UNIVERSITY OF SOUTHERN QUEENSLAND

EVOLUTION, ADOPTION AND ECONOMIC EVALUATION OF AN AGROFORESTRY-BASED FARMING SYSTEM WITH AND WITHOUT CARBON VALUES: THE CASE OF NEPAL

A Dissertation Submitted by

Arun Dhakal
MSc (Natural Resources Management), BSc (Forestry)

For the award of

Doctor of Philosophy

June 2013

Abstract

Modern agriculture, although high yielding, has several negative consequences such as land fertility loss through erosion and nutrient depletion and water source contamination. Most importantly it has deteriorated the global climate through emissions of greenhouse gases (GHGs): methane, nitrous oxide and carbon dioxide into the atmosphere. The modern agriculture has accelerated land degradation. The other human-induced phenomenon taking place around the globe is deforestation, which is mostly caused by agricultural expansion in order to feed the growing population. Nepal, as one of the least developed countries (LDC) with a fragile ecosystem, is not free of these global problems. Agroforestry, although not a panacea to deforestation and land degradation, has come to the forefront as a sustainable land-use strategy to mitigate these problems as agroforestry has the potential of enhancing soil quality and reducing emissions. However, the adoption of the agroforestry-based farming system is not widespread. Therefore, the aim of this research was to perform an integrated evaluation of such promising land use in Nepal, which covers adoption potential of agroforestry-based farming system at landscape as well as farm level, its financial return over other land uses such as agriculture and an integrated evaluation of GHG mitigation potential of it.

For this case study, out of 2000 households, a sample of 200 was randomly selected, using a random table. The study was carried out in nine VDCs of Dhanusha district, Nepal. Household survey, focus group discussion and inventory of agroforestry tree species were the three methods used to collect the required data. Considering the rotation period of horticultural trees, a 30-year time horizon was used for this study as one agroforestry cycle. Data on demography, adoption, cost and benefits and GHG emissions sources were collected from household survey questionnaires. The costs and benefits of farming systems were converted into monetary terms and discounted to produce net present values. One focus group discussion was conducted with agroforestry farmers to trace the history of agroforestry-based farming system development and to explore the major drivers behind this development. Diameter at breast height (DBH) and height were measured on five agroforestry tree species i.e. *Eucalyptus camaldulensis, Dalbergia sissoo, Gmelina arborea, Melia azedarach* and *Anthocephalus chinensis* and three horticultural tree species i.e. *Mangifera indica, Artocarpus heterophyllus* and *Litchi chinensis* to develop a tree growth model so as to estimate the carbon sequestration potential of agroforestry-based farming systems.

The study revealed that out of eight variables the farm size (*t=3.512*) was the most determining factor with regards to adoption of agroforestry. The results of a regression model for the household data showed that the model explained approximately 75% variation, out of which about 60% variation was explained by this variable alone. The other seven variables significantly influencing adoption were 'availability of irrigation water' (*t=6.271*), 'education level of household heads' (*t=3.582*), 'number of agricultural labour force' (*t=5.494*), 'frequency of visits' (*t=3.146*), 'expenditure on farm inputs' (*t=2.753*), 'household's experience in agroforestry' (*t=2.589*) and 'distance of home to government forest'(*t=2.676*). The benefit-cost analysis showed that all three indicators of financial analysis, NPV (Net present value), B-C (Benefit-cost ratio) ratio and return-to-labor, were higher in agroforestry systems than in subsistence agriculture, reflecting that integrating trees

on farms is financially more attractive. Although financially attractive, the finding suggests that the current harvest cycles of agroforestry tree species were below the optimum level which has stopped them from getting the actual benefits from tree planting and also minimised the carbon sequestration potential of the system.

