major plantation breeding objective for Sisau (*Dalbergia sissoo*) might be to produce a single-stemmed tree with clear bole. While in fuelwood deficit areas farmers using wood would be more interested in trees having low branches, multiple stems, and high coppicing ability such as Cassia. The selection of tree species for agroforestry, therefore, is based on the needs and end uses. Choosing tree species exclusively for agroforestry is a complicated task. For some species the selection criteria could be for biomass production both foliage, small timber, fuelwood and for others only fruit. It is because the tree is expected to fulfil many poorly defined functions and desired traits, agroforestry species are seldom evaluated. Additionally, no single species can grow on all sites, tolerate all types of management, or yield all types of products and offer services. Before choosing a species for an agroforestry system there is a need for careful review of some basic concepts.

- Define the intended use of planting, both immediate and in the future;
- Examine whether potentially promising species are available;
- Examine the quality and condition of the planting sites;
- Decide if the trees will be used in combination with crops and livestock;
- Determine how the trees will be managed.

The following are the desirable multipurpose tree characteristics for agroforestry systems (Table 19).

Table 19. Desirable tree characteristics in a given agroforestry system (Adapted from Wood 1990)

Attributes of tree	Relationship of attribute with performance in agroforestry system
Height	Ease of harvesting
Stem form	Suitability for timber, posts, poles shading effects
Crown size, and density	Quality of leaf, mulch and fruit production, shading/wind effects
Rooting pattern	Competitiveness with other components
Physical and chemical composition of leaves	Fodder and mulch quality, soil nutritional aspect
Thorniness	Suitability for barrier or alley planting
Wood quality	Acceptability for fuel and various other wood products
Phenology	Timing and labour demand for fruit, fodder, seed harvest, season of fodder availability
Di/monociousness	Sexual composition of individual species; important for seed production and pollen flow
Pest and disease resistance	Important regardless of function
Vigour	Biomass productivity, early establishment
Site adoptability	Suitability for extreme sites.
Response to pruning and cutting management	Use in alley farming or lopping or coppicing

Farmers' need to know about the planting site, characteristics of tree species and its value in terms of utilization before planting them on their agriculture fields.

Site

This is a part of the local environment which is difficult for people to alter i.e. climate, soil depth and topography. The effect of extreme differences in site are self-evident but even within a restricted area where a species is capable of surviving and growing, local differences in climate and soil can have a considerable effect on its rate of growth and yield of produce. An example is Masala (*Eucalyptus camaldulensis*) in Sagamath (Sarlahi District), where the average growth rate of Eucalyptus is 12.7 m3/ha/year in site quality I and 8.5 m3/ha/year in the site quality II according to the plantation inventory done by the Forest Survey Division in collaboration with FINNIDA in 1992. The better the site with adequate rainfall, warm temperature, deep and fertile soil, the wider the range of species which will flourish and the greater the difference between the inherently fast growing and inherently slow growing species.

Species

Agroforestry species, in general, are multipurpose in nature. They provide timber, fuelwood, fodder, food (fruits and nuts), medicinal and aromatic spices (bark and leaves) both for human beings and livestock. Some of the important agroforestry species farmers tend to plant on their farmlands are Utis (*Alnus nepalensis*, Lapsi (*Choerospondias axillaris*), Sisau (*Dalbergia sissoo*), Bot-Dhayaro (*Lagerstroemia parviflora*). Ipil-Ipil (*Leucaena latisiliqua*), Bakaino (*Melia azedarach*) and Sajiwan (*Moringa oleifera*). Among those tree species that are naturally presence on farmland are Khote sallo (*Pinus roxburghi)*, Rani Sallo (*Pinus wallichiana*), Chilaune (*Schima wallichii*) and Phalant, Banjh and Khasu (*Quercus spp*).

The choice of a tree species does differ with the different agroforestry systems. In general, the species chosen for an agroforestry system should reflect some of the seven properties underlined below:-

- They should be fast growing, light demanding, and have the ability to survive and remain healthy under the given conditions of site and cultural treatment;
- Resistance to local hazards, including pests, diseases, ease of regeneration for later rotations, i. e. advantages of coppicing;
- Root system should not be superficial thus making them liable to damage from the cultivators;
- They must be a quick starter and an ecologically pioneer species;

- They ought not to cast shade;
- They should not have a climbing habit;
- Their nutrient requirements should not be such that the soil is rapidly exhausted.

PEST AND DISEASE PROBLEMS

Diseases may also occur during agroforestry plantation establishment. It should be noted that trees of varied ages may be affected by fungal pathogens. Table (20) provides the type of diseases/pest and its causes in some of the important agroforestry tree species.

Table 20. Common diseases/pest of important agroforestry tree species

Local name of species	Botanical name	Disease/pest	Causes
Sisau	Dalbergia sissoo	*Cercaspora sissoo*	Leaf rot
Teak	Tectona grandis	*Armillaria mellea*	Root rot
Kimbu	Morus alba	*Agrobacterum tumefaciens*	Crown gall
Masala	Eucalyptus spp.	*Phytophthora cinnamomi*	Root rot
Utis	Alnus nepalensis	*Oreina spp.*	Defoliators
Ipil-Ipil	Leucaena latisiliqua	*Psyllid Heteropsylla cubana, Fusarium semitectum. Ganoderma lucidum*	Gummosis,

Sisau (*Dalbergia sissoo*) is one of the important agroforestry species in Terai belts of Nepal. Farmers have planted this species on their farmland especially on terrace bonds. Die-back on sisau have been observed in many plances in the past and in order to get rid of these sort of pest and diseases, application of systemic insecticides in the roots of infested trees @5 ml./5lt. water @ five to ten litres of this solution per tree at intervals of fifteen days would be helpful in controlling the pest and diseases. Alternatively, Bordeaux paste (50% lime +50% Copper sulphate

+ water) can be painted on the base of the stem up to 3 feet for prevention of termites. Joshi and Baral (2000) report that various type of termiticide can be applied at the roots of infested trees to get rid of pest problems.

