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Adaptation factors and futures of agroforestry systems in Nepal

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Abstract Farmers in Nepal mid-hills have practiced agroforestry for generations as main source or supplement of timber, firewood and fodder from government forests. The nature and extent of agroforestry practice is being challenged by rapid social and economic change particularly in the recent rise of labour out-migration and remittance income. Understanding is required of the critical factors that influence farmers in the way they adapt agroforestry to their circumstances. This paper analyses the relationship of households' livelihood resources and agroforestry practice to identify trajectories of agroforestry adaptation to improve livelihood outcomes. Using data from a survey of 668 households, it was found that landholding, livestock holding and geographic location of farmers are key drivers for agroforestry adaptation. A multinomial logistic regression model showed that in addition to these variables, household income, household-remittance situation (whether the household is receiving remittance or not) and caste influence adaptation of agroforestry practice. The analysis indicates that resource-poor households are more likely to adapt to terraced-based agroforestry while resource-rich households adapt to woodlot agroforestry. Appropriate agroforestry interventions are: (1) develop simple silvicultural regimes to improve the quality and productivity of naturally-regenerating timber on under-utilised land; (2) develop a suite of tree and groundcover species that can be readily integrated within existing terrace-riser agroforestry practices; (3) acknowledge the different livelihood capitals of resource-poor and resource-rich groups and promote terrace-riser and woodlot agroforestry systems respectively to these groups; and (4) develop high-value fodder production systems on terrace-riser agroforestry, and also for non-arable land. The analysis generates important insights for improving agroforestry policies and practices in Nepal and in many developing countries.

Keywords Farming system · Planted trees · Woodlots · Livelihood assets · Multinomial logistic regression · Remittance economy

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Introduction

The livelihoods, and thereby food security, of rural Nepali farmers is highly dependent on their access to tree resources, either from their own land or community forests. The fact that 42 of the country's 75 districts are reported to be food insecure (FAO 2010), this indicates a significant room for improvement in the contribution of tree resources to livelihoods. Our interest in this study is to understand how farmers adapt the use of tree resources in their farming systems to their socioeconomic circumstances. This knowledge may help inform agroforestry interventions that better support livelihoods of farmers under a range of socioeconomic circumstances.

There is a long history of Nepali farmers propagating trees on their land (Nuepane et al. 2002) and these traditional agroforestry systems have been well described by Amatya and Newman (1993) among others. Typical Nepali agroforestry is heavily reliant on fodder trees for livestock, as well as the resulting manure and forest litter used as bedding materials for maintaining soil fertility (Garforth et al. 1999; Palikhe and Fujimoto 2010). Agroforestry trees are the major source of fodder (Amatya 1990; Pandey et al. 2009), constituting up to 70% of dry matter intake for large part of the year (Degen et al. 2010). Farmers cultivate maize, wheat, millet and vegetable crops on their farms that are commonly terraced and bounded with trees. These agroforestry systems also provide subsistence products and environmental services such as soil amelioration and stabilisation (Gilmour and Nurse 1991; Malla 2000; Nuepane et al. 2002; Regmi and Garforth 2010; Pandit and Thapa 2004; Pandit et al. 2014; Nuepane and Thapa 2001) and biodiversity conservation (Acharya 2006).

Adaptation comprises decision making process and subsequent actions undertaken to deal with social-ecological changes (Nelson et al. 2007). The importance of the concept of adaptation in livelihood studies has been highlighted in the early work of Chambers and Conway (1991) who suggested that a livelihood is sustainable if it is able to cope with and recover from stress and shocks while maintaining and enhancing capabilities and assets (Sen 1993). Adoption and adaptation are two terms commonly used that sound similar but have different meanings. The term adoption is a mental process which starts from an awareness of a new idea and then deciding how to make full use of the new idea (Evans 1988). Adaptation, on the other hand, is a process of modifying practices or ideas to fit circumstances different from where it was originally developed (Anderson 1993; Smit and Pilifosova 2001; Agrawal and Perin 2008). Adoption and adaptation are decision-making and learning process that largely overlaps, but occurs sequentially wherein the former involves collection, evaluation and integration of new information while the latter involves improvement of the newly acquired information to suit a certain situation (Pannell et al. 2006). We recognise that adaptation can take different forms; it can happen automatically (usually called, autonomous adaptation in the context of climate change adaptation literature). Sometimes, farmers are assisted with knowledge, resources and policies for adaptation, usually by external agencies such as NGOs and governments (called, planned adaptation) (see Agrawal and Perrin 2008). In this paper, we discuss both forms of adaptation practices, but with more focus on the planned adaptation practices.

While there are many influences on how Nepali farmers adapt their agroforestry systems to changing circumstances, the dominant force is that of outmigration due to the emergence of remittance economy in recent years. The Central Bureau of Statistics Government of Nepal (2012) estimated that more than half of the Nepalese households have at least one member of active-labour-age working overseas. It is estimated that for 2011 remittance constitute about 30% of the household annual income (CBS 2012). Khanal et al. (2015) found in his study site in the mid-hills of the western development region in Nepal that about a third of remittance income is spent on food and clothing, about a fifth is spent on education and health care and about 10% is used to buy land and construct new house while only about 5% for agriculture purposes. Remittances define households' consumption and investment thereby transforming economic structure and people's well-being (Tuladhar et al. 2014). The positive impacts of labour migration include: the increase of household income; acquisition of skills; increased entrepreneurship, exposure, and awareness; and in some cases the empowerment of women who become the de facto head of their households in the absence of men (Sherpa 2010). The agriculture sector is hardly hit with the unprecedented outmigration of labour force in Nepal leaving most farm work to women (Maharjan et al. 2012; Maharjan et.al. 2013; Tamang et al. 2014). This has not only resulted to reduced agriculture productivity, but also burdened the work load of women (Tamang et al. 2014). Labour outmigration has been found to increase the likelihood for a household to exit farming (Bhandari 2013). The emergence of remittance economy has presented with opportunities and challenges in the life and livelihoods of many Nepali households, and it is reasonable to assess how this phenomenon has affected agroforestry practices.