Inclusion of carbon showed that it contributed by less than 0.5% to the total NPV. Therefore, the income from carbon could not be an incentive to motivate small farmers towards agroforestry intervention. However, considering emission reduction as a carbon benefit from agroforestry, a considerable amount of income could be generated from carbon sale and that could be a motivating factor for small holders to adopt agroforestry. The finding suggested that integrating trees could reduce GHG emissions by 40% to 64% in a hectare basis depending on tree density on the farm in a 30-year period compared to subsistence-based agriculture. However, given the land constraints the chance of small farmers moving to agroforestry-based farming system is heavily constrained. A mechanism for joint farming practice such as cooperative farming, i.e. integrating small farms together to form a larger one, could be a viable policy intervention to encourage small holders towards adopting the environmentally and economically viable land use system such as agroforestry-based farming system.

Certification of Dissertation

I certify that the ideas, results, analyses and conclusions reported in this dissertation are entirely my own effort, except where otherwise acknowledged. It is also certified that the work is original and has not been previously submitted for any other award except where otherwise acknowledged.

_____ _____

Signature of Candidate Date
Arun Dhakal

Endorsement

_____ _____

Signature of Principal Supervisor Date
Professor Geoffrey J Cockfield

_____ _____

Signature of Associate Supervisor Date
Dr Tek Narayan Maraseni

Acknowledgements

I express my deep gratitude to my supervisors Prof Geoffrey J Cockfield and Dr Tek Narayan Maraseni for their excellent guidance, supervision, encouragement, inspiration and critical feedback in different stages of my study at USQ and in the dissertation research. Their support is invaluable to me. I extend my thanks to the University of Southern Queensland (USQ) for providing a scholarship grant for this work.

I thankfully acknowledge the Terai Private Forest Development Association (TPFDA), and the farmers of the study villages in Dhanusha district, Nepal for their cooperation in the study, and TPFDA staff for their help with a household survey and tree measurement. I sincerely appreciate my colleagues Dr Dev Raj Paudyal, Govinda Baral, Shiva Shankar Pandey, Hemang Sharma, Arjun Neupane, Arjun K. C., Suman Aryal and Sanjib Tiwari of the University of Southern Queensland (USQ) for their help and moral support throughout my PhD study.

I would also like to thank Mr Him Lal Shrestha for his support in developing the study area map. My thanks are due to Dr Rajendra Prasad Adhikari for his support in searching relevant literature for this study. I would also like to thank Mr. Saroj Kant Adhikari, Livestock officer of Department of Livestock, Nepal for proving livestock-related data. I am thankful to all (all those I failed to name here) who helped me directly or indirectly during my study period. My special appreciation goes to Ms Paula de Keyzer for the final proofreading and editing of this dissertation. I would also like to thank Professor Raj Guru Rajan and Mrs Liz Whatson, Senior Administration Officer for providing all necessary help during my PhD study at USQ.

I am deeply indebted to my parents (Mr Bishnu Prasad Sharma and Mrs Madhu Maya Dhakal), my sisters (Mrs Bhawana Dhakal and Mrs Shashi Kiran Dhakal), and my brother (Mr Ramesh Dhakal) for their love and encouragement.

Finally, I express my gratefulness and indebtedness to my beloved wife Sushma and son Aaryan for their love, patience, support and motivation.