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Chapter 9

AGROFORESTRY RESEARCH IN NEPAL

Chapter 9

AGROFORESTRY RESEARCH IN NEPAL

STATUS OF AGROFORESTRY RESEARCH

Research in agroforestry is poor in Nepal. Though limited, Department of Forest Research and Survey (DFRS) has initiated research in agroforestry in the country. The focus during 1980s was on species selection/evaluation. Alley/inter-cropping, tree-crop interaction started after 1980s followed by growth monitoring of both indigenous and exotic trees species (Baral and Amatya, 2000). Amatya (1999) provides a list of research carried out by DFRS and its application status. Specific research results such as (Sisso dieback) are available in occasional papers published by DFRS (2000). A compendium of the articles published in Banko Janakari by the DFRS compiled by Basnet (Bulle. DFRS. No 24) provides a glimpse of author (s), research title and volume number of its publication.

PREFERENCE OF TREES FOR FODDER

The result of early observations/ research shows that farmers' prefer more than twenty species both leguminous and non-leguminous and indigenous. Most of them are common in the hills of Nepal. The predominant tree species were: *Ficus spp*., Sisau (*Dalbergia sissoo*), Koiralo (*Bauhinia spp*), Badahar (*Artocarpus lakoocha*), Cassia (*Cassia siamea*), Sesbania (*Sesbania aculeate*), and Kalo siris (*Albizia lebbek*) in the Terai region and Utis (*Alnus nepalensis*), Rato siris (*Albizia julibrissin*) and Phaledo (*Erythrina stipulata*) in the hill areas. Some of the commonly planted agroforestry trees and their major use are listed below (Table 21).

Table 21. Commonly planted agroforestry trees and their major use

Tree species	Local name	Major use
Albizia species	Siris	Timber, Fuel, Tanning, fodder
Alnus nepalensis	Utis	Fodder, Timber
Artocarpus lakoocha	Badahar	Fodder,
Bauhinia species	Tanki/ koiralo	Fodder, vegetables
Bassia butyracea	Cheuri	Fruit, Fodder
Dalbergia sissoo	Sissoo	Timber, Fuel
Eucalyptus camalulensis	Masala	Timber, Fuel
Erythrina arborescens	Phaledo	Fodder,
Ficus infectoria	Kabro	Fodder, vegetables
Ficus neriifolia	Dudhilo	Fodder
Ficus semicordata var semicordata	Khasro Khanyu	Fodder , fibre
Ficus semicordata var montana	Rai Khanyu	Fodder
Gargua pinnata	Dabdabe	Fodder,
Gliricidia sepium	Gliricidia	Fodder, Fuel
Juglans regia	Okhar	Fruit, Fuel,
Leucaena spp.	Ipil-Ipil	Fodderm Fuel, Fruit,
Litsea monopetela	Kutmero	Fodder, Fuel
Melia azaderach	Bakaino	Fodder, Fuel
Morus alba	Kimbu	Fodder, silk worm
Populus deltoides	Lahare pipal	Fodder, Green manure
Salix species	Bains	Fuel, Timber,, Tanning
Sauraria nepalensis	Saur	Fodder, Fruit

Some of the reasons of farmers' preference for these species are:-

- Palatable and without toxic effect to livestock
- Frequency of harvesting/lopping (2-3 times a year)
- Higher fodder yield

- Nutritional value (healthy stuff for animal) that would help milk production
- Availability of green stuff during lean period (Nov-May)
- Twigs for cooking and heating purposes

EFFECT OF TREE SPECIES GROWING ON AGRICULTURE CROPS (TREE CROP INTERFACE)

It is logical to assume that if agricultural crops are to be grown in conjunction with tree crops then both tree and agriculture crop species should be chosen carefully. They compete for light, moisture and nutrients.

The effect of Sisau (*Dalbergia sissoo*) on mustard (*Brassica nigra*) was one of the important researches conducted in Bara district. Similarly, the effect of Timilo (*Ficus roxburghii*) on ginger (*Zingiber officinale*) and turmeric (*Curcuma longa*) was another research conducted in the same district during early 1990s. The above ground interactions of Sisau (*Dalbergia sissoo*) with aromatic plants such as citronella (*Citronella spp*) were conducted in collaboration with Herbs Production and Processing Company Limited during early 1990s. No single tree / and agriculture crop can grow on all sites. It was observed in many hill district of Nepal that farmers' tend to avoid planting trees on their farmland as agroforestry species which has large crown and bear horizontal rooting system such as Badahar (*Artocarpus lakoocha*) and some Ficus species.In this context, Barakoti and Amatya (2004) have tested a modified a methodology to examine the effect of fodder trees on the growth and yield of maize (*Zea mays*) and finger millet (*Eleusine coracana*) in Dhankuta district. They modified a design for this study which is provided in Figure 19 below.

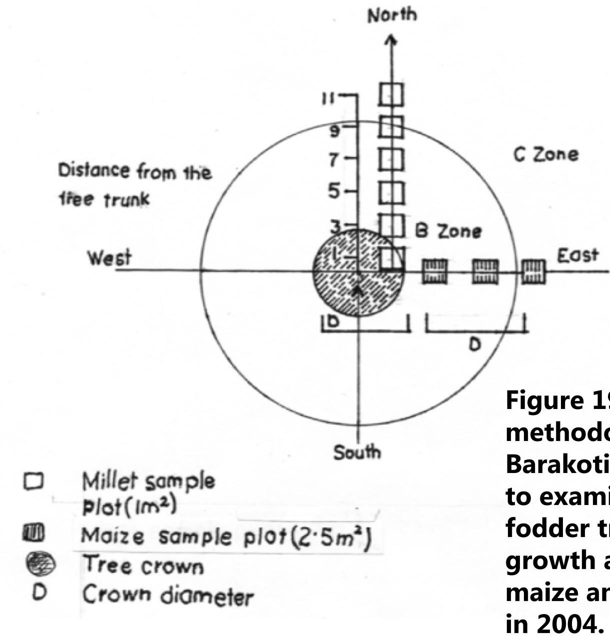

Figure 19. A modified methodology tested by Barakoti and Amatya to examine effect of fodder trees on the growth and yield of maize and finger millet in 2004.