Several studies on agroforestry adoption in the tropics have identified different variables interplaying in household decisions on the adoption of agroforestry innovations (Pattanayak et al. 2003; Mercer 2004; Meijer et al. 2015). Nuepane et al. (2002) identified drivers for agroforestry adoption in Nepal to include: membership of a male household member in local NGOs; female educational level; livestock holding; and farmers' positive perception towards agroforestry. Individual feelings and aspirations also influence adoption of technologies (Garforth et al. 1999; Thapa and Poudel 2002). Furthermore, access to forests is frequently argued to be a strong determinant of tree growing on private lands (Nuepane et al. 2002; Pandit and Thapa 2004; Sood and Mitchell 2011). Dhakal et al. (2012) in their study in the Terai plains of Nepal concluded that institutional support and infrastructure development promote agroforestry adoption while farm size, labour force, farm inputs were constraining factors.

While the factors affecting adoption of agroforestry innovations have been well studied, there is not much clarity around how socioeconomic factors, such as out-migration, influence household 'adaptation' of existing agroforestry practices. In the light of changing livelihood systems in Nepal, and the increasingly broadening scope of agroforestry to enhance environmental services in addition to food production, there is a need to examine the influence of household's resources in adapting specific agroforestry practices to improve food security and livelihoods.

To reinforce the contribution of this study, we recognise that agroforestry has been practiced in Nepal mid-hills for generations and adoption is not an issue, but our major concern here is about understanding the pathways of farmers' adaptation of different agroforestry practices so that resilient livelihood outcomes can be achieved. Hence, the aim of this paper is to examine relationships of households' livelihood resources and agroforestry practices given the changing availability of resources to farmers in the context of remittance economy. This is achieved by developing and testing a multinomial logistic regression model that explains the relationship of livelihood variables and agroforestry system being adapted by landholders using data from a survey of households in selected villages in two districts in Nepal mid-hills. The analysis generates some crucial insights for agroforestry policies and practices across the mid-hills of Nepal.

Methodology

Study area

The study was conducted in Kavre and Lamjung Districts in the mid-hills of Nepal (see map of research sites in Fig. 1). These districts were purposively selected for the EnLiFT Project as they represent the diversity of socio-cultural and ecological contexts, agroforestry practice, and livelihood and food security conditions in mid-hills Nepal. Kavre district is close to the capital, Kathmandu just about 40 km east, covering an area of 1396 km^2, and has 80,720 households with a total population of 381, 937 (CBS 2014). The elevation ranges from 300 to 3000 masl. Societies in Kavre are heavily exposed to the market, agriculture products are sold to the capital, educational level of the communities is higher than most other hill districts (except the major cities) and support to farmers for agroforestry adaptation has been higher either through NGOs or government agencies. On the other hand, Lamjung district is far from the market, located 179 km west of Kathmandu covering an area of 1692 km^2, with 42,079 households and a population of 167,724 (CBS 2014). The district features extremely diverse geography and climate with elevation ranging from 300 to 6400 masl with about a quarter above 3000 masl. Remittance has become one of the major source of income in Lamjung communities. There has been very limited support to farmers' adaptation to agroforestry practices. In each of these research districts (Fig. 1), three village development committees (VDC) were selected as research VDCs namely: Chaubas, Mithinkot and Dhunkharka in Kavre District and Nalma, Dhamilikuwa and Jita-Taksar in Lamjung District (see Paudel et al. 2014 for details on EnLiFT Project site selection).

Data collection and analysis

This paper uses data from the baseline survey of 668 randomly selected households conducted by the

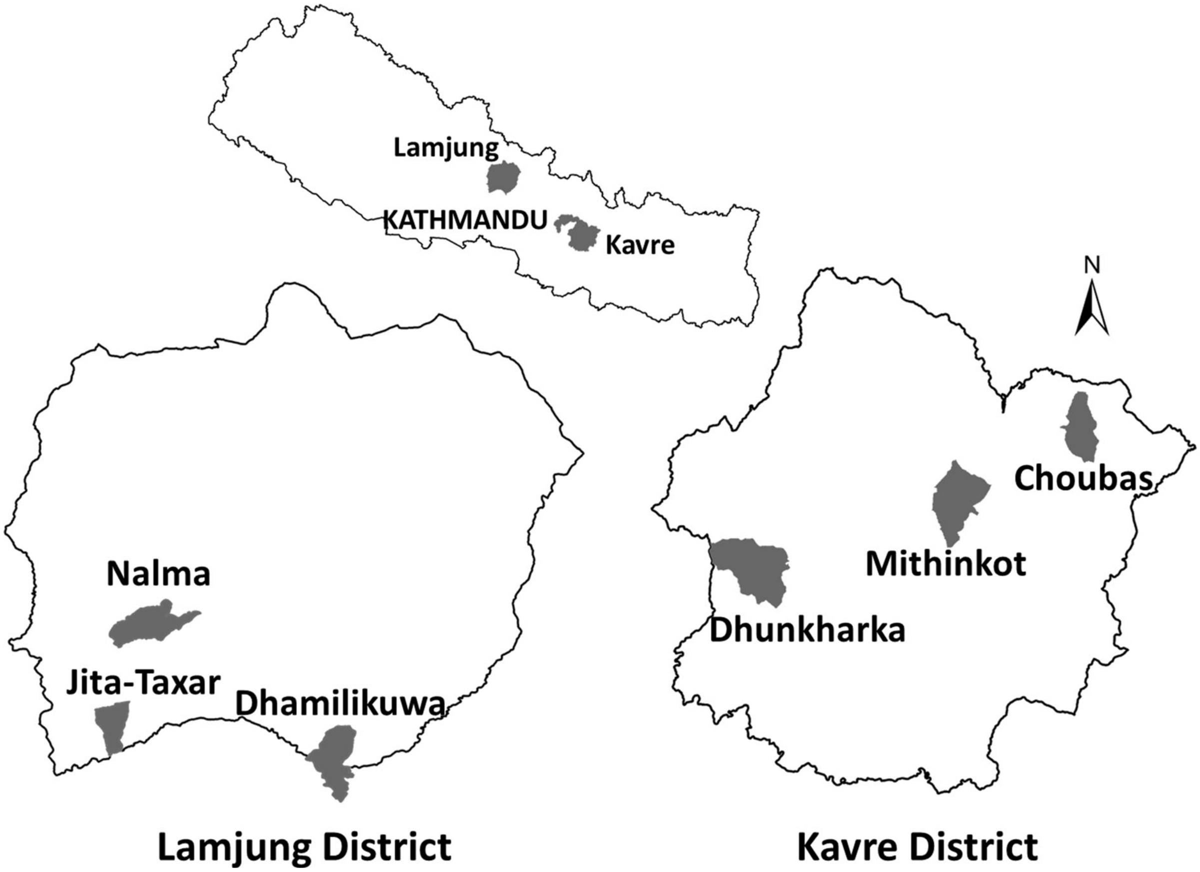

Fig. 1 Composite maps of research sites

EnLiFT Project (see acknowledgment for further details of this project) conducted in six selected VDCs in the two research districts between December 2013 and January 2014 as part of the larger baseline studies. The survey questionnaire was designed using systems framework to describe agroforestry, community forestry and land use systems in the EnLiFT Project research sites. A number of workshops were conducted with farmers, NGOs and government agencies to discuss and decide the appropriate nature and diversity of survey questions. Questionnaires were field-tested. The household survey covered five themes—*household demographics, farming system, agroforestry, community forestry and under-utilised land* (Table 1). The survey was implemented by 12 pairs of male and female enumerators trained by the EnLiFT Project. The survey sample was randomly selected from a list of households obtained from the community forest user groups in the research sites.