Table of Contents

List of Figures

List of Tables

Abbreviations

AF	Agroforestry
AFLMP	Agroforestry-based Land Management Practice
AFOLU	Agriculture, Forestry and Other Land Uses
AI	Adoption Index
BA	Basal Area
C	Carbon
CBA	Cost Benefit Analysis
CDI	Crop Diversity Index
CDM	Clean Development Mechanism
CF	Conversion Factor
CH_4	Methane
CI	Cropping Intensity
cm	Centimetre
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent
CSP	Carbon Sequestration Potential
D	Density
DAP	Di-ammonium Phosphate
DBH	Diameter at Breast Height
DDC	District Development Committee
DI	Diversity Index
FAO	Food and Agriculture Organization
FGD	Focus Group Discussion
FYM	Farmyard Manure
g	Gram
GHG	Greenhouse Gas
GWP	Global Warming Potential
H	Height
ha	Hectare
HH	Household
HI	Harvest Index
HIS	Highly Integrated Agroforestry-based Farming System
HYV	High Yielding Variety
ICRAF	World Agroforestry Centre
IDRC	International Development Research Centre
IF	Improved Fallow
IPCC	Intergovernmental Panel on Climate Change
kg	Kilogram
LDI	Livestock Diversity Index
LIS	Less Integrated Agroforestry-based Farming System
LPG	Liquefied Petroleum Gas
MAI	Mean Annual Increment
MIS	Medium Integrated Agroforestry-based Farming System
MoP	Muriate of Potash
MV	Modern Variety
N	Nitrogen

N_2O	Nitrous Oxide
NAF	Nepal Agroforestry Foundation
NR	Negative relationship
NPV	Net Present Value
PES	Payments for Ecosystem Services
Pg	Petagram
RCBD	Randomized Complete Block Design
REDD+	Reducing Emissions from Deforestation and Forest Degradation
SAS	Subsistence based Agricultural System
SFDP	Sagarnath Forestry Development Project
SOC	Soil Organic Carbon
TAP	Tri-ammonium Phosphate
tC	Ton Carbon
TFP	Total Factor Productivity
TPFDA	Terai Private Forest Development Association
UNFCCC	United Nations Framework Convention on Climate Change
USDA	United States Department of Agriculture
VAT	Value Added Tax
VDC	Village Development Committee

Glossary of Nepalese words

Bhari	A load that an adult male/female carries on his/her back. An average Bhari is 30 kg.
Gahat/Rahari	Type of pulse crops.
Katha	Unit of farm area measurement. 30 Kathas make a hectare.
Koro	Small-size timber produced from a eucalypt tree that is used as beams for house construction.
Terai	Plain area.

List of Publications during the PhD Study Period

1. List of Journal Papers during PhD

Dhakal, A, Cockfield, G & Maraseni, TN 2012, 'Factors Affecting Adoption of Agroforestry-based Land Management Practice: A Case of Dhanusha District Nepal', *Agricultural systems* (*Under review).*

Dhakal, A, Cockfield, G & Maraseni TN 2012, 'Evolution of Agroforestry-based Farming Systems: A Case of Dhanusha District Nepal', *Agroforestry systems*, vol. 86, pp.17-33.

Webb, EL & Dhakal, A 2011, 'Patterns and Drivers of Fuelwood Collection and Tree Planting in a Middle Hill Watershed of Nepal', Biomass and Bioenergy, vol. 35 no. 1, pp. 121-132.

2. List of Conference Papers during PhD

Dhakal, A, Cockfield, G & Maraseni, TN 2012, 'Factors Affecting Adoption of Agroforestry-based Land Management Practice: A Case of Dhanusha District Nepal', *Proceedings of the IUFRO 3.08.00 Small-Scale Forestry Conference on Science for Solutions,* Amherst, Massachusetts USA 24-27 September 2012, pp.20-32.

Dhakal, A, Cockfield, G & Maraseni, TN 2012, 'Agroforestry-based Farming Systems, *Madhesi* Community and Climate Change Mitigation: A Case of Dhanusha District, Nepal, *paper presented to the International Conference on Climate Change Mitigation with Indigenous Peoples and Local Communities: Practices, Lessons Learned and Prospects*, Cairns, Australia, 26-28 March 2012.

Dhakal, A, Cockfield, G & Maraseni, TN 2011, **'**Agroforestry-based Farming System, Farm Characteristics and Climate Change: A Study of Dhanusha District, Nepal', *Proceedings of Third International Conference on Addressing Climate Change for Sustainable Development through Up-Scaling Renewable Energy Technologies (RETRUD-011),* Kathmandu, Nepal, 12-15 October 2011,pp. 1-8.