The study showed that the closer the crops grown to trees, the more severe the effect on different parameters, where maize was more affected than millet (Barakoti & Amatya 1999). The mature trees had significant and negative effects on growth and yield up to 2-3 m from the tree trunk. Timilo (*Ficus auriculata*) had severe effects followed by RaiKhanyu (*Ficus semicordata* var. *montana*). However, Rato Siris (*Albizia julibrissin*) and Kutmero/Patmero (*Litsia polyantha*) trees favored the crops. The overall mean yield of maize under tree canopy was less (2601 kg ha-1) than outside (3757 kg ha-1). Effect on millet followed a similar trend. The yield was less (737 kg) in lower terraces than upper (1575 kg ha-1). Of the three, zone A was highly affected by shade. The study showed that fodder tree Tanki (*Bauhinia purpurea*) should be avoided to plant near maize and millet crops (maize up to 3m and millet up to 2 m. Similarly, if Rato siris (*Albizia julibrissin*) has been on the land, millet and maize crops should be planted 1m- 2m respectively from the tree crown. Barakoti (2016) found that the vertical length of terraces varies from 1.2 to 2.5 m depending on the hill slopes.

Available literatures suggest that effect of trees on crop growth and yield varies with tree species, size, distance from tree and crop species. Effects of above- and below-ground competition of shrubs and grass on *Calophyllum brasiliens*e (Camb) seedling growth in abandoned tropical pasture has been discussed by Hall (1998).

YIELD OF FODDER TREES

There is heavy demand of fodder by households to support livestock production which is a major livelihood activity in Nepal. Animals derive an estimated 35% of their feed from trees particularly in the dry season (November to February-March) when other green forage, pastures and feed resources are scarce. Some estimates on fodder yield are available for fodder trees in Nepal (Amatya, 1990). Baral and Shakya (2006) made some estimate of fodder yield for Badahar (*Artocarpus lakocha*) and Kairalo (*Bauhinia variegata*) on community forests. Howeever, response of fodder yield to lopping intensity and frequency are yet to be ascertained.

Department of Forest Research and Survey (DFRS) had also conducted several other researches focusing on yield of fodder trees in collaboration with other institutions such as World Neighbours. Upreti and Devkota (2017) have carried out study on the yield of three Badahar (*Artocarpus lakoocha*); Kutmiro (*Litsea polyantha*); and Kabro (*Ficus lacor*) fodder trees and their biomass production in four districts of Nepal (Tanahun, Dhading, Dolakha and Sindhupalchok). They have found that Kabro had significantly higher biomass yield (31.7kgDM/tree), followed by Badahar (26.80 kg DM/tree) and Kutmiro (23.80 kg DM/tree). Additionally, fodder biomass production was positively related with the age of the tree species.

A study carried out by Ghimire et al in 2013 to assess the effect of season and defoliation frequency on the fodder yield and the chemical constituents of *Flemingia macrophylla* under different defoliation frequencies showed that plants harvested on wet season had higher dried fodder yield than harvested in dry seasons. Similarly, the fodder harvested in the wet season had better nutrient composition compared to dry season. The study recommends that harvesting of Bhatmase (*Flemingia macrophylla*) in three months interval could be the better practice for higher fodder yield with bette rnutrient composition.

RESEARCH ON LOPPING TECHNIQUES

Nepal Agroforestry Foundation in technical collaboration with DFRS carried out a research to find out the cutting height of the fodder species Kimbu (*Morus alba*), Kanyu (*Ficus semicordata*) and Ipil-Ipil (*Leucaena latisiliqua*) in Kavrepalanchowk district of Nepal during late 1980s and found that 2-2.5 m is suitable for optimum fodder production.

Lopping fodder trees at breast height in second-third year, not allowing to grow taller, prevented from shade effect to the crop.

A study carried out by Ghimire et al (2015) with Bhatmase (*Flemingia macrophylla*) show that low density (0.9m × 0.7m) planting and lopping at 0.75m from the ground level would yield higher dry fodder biomassin comparison to Ipil-Ipil (*Leucaena latisiliqua*) and Mendula (*Tephrosia candida*).

OTHER RESEARCH RELATED WITH AGROFORESTRY SPECIES

Some research was also devoted towards feed deficit in terms of crude protein and total digestible nutrients available from fodder trees. Barakoti (2014) has evaluated two dozens of fodder species in terrace riser of bari land under agri-silvo-pastoral system in the hills (1200-2000 masl) of eastern Nepal with the objective of exploring feasibility of forage crops production in terrace riser (T-riser) by testing new model hypothesis of agri-silvo-pastoral system. The results showed that improved forage crops and fodder trees can be cultivated successfully in the terrace risers of cropping land where performance of fodder species found encouraging. Survival of the fodders was 70 to 100 percent based on species. Dry matter content of trees varied 31-49 percent, and ground forages, 19-32 percent. Dry matter yield ranged 3.0 t/ha (Stylo) to 26.5 t/ha (Napier). There was little positive effect of Tanki (*Bauhinia purpurea*), Bhimal/Ghotli *(Grewia oppositifolia*), Patmero (*Litsea polyantha*), Khari (*Seltis australis*) whereas Raikhanyu (*Ficus semicordata* var. *montana*) and Nebaro/ Timilo (*Ficus auriculata*) had some negative effect on maize but had higher fodder yield. The forages Napier, Dhus, Amriso, Desmodium, Ryegrass, Para, Molasses, Stylo performed best in terms of its yield (Barakoti, 2016).