While the baseline survey was developed based on systems principles, a considerable amount of data relating to farmers' livelihood were collected. In view of these, the sustainable livelihood framework (SLF) described by Scoones (1998) was used as overarching framework in using the survey data to describe agroforestry farmers and analyse agroforestry adaptation in the research sites. Conceptually, "livelihoods" connote the means, activities, entitlements and assets by which people make a living. Assets are defined as not only natural and biological resources (i.e., land, water, common-property resources, flora, fauna), but also social (i.e., community, family, social networks, participation, empowerment, human (i.e., knowledge, creation by skills) and physical resources (i.e., roads, markets, clinics, schools, bridges). The Brundtland Commission in 1987 introduced SL in terms of resource ownership and access to basic needs and livelihood security, especially in rural areas. SLF is a tool which can be used to conceptually organize the

Table 1 Summary of parameters covered in the household survey

Household demographics	Agroforestry
A. 1. Location and key respondent information (village name, ward number, forestry office area, respondents name, caste, language spoken, family structure)	C. 1. Agroforestry system (trees and non-timber forest products grown, location of these trees and NTFPs on the farm, production costs and revenues)
A. 2. Household information (for all household members the following information are obtained: name, sex, relationship to household head, marital status, educational attainment, main occupation in Nepal, is the household member overseas and what purpose, is the household member in Nepal for the last 3 months)	C. 2. Forage grasses and understorey crops (types and forage grasses and understorey crops grown, area planted and location of these crops)
Farming and farming system	C. 3. Agroforestry decision-making (household member who makes agroforestry decision)
B. 1. Land use and farming system (land area cultivated by land type—Khet, Bari, Pakho bari, Khar bari; who has legal ownership of the land; crops grown in the las 3–5 years)	C. 4. Agroforestry aspiration and problems (problems encounters in agroforestry and future plans)
B. 2. Food purchases (amount and type food purchase)	C. 5. Agroforestry product collection (amount of agroforestry products collected by product type)
B. 3. Farm inputs (amount of farm yard manure, livestock manure, chemical fertiliser, and others)	C. 6. Benefits and disincentives of Agroforestry (perceptions in benefits and disincentiveis of agroforestry)
B. 4. Agroforestry crops (type of trees, grasses, agronomic crops grown)	*Community forestry*
B. 5. Livestock, products and revenue (number of animals by livestock type grown, products and revenue derive)	D. 1. Community Forestry (income derive from community forestry, products collected from community forests)
B. 6. Off-farm income (amount of income from various off-farm sources)	D. 2. Perception on Well-being ranking as part of community forest management
B. 7. Credit and Finance (how much and from whom money was borrowed, attitudes to loans and investment)	D. 3. Benefits from participation on community forest management
B. 8. Organisation membership (roles and membership in community organisations)	D. 4. Perceptions and opinions on community forest issues
B. 9. Self-assessed Household Well-being (respondents are asked to choose which of the well-being rank best suit their socio-economic situation: well-off, non-poor, poor)	*Under-utilised land* E. 1. Area, land type, products from under-utilised land

factors that impact people's livelihood strategies (Sen 1993; Scoones 1998; DFID 1999).

The survey data was compiled using Statistical Package for Social Science (IBM SPSS®) Version 21. Recoding, categorisation, computation and transformation of several variables were made on SPPS to arrive at an appropriate variable measurement. Respondents were grouped into the broad caste classification of Brahmin/Chhetri, Janajati and Dalit as used in some studies in mid-hills Nepal (e.g. Oli et al. 2015; Bhandari 2013). This classification represents the upper caste, middle caste and the disadvantaged caste respectively. This paper utilises data relating to household demographics, farming system and agroforestry—i.e. items labelled A.1 to C.6 in Table 1. Descriptive statistics were first obtained to characterise agroforestry systems and livelihood assets across the six research sites. Then, one-way analyses of variance (ANOVA) and Chi square test were used to examine significant differences across research sites for each livelihood variables. Researchers' fieldwork involving observation, discussion and informal interviews were used to triangulate the survey data.

Profiles of research sites were obtained from secondary sources, internet sources and field observations of the authors. Data on relative site productivity was obtained from Pandit (2014), the population and household data was obtained from the 2011 Census (Central Bureau of Statistics 2012) and annual rainfall was obtained as average from 1990 to 2009 from the website site of Department of Hydrology and Meteorology Government of Nepal (http://www.dhm.gov.np/dpc/). The distances from research sites to the nearest market and the Kathmandu market were determined from digitised road segments of 2012–2014 Google Earth® images as point-to-point distance. The village bazaar (market) was used as the point of origin at villages, while a corner of the district headquarter market centre closest to the national road is used as point at the district level, and the final point is the Kathmandu Kalimati Wholesale vegetable market as the final point. The presence or absence of local market or value chain for agroforestry products were made from visits of the authors to the research sites.