Research conducted at Kawere Bhanjyan of the western mid hills of Nepal by Pandit (2012) suggests that planting RaiKhanyu *(Ficus semicordata* var. *montana*) at 6 meter interval produces additional fodder without negative significant effect on Maize (*Zea mays*) yield and moderate effect on finger millet (*Eleusine coracana*). Similarly, Upreti and Shrestha (2006) and Osti et al (undated) made some estimates of nutrients contents of tree fodder (Table 22).

Table 22. Major nutrient elements (Nitrogen, Phosphorus and Potassium) content of some common agroforestry species of Nepal.

S.N.	Local (Nepali) Name	Scientific Name	Major Nutrients (%)		
			N	P	K
1.	Kalo Siris	*Albizia lebbek*	2.89	0.65	2.59
2.	Bakaino	*Melia azedarach*	3.24	0.19	1.76
3.	Khirro	*Sapium insigne*	2.70	0.79	2.89
4.	Chilaune	*Schima wallichii*	1.68	0.09	0.37
5.	Tooni	*Toona ciliata*	2.44	0.16	0.71
6.	Asuro	*Adhatoda vasica*	4.30	0.88	4.49
7.	Titepati	*Artemisia vulgaris*	2.40	0.41	4.90
8.	Kalo banmara	*Eupatorium adenophorum*	1.34	0.17	2.75
9.	Seto banmara	*Eupatorium antidysentrica*	2.91	0.35	2.68
10.	Saziwan	*Jatropha curcas*	2.76	0.32	2.27
11.	Simali	*Vitex negundo*	2.08	0.14	0.56

ONGOING AGROFORESTRY RESEARCH

Currently Agroforestry Section of DFRS is conducting a study on Kadam tree (*Neolamarckia cadamba*), species with NTFPs to examine the interaction between Kadam and NTFPs in participation of farmers and leasehold groups in Kavre palanchowk district since last 10 years. The result of the study showed that grass production was 40 ton/ha along with fruit production of 25kg or 1.5 kg/tree in first fruiting year. It is also carrying out research on production of Pipla (*Piper longum*) under different canopy cover of Kadam (*Neolamarckia cadamba*) plantation at Yogikuti Butwal of Rupandehi district since 2062/063 (BS). The result showed the promising survival and growth of Kadam.

POTENTIAL RESEARCH AREAS IN AGROFORESTRY

Agroforestry research calls for multidisciplinary approach integrating forestry, animal husbandry, sociology, etc. Study such as growth rates and yield of tree and fodder species, their effect on agricultural crop growth and yields, needs to be ascertained. A combination of trees with herb species could be a potential area where research could focus on. Bamboo growing is also emerging as a viable land use options in the Terai. The following are some of the areas of agroforestry research.

Nursery

Research on improved tree seed is one of the demands at this stage. Some plants such as Lapsi (*Choerospondias axillaris*) produce male and female flowers on different specimen plants and there is a danger that planted specimen does not produce fruits if it happens to be a male one.This is the case with Pipla (*Piper longum*), a dioecious plant. It won't fruit if the plant happened to be a male. Therefore, nursery research is very important on this type of plant species.

In case of Lapsi (*Choerospondias axillaris*), Paudel (2002) suggests research on tree breeding, development of morphological markers for early sex determination and tree-crop interaction for better fruit productions should be carried out.

Propagation techniques

Literature on the propagation techniques of many agroforestry tree species is available. Farmers are interested in planting

Dabdabe (*Garuga pinnata*) and Phaledo (*Erythrina arborescens*) on their farmlands. They know that cuttings of these tree species are best for propagation, but they are not aware about the optimal size and length of cutting. Research on this aspect would be very useful for propagating these and other vegetatively propagating species.

Above and below ground tree crop interface

Appropriate techniques have to be developed for measuring below and above ground competition and utilisation of agroforestry products. There is a clear need that farmers should be exposed to the modern agroforestry technologies. One of the reasons of not planting trees by farmers is due to the possible damage by surface rooting of trees to the agriculture crops and the other is the problem of shading. Hence, the rooting habits of potential agroforestry tree species should be studied. In this case Sthapit (1996) had carried out some study on Wind thrown Tree Roots of species such as Khaer (*Acacia catechu*), Haldu (*Adina cordifolia*), Kalo siris (*Albiziaia lebbek*), Sisau (*Dalbergia sissioo*), Bot-Dhangero (*Lagerstroemia parviflora*), Amp (*Magifera indica*) and Sal (*Shorea robusta*) in Jhapa district Nepal. The study showed that majority of these species has tap root and lateral roots. In fact, those species which has deep tap root system are good as agroforestry tree species in comparison to those having lateral rooting system because there are less chance of competition between the tree and agricultural species grown.

Agroforestry survey conducted in the past and recently in various districts of Nepal revealed that following research topics would be more beneficial to Nepalese farmers to take up agroforestry as a viable option of land use.

- Terrace riser farming of fodders
- Improved fodder saplings for cultivation in larger areas
- Farming technique
- Integration of non-timber forest products and medicinal and aromatic plants

Most agroforestry practices in the country are in the hills. There are needs to carry out terrace-based research. Some of the following points as compiled by Dr. Barakoti (2016) reflect its need.

- Crop and animal production are interdependent, particularly in hills, need to sustain both.
- Farmers have to meet daily need of fodder for livestock, leaf litter for manure and fuel-wood for cooking.
- Lack of fodder is crucial, need to increase fodder supply during lean period of the year.
- Majority of farmers has small holdings, limited land for fodder planting/production.
- 1/3 land in terrace riser in the hills is left unutilized, uncultivated.
- Need to apply increased organic manure for soil fertility and crops productivity.
- Fodder collection time is saved and reduces the women's drudgery.
- To help control erosion, conserve soil and improve farm environment.