Model specification

Multinomial logistic regression (MLR) has been used in many agroforestry studies particularly investigating outcomes for binary variables (e.g. Adesina et al. 2000; Bayard et al. 2007; Dhakal et al. 2015). The technique is used in this study where it is hypothesised that agroforestry system adaptation is influenced by a combination of livelihood resources that are shaped with socio-economic and eco-physiological factors. The MLR model for agroforestry system adaptation of a sample household can be described as (see Table 2 for definition of the model variables):

$$PAF(k,i) = \beta_{0,k} + \beta_{1,k} \times \mathrm{LH} + \beta_{2,k} \times \mathrm{LSU} \times \beta_{3,k} \times \mathrm{HS} + \beta_{4,k} \times HREM(cat) + \beta_{5,k} \times INC(cat) + \beta_{6,k} \times CAST(cat) + \beta_{7,k} \times RS(cat) + \beta_{8,k} \times HGEN(cat) + \beta_{9,k} \times HEDU(cat) + \varepsilon_k$$

where $PAF(k,i)$ is the logarithm of the ratio of probability of adapting agroforestry and not adapting agroforestry (reference outcome) expressed as $PAF(k,i) = ln[\frac{\Pr(AF=k)}{\Pr(AF=0)}]$. The subscript k denotes the possible agroforestry practices: (1) trees on terrace risers; (2) trees on terrace risers and non-arable l ands; (3) trees on non-arable lands; (4) trees on other location; (5) no agroforestry; and i denotes sample household. $\beta_{0,k}$ is the intercept term, and $\beta_{1,k}$, $\beta_{1,k}$, $\ldots\beta_{9,k}$ are coefficients associated with the explanatory variables LH, LSU, HSIZE, HREM, INC,CAST, RS, HGEN, and HEDU. These coefficients should be interpreted as the effect of each explanatory variable on its log of odds, $ln[\frac{P}{1-P}]$. In other words, a positive coefficient means an increase on the log of odds when level of the corresponding explanatory increases (Hosmer et al. 2013). This model was built and fitted in SPSS which produced the model coefficients, corresponding p-values and odd ratios (including corresponding confidence limits at 95%). The goodness-of-fit of the model was evaluated using the Chi square and its associated p value. Four models were produced to evaluate the log of odds of the explanatory variables on agroforestry system being adapted, e.g. *trees on terrace risers* against *no agroforestry adapted*.

Results

Spatial pattern of agroforestry systems in Nepal mid-hills

Over 80% of respondents practice different forms of agroforestry including trees on terrace risers on khet (irrigated land) and bari (rainfed land), trees on contours, gullies, ravines, rivulets, and grassland (Table 3). Majority (79%) of the farmers grow trees on terrace risers on bari[1] lands with high proportion of tree growing in Kavre than in Lamjung. About half of farmers in Dhunkharka grow trees on grasslands or kharbari, a practice that is not commonly observed in other five sites. In Nalma, about half of the respondents grew trees on terrace risers on khet[2] land. The differences on agroforestry system being practiced between research sites is significant ($p = <0.001$) implying adaptation of agroforestry system to socio-economic and eco-physiological conditions of the locality.

In terms of number of trees, Chaubas and Dhunkharka sites showed a very high number of trees grown—17,044 and 19,504 trees, respectively while the rest are 5000 or below. Species wise, Sallo (Pine trees) is the most widely grown tree species followed by Uttis, Chilaune, Dhudilo,and Katus (Table 4 for scientific names). Pine trees are mainly grown in Dhunkharka on previously grasslands (Table 4). Other

[1] Bari—this land is rainfed and typically located on hillsides where ploughing by bullock is possible. When bari land is abandoned, it became kharbari.

[2] Khet is generally a piece of private land that is irrigated, often located on valleys and foot hills.

Table 2 Definition of input variables of the multinomial logistic regression model

Abbreviation	Data type	Unit	Explanation
LH	Continuous	Ropani	Total area of land owned in ropani (1 ropani = 508.72 m^2)
LSU	Continuous	Livestock unit	Number of livestock unit owned by household. The number of individuals of animals expressed in livestock using the following conversion. Buffalo = 1 (Oli et al. 2015), adult cow or ox = 0.7, adult goat = 0.10, adult pig = 0.2 (Otte and Chilonda 2002), calf = 0.12 (assuming a weight of 15 kg, FAO 1999)
HS	Continuous	Persons	Number of household members
HREM	Categorical	–	Household receiving remittance: 1 = Yes, 2 = No
INC*	Categorical	–	Annual household income from agroforestry, service work, labour, business, hotel/tourism, wine, foreign employment
			1 = less than 100,000 NRs, 2 = 100,000–150,000 NRs, 3 = 150,000–200,000 NRs, 4 = 200,000–250,000 NRs, 5 = greater than 250,000 NRs
CAST	Categorical	–	Caste: 1 = Brahmin/Chhetri, 2 = Janati, 3 = Dalit
RS	Categorical	–	Research village development committees: 1 = Chaubas, 2 = Dhunkharka, 3 = Mithinkot, 4 = Dhamilikuwa, 5 = Jita-Taksar, 6 = Nalma
HGEN	Categorical	–	Gender of household head: 1 = Female, 2 = Male
HEDU	Categorical	–	Education of household: 1 = no education, 2 = primary, 3 = high school, 4 = senior high school (plus 2), 5 = college or university

* USD 1 = NRs 105 (November 2015)

Table 3 Frequency of respondents practicing some forms of agroforestry based on spatial location of trees

Location of trees	Kavre district				Lamjung district			Both	
	Chau bas	Dhunkharka	Mithinkot	All sites	Dhamilikuwa	JitaTaksar	Nalma	All sites	Districts
Terrace risers on Khet	23	1	5	29	12	6	53	71	100
Terrace risers on Bari	100	105	102	307	49	62	45	156	463
Contours and gullies (non-arable)	13	27	12	52	13	4	26	43	95
Ravines and rivulets (non-arable)	8	0	1	9	2	5	7	14	23
Grassland (under-utised)	31	63	19	113	11	17	14	42	155
AF practice not specified	7	9	3	19	3	1	3	7	26
All AF types	114	115	106	335	73	83	93	249	584
Not practicing agroforestry	4	12	5	21	27	23	13	63	84
Total number of respondents	118	127	111	356	100	106	106	312	668
Total number of trees	17,044	19,504	5714	42,262	1383	2894	5308	9585	51,847
Average tree holdings household (trees)	149.5	171.1	54.4	118.7	19.8	34.9	57.1	30.7	89.5

trees grown on previously grasslands or kharbari are Uttis, Chilaune, Sal, and Paiyu with Sal mainly grown in Lamjung District. Trees grown on terrace risers on bari are Sallo, Uttis, Chilaune, Dhudilo and Paiyu. Uttis was reported to be a specialty tree species for tree growing on contours or gullies, generally uncultivable due to steep slope. Dhudilo which is the main fodder species grown on terrace risers on bari, grassland, near

Table 4 Distribution of trees by species and by tree growing location (number of trees)