DEVELOPMENT OF BEST BET AGROFORESTRY MODELS

Agroforestry model, which could be acceptable to farmers' environmentally sound, economically feasible and replicable in most of hill physiographic condition of the country need to be developed and implemented. The role of women in agroforestry has been grossly underestimated. Agroforestry model that would increase the labour productivity should be adopted.

Any model should perform three important criteria. They must be simple, easy to replicate and follow, and should meet the desired objectives and or goal. Agroforestry is no exception. All agroforestry models must satisfy all these criteria. In Nepalese context it is more applicable because farmers will not be interested to adapt any unrealistic and hypothetical model that will not meet their objectives in a given time and space.

Aroforestry models in Nepal can be segregated as with the prevailing five physiographic zones of the country. Bajracharya (2014) has proposed agroforestry model for each physiographic zone of the country.

In the Terai plains, agri-silvi-pastoral models having north-south belts of trees with wide gaps of 10-15 meters for crop cultivation covering up to only about 10% of the land by the tree crop would be suitable. Such belts or rows of trees and shrubs will not create permanent shade to cultivated crops, but will also act as a wind-break and shelterbelt during the dry season thereby enhancing soil moisture retention in the agricultural crops on one hand, and preventing dust blowing on the other. Such a practice of agroforestry and agricultural crop cultivation would improve crop productivity as well as provide additional benefits of timber, fuel wood and fodder besides improving the environment and rural health.

In the Bhabar tract there is a need to improve the degraded forests through timber stand improvement of the existing forests and enrichment planting of high value local tree species in a north-south line with such land being spaced at 15-20 meters lines in apart. Where there is a gap in the forest, broadcasting of maize seed could be grown for consumption by wildlife.

In Siwaliks there is a necessity of growing soil-holding shrubs and grasses to reduce erosion in addition to enhancing of rain water. However, the northern side of Siwalik hill which constitutes a geological dip and mild slopes and deep soils has already some high value tree crops. But these can be further enhanced through agroforestry practices with contour planting of trees, shrubs and grasses for conserving adequate soil moisture to reduce fire risks during the dry season.

The larger Doon valleys, Terai models of agroforestry and agri-slivi-pastoral systems should be adapted.

In the Mahabharat Range, both the south and north slopes, would be best benefited by conservation through agroforestry practices with tree and shrub plantation along the contours according the needs of the local people.

The Midland valleys, agroforestry models should aim at water conservation. Model should look at the harvesting of greater proportion of rain water for direct consumption of people and domestic animals as well as for recharge of groundwater. This could be integrated with community and lease-hold forest user groups of women as well as poor and deprived people so that they are able to generate income and economic power for themselves. Fodders and medicinal herbs and shurbs are started to include in the community and leasehold forests. They should be promoted in the mid-hill regions.

INTEGRATION OF NON-TIMBER FOREST PRODUCTS (NTFPs) AND MEDICINAL AND AROMATIC PLANTS (MAPs)

Research on medicinal and aromatic plants in the country has so far been focused on use, amount marketed, marketing chains and market mechanisms. Some recent works concentrate on inventories and estimates of growth rates and sustainable harvesting. The silviculture techniques including propagation system of some important low volume high value products are important for their development and these materials, based on research, are yet to be developed.

Existing ecological database regarding NTFPs/ MAPs are extremely scanty regarding the status of the resource base, the probable impact of harvesting/collection practices, and area-specific sustainable harvesting. This database is extremely important for charting a strategy for the development of NTFP's. The Department of Forest, Department of Plant Resources, Tribhuvan University, have developed some database. Local Non-Government Organizations (NGOs) and International Non-Government Organisations (INGOs) (ICIMOD and IUCN) do have some information (data) on NTFP's of their respective project areas but these types of data do not cover the entire country.

INSTITUTIONS INVOLVED IN AGROFORESTRY RESEARCH

- Department of Forest Research and Survey
- Department of Forests

- Department of Plant Resources
- Tribhuvan University, Institute of Forestry
- Agriculture and Forestry University, Faculty of Forestry,
- Nepal Agricultural Research Council

Most forestry-oriented NGOs and INGOs such as Forest Action, Nepal Agroforestry Foundation, Asia Network for Sustainable Agriculture and Bio-resources and INGOs such as International Centre for International Mountain Development, IUCN are being involved in the agroforestry research and development in the country.

GAPS IN AGROFORESTRY RESEARCH

There are gaps in agroforestry research in the country. Some of the action research in all the regions of Nepal should include:

- Selection of tree species from among some three dozen indigenous and one-dozen successful exotics vis-à-vis their silvicultural characteristics and local suitability;
- Choice of shrubs and herbs of economic value for commercial and general purposes, such as, medicine, essential oil, fibres, floss, food, etc.;
- Planting out of two-dozen known fodder trees and grasses according local preferences;
- Adoption of proven cereals, fruits, and crops;
- Development of soil and water conservation techniques to suit slow soil, aspect, and microclimatic conditions;
- Generation of additional income and employment opportunities through agri-slivi-pastoral systems.
- Response of fodder yield to lopping intensity and frequency of widely grown fodder trees in terms of determining annual fodder yield of existing fodder trees as influenced by lopping intensity and frequency,
- Derive relationship between tree basal diameter, total tree height, lopping regime and yield, and
- Assess farmers' perceptions on effect of varying lopping regime on fodder yield and overall fodder production.

FACTORS LIMITING AGROFORESTRY RESEARCH AND DEVELOPMENT IN NEPAL

Agroforestry has not been developed in the country mainly because of the following reasons.

Limited knowledge on the subject matter

Agroforestry research calls for multidisciplinary approach integrating forestry, livestock, animal husbandry including sociology and anthropology. Experts on one filed is not adequate enough to conduct research on this complex discipline and hence acquire optimal output.

Some of the important agroforestry species have dioecious nature (dioecious having the male and female reproductive organs in separate individuals). This makes very difficult to select female plant for desired output. This calls for research on tree breeding and development of morphological markers for early sex determination. This is complex and costly affairs.