Species	Terrace risers on Khet	Terrace risers on Bari	Contours and gullies	Ravines or rivulets	Grass land	Not stated	Total
Sallo *(Pinus wallichiana)*[a,b]	403	2617	1614	285	9707	1230	15,856
Utis *(Alnus nepalensis)*[a,b,c]	1387	1787	3739	253	4 524	396	12,086
Chilaaune *(Schima wallichii)*[a,b,c]	2631	2900	596	49	1318	336	7830
Sal *(Shorea robusta)*[a,b]	717	363	170	28	2992	507	4777
Dudhilo *(Ficus nemoralis)*[c]	64	2577	9	500	890	126	4166
Katus *(Castanopsis tribuloides)*[b,c,d]	1170	516	202	29	456	523	2896
Paiyu *(Prunus cerasoides)*[a,b,c]	22	1320	27		102	19	1490
Kutmero *(Litsea monopetala)*[c]	173	929	9	13	2	8	1134
Lapsi *(Choerospondias axillaris)*[d]	60	110	2		310	6	488
Phimsenpati *(Buddleia asiatica)*[b,c]	1	422	12			11	446
Timilo *(Ficus auricolata)*[b,c]	1	364				7	372
Thotne *(Ficus hispida)*[b,c]	9	233	5	27	32		306
Total	6638	14,138	6385	1184	20,333	3169	51,847

Letters on superscripts indicate the major end-use of the tree. [a] timber, [b] firewood, [c] fodder, and [d] fruits

rivers and few on terrace risers on khet. Lapsi, grown mainly for its fruit for condiment-making is also grown on kharbari and bari terrace risers.

Profile of household's livelihood resources

The information on household livelihood resources are summarised in Table 5.

Human capital

The human capital of sample households in the research sites were examined in terms of household size, proportion of household members in the active labour force, gender of household head, education of household head, and proportion of female in the labour force (Table 5). The average household size in the research sites is 6.1 persons which include other household members who are out of the village or out for the country at the time of survey. Households in Kavre District are significantly larger than those on Lamjung sites. More than half of the household is defined as 'active labour' (i.e. between 15 and 59 years old). Also about half of the labour force is female.

Table 5 showed that more than half of active labour forces of the respondents' household in the research sites are engaged in agriculture as main livelihood activity. Less than 10% of respondents are engaged in business as livelihood activity. The average education of household head is 3.2 years but this vary significantly between research sites with Chaubas having an average of 2 years of education and Dhamilikuwa having the highest years of education (4.6 years). District wise, respondents in Lamjung showed to have higher number of years of attended education than respondents in Kavre. It can be generalised that households' head who are the primary decision makers in Nepali households generally have basic or primary education level.

Financial capital

Table 5 presents the financial capital of sample households. The average landholding of respondents is 16.9 ropani or about 0.86 hectare (1 hectare = 20

Table 5 Livelihood resources by research sites (N = 668)

Resources	Kavre district				Lamjung district			
	Chau bas	Dhunkharka	Mithinkot	Across Sites	Dhamilikuwa	Jita-Taksar	Nalma	Across sites
Human capital								
Average years of education of household head (years)***	1.6	4.1	2.6	2.8	4.6	4.1	3.0	3.9
Average household size (persons)**	6.9	6.4	6.0	6.4	5.8	5.5	6.1	5.8
Average proportion of household active labour force (%)[ns]	0.66	0.68	0.67	0.67	0.66	0.68	0.64	0.68
Average proportion active female labour force (%)*	0.48	0.50	0.53	0.50	0.45	0.46	0.46	0.46
Household head (frequency)								
Female	15	18	13	46	17	20	14	51
Male	103	109	98	310	83	86	92	261
Main livelihood source (frequency of household members >15 years)[+]								
Agriculture	287	327	298	912	234	250	254	738
Business	37	61	34	132	22	14	9	45
Job holder	106	73	69	248	81	87	34	202
Service	0	3	0	3	7	2	2	11
Student	92	93	76	261	71	80	71	222
Foreign job	88	17	7	112	8	19	99	126
Not indicated	0	16	10	26	8	1	7	16
Financial capital								
Average landholding (Ropani)***	22.9	12.7	12.1	15.5	18.1	8.2	29.5	18.5
Average livestock holding (livestock unit[a])[ns]	2.25	2.38	1.81	2.15	1.91	2.17	3.49	2.54
Average annual household income[f] (1000 NRs)***	107.7	204.6	226.7	174.1	190.2	224.7	136.0	183.9
Household receiving remittance (%)[+]	21.2	16.5	23.4	20.2	33.0	35.8	51.9	40.5
Social capital								
Caste (frequency) (N = 645)[+]								
Brahmin/Chhetri	54	58	54	–	47	62	8	–
Janajati	59	59	37	–	30	14	68	–
Dalit	4	2	15	–	22	30	21	–
Membership of community organisation (frequency of households)	51	110	49		69	28	46	
Natural capital								
CF area to HH ratio (ha)	0.7	0.7	0.5		0.4	0.7	1.5	
Annual rainfall (mm)[b]	1160	1373	1179		2581	2581	2581	
Land productivity class[d]								
Khet/Bari	2	2	3		3	2	4	
PakhoBari/KharBari	1	1	2		2	2	1	
Physical capital								
Road type from major road to village[e]	D	G	G		G	G	D	
Distance to district headquarter (km)[c]	49	19	28		27	21	19	
Distance to Kathmandu (km)[c]	73	43	52		157	172	191	

Table 5 continued

Resources	Kavre district				Lamjung district			
	Chau bas	Dhunkharka	Mithinkot	Across Sites	Dhamilikuwa	Jita-Taksar	Nalma	Across sites
Agroforestry market facility availability	SM	SM	SM		–	–	–	

SM saw mill

[ns] One-way ANOVA Test between research sites: not significant ($p > 0.05$)

[+] Pearson's Chi square test: strongly significant ($p < 0.001$), based on multiple responses of household members

[a] Livestock unit (LSU) calculated as 1 adult buffalo = 1 LSU, 1 cow/ox = 0.7 LSU, 1 adult goat = 0.12 LSU, 1 adult pig = 0.2 LSU

[b] Reference

[c] Road length estimated from digitised road segments using 2012 Google Earth Image

[d] Class 1 to 5, 1 low site productivity, 5 high site productivity

[e] *D* dirt road, *G* gravel road

[f] USD 1 = NRs 105 (November 2015)

* One-way ANOVA Test between research sites: significant ($0.01 < p < 0.05$), ** One-way ANOVA Test between research sites: moderately significant ($0.001 < p < 0.01$), *** One-way ANOVA Test between research sites: strongly significant ($p < 0.001$)

ropani) in which 63% are below this average. Brahmin/Chhetri and Janajati households have average landholding of 18.3 ropani and 18.6 ropani respectively while Dalit households have average landholding of 8.2 ropani. The average tree holdings per household is 90 trees however there is huge variation of average tree holdings between research sites ranging from 31 to 171 trees. Kavre district has average tree holdings of 119 trees per household while in Lamjung only 31 trees.