Limited landholding for agroforestry development

Majority of farmers are small holders, they own limited land for crop production. Land holding is limiting commercialization of agroforestry products.

Absence of Agroforestry policy

There is no separate policy on agroforestry. This is somehow restricts the development of agroforestry in the country.

Lack of extension materials and training opportunities

There is a need of training centres for private individuals who would like to have entrepreneurship knowledge in agroforestry. Training should focus on skill development, market and its linkages and optimal use of available resources, optimal use of spacing, livelihood development and enhancement.

In Nepalese context, research, training and extension activities are run parallel with each other. These activities hardly converse at one point. Both agriculture and forestry ministries have training centres. But none of them does training in agroforestry discipline.

Both Tribhuvan and Agriculture and Forestry Universities and their affiliated institutions awards degrees in Agroforestry. These institutions have very well-designed curriculum.

Currently, Regional Training Centres of Government of Nepal are imparting training to forest guards and game scouts. The need of the time is that these institutions should also run refreshers coursers in agroforestry.

There are quite a few Local and International Non-Governmental Organizations actively engaged with agroforestry training and extension programmes. Some are devoted solely to women's development and others deal with various farming systems approaches. Exchange visits to learn farmers' technologies could be effective in capturing new innovations in agroforestry.

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Chapter 10

TOOLS AND TECHNIQUES USED IN AGROFORESTRY RESEARCH

Chapter 10

TOOLS AND TECHNIQUES USED IN AGROFORESTRY RESEARCH

Agroforestry is a complex discipline. Hence it requires a multidisciplinary tools and techniques to know its complexity and then focus on a specific problem. Basically there are five techniques frequently used to tackle a complex natural resources management issue of agroforestry system. Such techniques, in the past, were found to be effective in identifying key problems quickly, as opposed to the more detailed questionnaire surveys, which are time-consuming, expensive and often generate data that are not used. These techniques are:-

- Farming Systems Research (FRS)
- Agro-Ecosystems Analysis (AEA)
- Rapid Rural Appraisal (RRA)
- Participatory Rural Appraisal (PRA)
- Diagnosis and Design (D & D)

These interdisciplinary appraisal techniques share a common background and history. Farming systems research, agro-ecosystems analysis, rapid rural appraisal methodologies have over the years been adapted and modified by practitioners and researchers.

Of the five tools mentioned above only three are practised in Nepal. Fanning Systems Research has been commonly used while carrying out on-farm trials. Most social studies have been adopting Rapid Rural Appraisal technique for identifying problems. These tools and techniques are discussed in brief.

DIAGNOSIS AND DESIGN (D & D)

The D & D method was developed by John Raintree and colleagues at ICRAF, Nairobi during the early-to-mid 1980s. It is a methodology for the diagnosis of land management problems and the design of agroforestry solutions, and is intended to assist agroforestry researchers and development field workers to plan and implement effective agroforestry interventions.

The basic unit of D & D analysis is the land use system (Raintree, 1984) and is based on the premise that knowledge of a system (diagnosis) is essential to design effective agroforestry research for development (Raintree, 1987). There are three key features of this analysis technique:

- flexibility: can be adapted to fit the needs/resources of different users
- speed: "rapid appraisal" application at planning stage (in-depth follow-up during implementation)
- repetition: open-ended, iterative learning process to refine diagnosis and improve technical design with feedback and new information

D & D can be used to address major decisions in land use system delineation and description, constraints analysis, technology design and evaluation, and research planning, implementation and analysis.

There are two types of Diagnosis and Design programme. One is "Macro" and the other 'Micro'. Depending on the objectives they are used in identifying the problems and designing the solution.

"Macro D & D" is a rapid appraisal technique that relies heavily on secondary data that can be verified with quick surveys. Its objective is to identify broad issues and problems constraining all Land Use Systems in a given eco-zone.

The objectives of "Micro D & D", on the other hand, are to describe and analyse the constraints of a given Land Use System, and then design and evaluate the agroforestry technologies, or the appropriate research programs to develop such technologies.

The Diagnosis & Design process

It follows five stages:

- Pre-diagnostic,
- Diagnostic,
- Design and evaluation, and
- Panning and implementation.

The basic logic of the procedure put forward by ICRAF (1987) is presented in Table 23, which summarizes the basic questions, key factors and modes of inquiry regarding the different stages.

Table 23. Basic procedures and stages of D & D

D & D stages	Basic questions to answers	Key factors to consider	Mode of inquiry
Diagnostic	Which system to focus on?	Distinctive combinations of resources, technology and land user objective	Setting and comparing the different land use system Analysing and describing the system
	How is it organized? How does it function to achieve its objectives?	Production objectives and strategies, arrangement of components	
Design & Evaluation	What is needed to improve system performance?	Specifications for problem solving or performance enhancing interventions	Diagnostic interviews and direct field observations Troubleshooting the problem subsystem
Planning	What to do to develop and disseminate the improved system?	Research and development needs extension needs	Research design project planning
Implementation	How to adjust to new information?	Feedback from on-station research, on farm trials and special studies	Re diagnosis and redesign in the light of new information

Limitation of D and D

There appears to be some potential limitations to this method. These include:

- Tendency to focus on agroferestry technologies only;
- Process may be driven by external researchers; and

- Macro D & D requires a large amount of secondary a data and time.

ACTIONS RESEARCH AND PARTICIPATORY RESEARCH METHODS

Farming Systems Research (FSR)

Focusing on resource poor farmers an FSR approach seeks to adopt farm management practice, help improve technology transfer and increase agricul-tural development.

The salient characteristics of Farming Systems Research are:

- An applied 'problem-solving' approach, conducted by multidisciplinary teams, with a degree of farmer-participation;
- Assessment of the scope for, and potential impact of, technology change within a farming systems framework;
- Identification of a homogenous group (usually resource-poor farmers) within specific agro-climatic zones as clients of research;
- A dynamic iterative process, in which one year's trial results generates hypotheses for the next.