The tree holdings vary significantly by caste: Dalit's have an average of 25 trees/household, while Brahmin/Chhetri and Janajati have average of 73 and 100 trees/household respectively. This large difference in tree holdings between Dalit households and the upper castes is primarily due to small land holdings by Dalits. Though Dalits have generally low tree holdings, the tree density on their farms is high with an average of 317 trees/ha while Brahmin/Chhetri and Janajatis have average of 120 and 135 trees/ha, respectively. Livestock holdings did not vary significantly between groups, indicating that households with low tree holdings (i.e. Dalits) are able to access tree and fodder resources in community forests and public forests.

Respondents have estimated their annual income consisting of cash made from farming, wages, business, pensions and remittances. Dalits have average annual income of NRs 134,225 (USD 1 = NRs 105), which is significantly lower than Janajati and Brahmin/Chhetri of NRs 167,513 and NRs 210,315 respectively. About 41% of respondents from Lamjung receive remittance compared to 20% of respondents in Kavre.

Social capital

The three major caste categories are found across all research sites, with the disadvantage groups at higher proportions in the Lamjung sites (22–28% cf. 2–14% in Kavre). It was found that majority (87%) of sample households in Dhunkharka site were members of a community organisations while about half in other sites except Jita-Taksar where only about a quarter are members. All respondents were found to be members of a community forest user group.

Natural and physical capital

Table 5 also shows that Dhamilikuwa has the lowest ratio of community forest to household yet it also has the lowest tree holdings per household. Conversely, the villages with the highest tree planting rate have the median community forest to household ratio. Moisture distribution is a crucial factor in field crop production. Kavre research sites are generally drier with average annual rainfall of 1160 mm to 1373 mm compared to research sites in Lamjung receiving average annual rainfall of 2581 mm. The higher number of trees in Kavre indicates that tree growing may be the best-land use alternative to field crops when moisture is limiting.

Road infrastructure and the distance to a major trading centre are equally important factor in the promotion of agroforestry. The major trading centre for the Kavre sites is Kathmandu which is about 43–73 km away, while Lamjung sites are 157–191 km away from Kathmandu. The road infrastructures from a major arterial road to villages are either dirt road or gravel which often are unpassable during monsoon season. All of the Kavre sites have access to a saw mill approximately within 2 km from the villages centres, the sawmill being a major market facility for agroforestry trees. The sawmill in Kavre research sites are relatively young, approximately operated at least in the last 10 years and is difficult to establish association between the sawmill operation and agroforestry adaptation. Certainly however, the presence of the saw mill had provided better revenue to agroforestry farmers who made the considerable effort to sell agroforestry trees. In fact, in Dhunkharka and Chaubas, agroforestry has been perceived as a profitable venture due to access to nearby markets.

Factors of agroforestry adaptation

The MLR model showed *landholding*, *livestock holding and research sites* to have significant contribution to the general model. The likelihood (as expressed by the term 'odd ratio' in Table 6) estimated for *caste*, *remittance* and *income* have shown to considerably influence adaptation of specific agroforestry model as discussed below.

Model 1: adapting trees on terrace risers

Table 6 shows that the likelihood of households adapting *trees on terrace risers* is inversely related to annual income with households having income of NRs 100,000 to NRs 150,000 showing an odd ratio of 2.4. The influence of livestock holding on the likelihood of adapting *trees on terrace risers* against *no adaptation* increases by 35% with every unit increase of livestock holding. The likelihood of Janajati or Brahmin/Chhetri in having trees on terrace risers is 20% while Dalit households are 80% likely to practice this form of agroforestry. The reason for Brahmin/Chhetri and Janajatis low likelihood of adapting trees on terrace riser is because most of their terraces are planted to high valued food crops which are intolerant to shading. Lastly, the likelihood of households in Chaubas and Mithinkot sites to adapt trees on terrace risers is over two times greater than any other site. The reason for this could be due to scarce fodder and grasses from community forests and public lands which is the not the case in other sites.

Model 2: adapting trees on terrace risers and non-arable lands

Table 6 shows that households receiving remittance is twice likely to adapt terrace-based agroforestry and woodlots on non-arable lands than non-remittance households. The likelihood of adapting these combined agroforestry practices by households within the NRs 200,000–250,000 annual income is 1.4 times higher than low income households (<NRs 100,000); but this likelihood decreases when income goes beyond NRs 250,000. The likelihood of adapting trees on terrace risers and non-arable lands increases by 45% for every unit increase of livestock holding. This has been observed in Dhunkharka where tree growing and management has intensified since the change of herding goats to milking buffalos which require considerably higher quantities of fodder. The likelihood of adapting both agroforestry systems is 2.5–2.9 times higher in Chaubas and Dhunkharka indicating suitability of these systems on these sites. The negative coefficients and the low odd ratios for Dhamilikuwa and Jita-Taksar showed that farmers in these sites are less likely to adapt these combined agroforestry system.

Model 3: Adapting trees non-arable lands only

Trees on non-arable lands are adapted mainly by households who have attained senior high school and annual income of NRs 100,000–150,000. The odd ratios of these variables are 2.7 times and 3 times compared to non-adaptation of agroforestry system, respectively. Analysis of livestock holding and landholding showed that households who adopted trees on non-arable lands only have low livestock holding (average of 1.74 LU within the group compared with average of 2.27 LU for all respondents). Adaptation of trees on non-arable lands by household on the lower income level is explained with the fact that landholdings of poor households are generally non-irrigated

Table 6 Coefficients, odd ratios and confidence limits of multinomial logistic regression models of agroforestry adaptation

Variable	Coefficent	Odds ratio	OR CL (95%)
Model 1:Trees on terrace risers[a]			
Intercept	1.56		
Landholding (ropani)	0.05*	1.0	1.0–1.1
Livestock holding (LSU)	0.35**	1.4	1.1–1.8
Household size	0.01	1.0	0.9–1.2
Gender of household head			
Female	0.77	2.2	0.9–5.2
Male	0[b]		
Is family receiving remittance?			
Yes	0.39	1.5	0.7–3.3
No	0[b]		
Annual household income (NRs)			
>250,000	−0.15	0.9	0.3–2.1
200,000–250,000	−1.08	0.3	0.1–1.1
150,000–200,000	−0.19	0.8	0.3–2.3
100,000–150,000	0.88	2.4	0.8–7.5
<100,000	0[b]		
Education of household head			
No education	−0.32	0.7	0.1–4.9
Primary	−0.48	0.6	0.1–4.3
High school	−0.37	0.7	0.1–4.8
Senior high-school (+2)	0.06	1.1	0.1–10.2
College/university	0[b]		
Caste			
Brahmin/Chettri	−0.85	0.4	0.2–1.1
Janajati	−0.82	0.4	0.2–1.1
Dalit	0[b]		
Research site			
Chaubas	0.88	2.4	0.5–12.4
Dhunkharka	−0.54	0.6	0.1–2.4
Mithinkot	0.99	2.7	0.6–11.9
Dhamilikuwa	−1.70*	0.2	0.1–0.6
Jita-Taksar	−0.82	0.4	0.1–1.8
Nalma	0[b]		
Model 2:Trees on terrace risers and non-arable lands[a]			
Intercept	0.96		
Landholding (ropani)	0.07**	1.1	1.0–1.1
Livestock holding (LSU)	0.45**	1.6	1.2–2.1
Household size	−0.05	0.9	0.8–1.1

Table 6 continued

Variable	Coefficent	Odds ratio	OR CL (95%)
Gender of household head			
Female	0.16	1.2	0.4–3.3
Male	0[b]		
Is family receiving remittance?			
Yes	0.76	2.1	0.9–5.2
No	0[b]		
Annual household income (NRs)			
>250,000	−0.19	0.8	0.31–2.20
200,000–250,000	0.31	1.4	0.35–5.25
150,000–200,000	−0.25	0.8	0.22–2.82
100,000–150,000	−1.31	0.3	0.07–1.03
<100,000	0[b]		
Education of household head			
No education	−0.33	0.7	0.1–6.3
Primary	−0.66	0.5	0.1–4.7
High school	0.36	1.4	0.2–12.9
Senior high-school (+2)	−0.57	0.6	0.0–8.1
College/university	0[b]		
Caste			
Brahmin/Chettri	−0.76	0.5	0.2–1.4
Janajati	−1.11	0.3	0.1–1.0
Dalit	0[b]		
Research site			
Chaubas	1.1	2.9	0.5–15.5
Dhunkharka	0.9	2.5	0.6–10.6
Mithinkot	0.6	1.8	0.4–8.6
Dhamilikuwa	−3.1**	0.0	0.0–0.2
Jita-Taksar	−2.6**	0.1	0.0–0.4
Nalma	0[b]		
Model 3:Trees on gnon-arable lands			
Intercept	−0.76		
Landholding (ropani)	0.06**	1.1	1.0–1.1
Livestock holding (LSU)	0.16	1.2	0.8–1.6
Household size	0.18	1.2	1.0–1.4
Gender of household head			
Female	0.39	1.5	0.4–5.0
Male	0[b]		
Is family receiving remittance?			
Yes	−0.47	0.6	0.2–1.9
No	0[b]		
Annual household income (NRs)			
>250,000	0.07	1.1	0.3–3.7

Table 6 continued

Variable	Coefficent	Odds ratio	OR CL (95%)
200,000–250,000	−0.40	0.7	0.1–3.2
150,000–200,000	0.21	1.2	0.3–4.8
100,000–150,000	1.10	3.0	0.7–12.2
<100,000	0[b]		
Education of household head			
No education	0.07	1.1	0.1–16.1
Primary	−0.67	0.5	0.0–8.6
High school	0.60	1.8	0.1–27.7
Senior high-school (+2)	1.00	2.7	0.1–53.5
College/university	0[b]		
Caste			
Brahmin/Chettri	−0.50	0.6	0.2–2.2
Janajati	−0.79	0.5	0.1–1.7
Dalit	0[b]		
Research site			
Chaubas	−1.53	0.2	0.0–2.1
Dhunkharka	−1.92	0.1	0.0–1.0
Mithinkot	−2.45	0.1	0.0–1.1
Dhamilikuwa	−1.96*	0.1	0.0–0.6
Jita-Taksar	−1.02	0.4	0.1–1.9
Nalma	0[b]		
Model 4:Trees on other location[a]			
Intercept	0.52		
Landholding (ropani)	0.05*	1.1	1.0–1.1
Livestock holding (LSU)	0.24	1.3	0.9–1.8
Household size	0.02	1.0	0.9–1.2
Gender of household head			
Female	−1.03	0.4	0.1–1.9
Male	0[b]		
Is family receiving remittance?			
Yes	0.36	1.4	0.5–4.1
No	0[b]		
Annual household income (NRs)			
>250,000	0.25	1.3	0.4–4.2
200,000–250,000	−0.51	0.6	0.1–3.3
150,000–200,000	0.34	1.4	0.4–5.6
100,000–150,000	0.15	1.2	0.2–5.9
<100,000	0b		
Education of household head			
No education	−0.20	0.8	0.1–11.7
Primary	−0.26	0.8	0.1–11.6
High school	0.12	1.1	0.1–16.6
Senior high-school (+2)	−19.48	0.0	0.0–0.0
College/University	0[b]		
Caste			
Brahmin/Chettri	−0.73	0.5	0.1–1.8
Janajati	−1.09	0.3	0.1–1.3
Dalit	0[b]		
Research site			
Chaubas	0.52	1.7	0.3–10.6
Dhunkharka	−0.63	0.5	0.1–2.9
Mithinkot	−0.86	0.4	0.1–2.8
Dhamilikuwa	−2.21*	0.1	0.0–0.5
Jita-Taksar	−2.35	0.1	0.0–0.6
Nalma	0[b]		
$x^2 = 282.782$, df = 80, $p < 0.001$			

[a] The reference category is: non-AF

[b] This parameter is set to zero because it is redundant

* One-way ANOVA Test between research sites: significant ($0.01 < p < 0.05$), ** One-way ANOVA Test between research sites: moderately significant ($0.001 < p < 0.01$)

which are less suitable for food production (Malla et al. 2003). Additionally, tree planting of poor households could be explained by the role of trees for 'contingencies' (Chambers and Leach 1987 and Chambers and Leach 1990; Conroy 1992) and are important bequest for family members (Cedamon et al. 2004).