Four research categories usually fall under this system. They are :

- Basic (On-station, generate new understanding of biological process)
- Strategic (On-station, solve specific research problem)
- Adaptive (On-farm, adjust technology to representative environment)
- Applied (On-farm, create new technology)

According to Knipscheer and Harwood (1988), the difference between on-station and on-farm research depends on the need to control variables versus the need to test a particular technology to local conditions, working with farmers in the process of technology development and selection.

Farrington et al. (1988) suggest various methodological techniques for the conduct of FSR. These techniques include:

- Analysis of secondary data and exploratory surveys
- Formal surveys and farmer monitoring
- Laboratory tests
- Direct observation in farmers' fields
- On-farm trials

Limitations in FSR

Chambers and Jiggins (1988) have identified the shortcomings of the "traditional" FSR approach. These include

- Problems in multi-disciplinary collaboration, specifically interactions between social and natural scientists;
- Generating a 'holistic' view of the farming system has led to the collection of huge, unwieldy data-sets; FSR does not focus specifically on poor farmers;
- Researchers dominate the design, content, conduct and evaluation of on-farm trials.

AGROECOSYSTEMS ANALYSIS (AEA)

This system was developed by Gordon Conway and researchers working in Khon Khaen University in Thailand in the early 1980s. AEA is often used in the diagnostic or planning stage of program development.This actually employs rapid rural appraisal methodology in planning research activities.

An agroecosystem may be defined as "an ecological system modified by human beings to produce food, fibre and other agricultural products. Defined by some on purely biophysical characteristics; or socioeconomic components" (Conway' 1987). This system attempts to integrate research with rural development objectives and tends to follow a step-wise procedure.

The process of agroecosystems analysis involves:

- Participants define objectives of analysis (e.g; improving agricultural productivity) and identify research priorities.
- Participants identify relevant systems to be investigated and their boundaries and hierarchic arrangements.

- Pattern analysis conducted by interdisciplinary team to analyze system in terms of space time flows decision affecting key agroecosystems properties-sustainability equity stability productivity.
- Outcome: series of key questions for future research or guidelines for development.

Agro-ecosystem Properties

Both Conway (1985) and Molnar (1989) have outlined the following four key agro-ecosystem properties. They are:-

- Productivity: "the net increment in valued product per unit of resources, commonly measured as yield. or net income per hectare";
- Stability: "the degree to which productivity remains constant despite fluctuations in environmental variables such as climate or economic conditions such as market";
- Sustainability: "the ability of a system to maintain its productivity when subject to stress or disturbance, often difficult to measure"; and
- Equity: "measure of how evenly productivity of the agroecosystem is distributed among its human beneficiaries".

These properties, especially sustainability and stability are often difficult to measure using direct indicators.

Tools for Pattern Analysis

AEA uses semi-structured informal interviews as mechanisms for eliciting information from key informants in the village. The following tools are generally used to determine the existing patterns within the agroecosystem.

System definition

System boundaries and hierarchies are usually delineated by biophysical features such as watersheds, administrative boundaries and economic boundaries.

Spatial analysis

Spatial patterns are usually determined using simple sketch maps, and agroecosystem transects indicating functional relationships with physical features (soils, elevation).

Time analysis

Temporal patterns are best analyzed through graphs and charts showing trends such as seasonal change, longer term changes such as prices, and changes in landscape over time. Patterns of stability, productivity are revealed in such diagrams.

Flow analysis

Flow diagrams help indicate the patterns of flow and transformation of commodities such as money, agricultural produce, information these can be represented as decision trees, or spheres of influence (vertu diagrams).

Key questions

These arise throughout the whole procedure of systems definition and are continually revised throughout the process. At the end of the exercise these questions form researchable hypotheses which should fit into a conventional research or development programme.

Limitations of AEA

Agroecosystems Analysis, although this does have a scope for systems analysis, and is useful as a research and development planning tool, it also has some limitations. These include:

Extractive nature of the exercise

Researchers gather information from villagers in a non-participatory manner. Often the villager is simply viewed as an informant rather than an active participant in the exercise.

Less time available for field analysis

The relatively short time required to conduct the analysis can sometimes result in superficial data collection, and in the generation of incorrect research hypotheses. This can be rectified by increasing the duration of time spent in the field collecting data and verifying the accuracy of the data by triangulation and cross-checks with secondary sources.

RAPID RURAL APPRAISAL (RRA)

This technique was developed in the early 1980s to create a new investigate tool to improve data gathering in natural resources management programmes. International Institute of Environment and Development (IIED) in London, and the Universities of Khon Kaen in Thailand and Sussex in the UK, and other several international institutes working on agricultural research have developed RRA appraisal methodology during the 1980s (Townsley, 1996).

RRA uses a multi-disciplinary approach, where specialists from different disciplines gather and analyze information as a team on a variety of technical subjects (Molnar 1989).

RRA differs from traditional survey approaches in a number of ways:

- it allows a number of technical specialists to introduce different perspectives in solving a particular problem;
- it allows a redefinition of research priorities based on information from different fields;
- it attempts to create a dialogue between clients and researchers; and most RRA methods are short-term and provide a rapid, qualitative under-standing of a particular problem. The quality of the RRA is dependent on the analytical capabilities of the team.

According to Chambers (1992) the techniques used in RRA include:

- Mapping and modelling to make thematic maps of resource use
- Analysis of aerial photographs
- Transect walks

- Time lines, chronology of events
- Trend analysis
- Seasonal diagrams of climate, labour, food, prices Livelihood analysis
- Ranking exercises
- Case studies
- Check-list, simple questionnaires
- Analysis and report writing

The RRA is a powerful data collection tool in a relatively short span of time.

Limitations of RRA

Chambers and others have identified several limitations in the use of RRA. These include:

- overlooking local people's knowledge and understanding of a problem;
- focusing on outsiders (researchers/planners) extracting information from villagers through a series of exercises or interviews;
- the data remains with the researcher and is not shared with the village; and
- the outcome of the RRA exercise is usually used for a planned external intervention such as project or research study.

Another major limitation is that the "rapid" part of the RRA is often stressed by researchers and planners which can lead to poor data gathering and analysis by people with limited experience in RRA methodology.

PARTICIPATORY RURAL APPRAISAL (PRA)

This approach emerged in the late 1980s and is based on further refinement and modification of AEA and RRA techniques. Participatory Rural Appraisal is a tool that helps target group or community through exercises in the field itself. One of the essential features of this tool is that it empowers communities to make appropriate demand on development agencies and institutions.

The focus of the activity is usually sustainable because it is conducted through local action and institutions.

Key features of PRA methodology

- Building on villagers' knowledge and capabilities: PRA builds on villagers' knowledge through techniques such as participatory maps and models using simple materials often constructed on the ground. The strength of this tool lies in 'handing over the pencil or stick' to the villager, and thus enabling villagers to express their capabilities.
- Relaxed rapport: The PRA process tries to develop a relaxed rapport between outsiders and villagers early in the process, to increase participation. This helps build the team spirit between the outsiders and the villagers, and sustains the participatory process.
- Diagramming and visual sharing: Using diagrams, models, maps on the ground with local materials (sticks, stones, seeds) helps share the information being collected with a group of people; this allows cross-checking by the group and greater participation in the analysis.
- Sequences: Going through a series of PRA tools, such as maps, transects, and matrix ranking, allows local people to see the interaction between different sub-systems in the village, increases their interest in the activity and allows for greater learning and analysis. Villagers are able to use their own Criteria in generating a local agenda and assessing priorities.
- Training and reorientation for outsiders: PTA training is simple and can have a profound effect on researchers, in terms of their behaviourial outlook towards villagers and learning from local people.

PRA has been used in four major types of processes:

- participatory appraisal and planning;
- participatory implementation, monitoring and evaluation of programs;
- topic investigations (such as natural resources management, food security, health, etc.); and
- training and orientation of outsiders and villagers.

Limitations of PRA

Like all methodologies there are limitations to PRA. Some of the limitations identified by PRA practitioners include (Theis and Grady 1991):

- building the right team dynamics;
- superficial data collection, generalizing based on small sample;
- failure to involve all members of a community;
- overlooking the invisible; lecturing instead of learning and listening;
- imposing external ideas and values without realizing; and
- raising expectations in the community where the PRA is conducted regarding follow-up activities and interventions.

There are commonalities and differences between these various interdisciplinary research methods. Table 24 below illustrates these points in brief.

Table 24. Comparison between modes of interdisciplinary research (Adopted from Theis and Grady 1991; Chamber 1992 and modified from the reading materials obtained during a workshop at Khon-Khen, Thailand, 1993.)

Parameters	PRA	PRA/AEA/ D&D	SURVEY RESEARCH	ETHNOGRAPHIC RESEARCH
Duration	Short	Short	Long	Long
Depth	Preliminary	Preliminary	Exchange	Exhaustive
Scope	Wide	Wide	Limited	Wide
Structure	Flexible informa l	Flexible	Fixed formal	Flexible informal
Direction	Bottom-up	Beetween PRA and survey approach	Top-down	Not applicable
Participation	High	Medium	Low	Medium-high
Major research tools	Semi-structured interview diagrams	Semi-structured interview pattern analysis	Formal questionnaire	Participant observation
Sampling	Small sample size based on variation	Same as PRA	Random sampling representative	None
Statistical analysis	Little or non	Same as PRA	Major part	Same as PRA
Case study	Important	Important	Not important	Important
Organization	Non-hierarchical; facilitating	In-between PRA and surveys extractive	Hierarchical	Not applicable
Measurements	Qualitative or indicators used	Qualitative and data trends	Detailed; accurate	Detailed accurate
Analysis/ Learning	In the field with the community	At the research station with researchers	Same as PRA/AEA	Same as PRA

Farmers are not much aware of tursery techniques for impoetant fodder species. It is very difficult to them to select male and female trees in the nursery stage. Agroforestry has the components of market, qulauty control and certification as well. Farmer level management have not been able to fulfil these aspects. Some of the importat areas of action research in agroforestry should be:

- Selection of tree species from among some three dozen indigenous and one-dozen successful exotics vis-à-vis their silvicultural characteristics and local suitability;
- Choice of shrubs and herbs of economic value for commercial and general purposes, such as, medicine, essential oil, fibres, floss, and food,
- Development of soil and water conservation techniques to suit slow soil, aspect, and microclimatic conditions;
- Generation of additional income and employment opportunities through agri-slivi-pastoral systems.

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Dr. Bishwa Nath Oli

Dr. Bishwa Nath Oli is currently working as Secretary at Ministry of Forests and Environent Government of Nepal. Dr. Oli has received Bachelor's Degree in Forestry from Tribhuvan University, Nepal, Master's Degree in Natural Resource Management from University of Life Sciences, Norway and Ph D in Forest Governance from University of Copenhagen, Denmark.

Dr. Oli has rich experiences in the forestry sector of Nepal. He worked as Forest Research Officer at Department of Forest Research and Survey, as Regional Forest Director at mid-western Nepal, as Division Chief of the Ministry of Forests and Soil Conservation. Dr. Oli has served as a Director General of Department of Forests during 2013-2014 for almost one and half year.

Dr. Oli has more than two dozens of research papers published in national and international journals to his credit. He has also worked in the editorial team of BankoJanakari journal and reviewed papers from national and international peer reviewed journals. Dr. Oli has also served as External Supervisor of M.Sc. and B. Sc. students of Nepal and abroad.

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