Model 4: adapting trees on other locations (or sporadic tree systems)

Approximately 8% of sample households are growing or managing trees on several sporadic locations. The locations include border or boundary planting, sparse trees on terrace risers and trees around the house. This agroforestry system is widely adapted in Chaubas wherein the likelihood of a household adapting this agroforestry is nearly doubled than in any other sites. Households with lower education levels tend to adapt a less organised agroforestry than households who have senior high school or higher. Income levels appear to have little effects on the likelihood of adapting agroforestry in sporadic locations.

Discussion

The Nepal mid-hills is characterised by a mosaic of agroforestry practices. With the changing political economy in Nepal brought about by remittance economy and labour out-migration, agroforestry as a livelihood activity is no doubt impacted. The intersection of livelihood resource to agroforestry adaptation has been examined and the following trajectories of agroforestry adaptation are derived from the findings of this study.

Agroforestry on under-utilised land

Households members undertaking seasonal, temporary or permanent out-migration have higher household income and more likely to be food secure. However, this reduction in the need for agricultural activity for food security has resulted in agricultural land being abandoned (Khanal et al. 2015). This study found that remittance-receiving households are likely to intensify tree growing and management on terraces and non-arable lands and the likelihood of tree growing on abandoned land increases when household income increases. This was observed in the Nalma site where about half of respondents are receiving remittance and pensions and have responded by allowing, and even planting trees on previously irrigated terraces (*khet*). Lack of labour is the main reason for abandoning the land, but the under-utilised sites were also those that relatively have difficult access to good irrigation. Apart from a few fodder trees that might be planted, the trees naturally regenerating were not being managed for high-value tree products. These naturally regenerating woodlots could readily be converted using conventional silvicultural practices into high-value agroforestry systems given supportive policies for selling farm grown timber. Currently the regulatory regime around the sale of farm grown timber is highly cumbersome, expensive and difficult to navigate. There are ten discrete steps involving different local and national government agencies, each step incurring a cost to the farmer-seller that have to be completed at least 35 days (Amatya et al. 2015).

Improved terrace-based agroforestry for resource-poor households

Terrace-based agroforestry is the most common practice with more than 80% of respondents growing trees on terrace risers on both rainfed (bari) and irrigated (khet) lands. There is a wealth of local knowledge on tree selection and traditional management, e.g. lopping for fodder and removal of shade from field crops. However, there is little development of improved practices, such as high density hedgerows of nitrogen-fixing trees, even though attempts have been made to introduce this practice in Nepal (Neupane et al. 2002). The appeal of terrace-based agroforestry is that it can maximise the production of tree products on small landholdings. This study shows that resource-poor Dalit households are more likely to adapt this practice because of their smaller and less-productive landholdings. Resource-rich households have less incentive to manage or improve such systems. The improvements required that Dalits could readily adapt into their practice are simple mixed-species inter-plantings and groundcovers along existing terrace-riser plantings with some thought to reducing competition in the vertical and horizontal strata. Appropriate new species for terrace-riser plantings already exist in Nepal. However their promotion has been in the context of establishing model plantings on bare terraces. This does not fit the context where terrace-risers already have irregular and disparate plantings of traditional trees on terrace risers. Research is needed to find the best way to arrange these new species into existing terrace-risers planted with traditional species.

Differentiation of agroforestry practice by caste

Providing equitable access to resources and opportunities, regardless of caste, ethnicity and gender, is axiomatic in all considerations of rural development in Nepal. It is written in law and imbued in all deliberations in the Nepali research and development community. A possible consequence of this highly laudable ethos is that there can be a one-size-fits-all approach to designing agricultural interventions. However, this study has shown that the natural adaptation of agroforestry practice does vary between castes; Dalit households are more likely to adapt terrace-based agroforestry while resource-rich Brahmin/Chhetri and Janajati households show the tendency to abandon agricultural land allowing natural vegetation or tree succession to occur.

A program of agroforestry intervention using this knowledge would differentiate activities with disadvantages farmers towards improved terraced-based agroforestry; while the better-off farmers would respond better to improved woodlot agroforestry. It is important to recognise these broad categories of agroforestry adaptation will produce different commodities. Terrace-based agroforestry would produce mainly for fodder, fruit and firewood for domestic consumption along with products for cottage industries such as broomgrass (*Thysanolaena maxima*) or medicinal and aromatic plants (e.g. *Swertia chirayita*, *Anomom* sp, *Taxus* spp). In contrast, woodlot agroforests will produce commercial timber, or with a bit more management input even block 'protein bank' plantings of nitrogen-fixing fodder species for commercial livestock.

Tree growing to support livestock production

Livestock production is an integral part of Nepalese farming system where more than half of the population have at least a cattle, buffalo or goat (CBS 2012). The net sale of livestock constitutes 48% of the household farm income in a year (Maltsoglou and Taniguchi 2004). There are also foregone financial benefits from home consumption of milk, meat products, manure and draft power. The models of agroforestry adaptation in "Factors of agroforestry adaptation" section have shown that agroforestry practice is directly related to household's livestock holding. The MLR model indicated that livestock holding encourages to adapt a more intensified agroforestry such as agroforestry on terrace risers and in non-arable land (Model 2). With increasing production of stall-fed buffalo and goat for income generation in Nepal (Gurung 2010), there is an increase demand for fodder and therefore the need to increase yield and quality of fodder from agroforestry is inevitable. Although nutritive value are already determined for many local species (Degen et al. 2010; Upreti and Shresta 2006), there is still no solid evidence for silvicultural management (i.e. lopping and tree density) of local and exotic fodder trees for agroforestry systems in Nepal mid-hills.

Conclusion

Agroforestry practices in Nepal are not static; farmers change and adapt their practice in response to their livelihood capitals, which are in turn influenced by broader socioeconomic and cultural change. Understanding how these broader changes in society operate in a multi-functional landscape is needed to improve food security particularly among poor households. This study has shown that the influence on farmer adaptation of their agroforestry practice is largely driven by financial capital; in particular as a response to remittance income. Resource-poor, disadvantaged households tend to adapt terraced-based agroforestry while richer households tend to adapt woodlot agroforestry. This trajectory of agroforestry adaptation is generally driven by livelihood capitals embedded within social and cultural norms.

Four recommendations for design of appropriate agroforestry interventions are: (1) develop simple silvicultural regimes to improve the quality and productivity of naturally-regenerating timber on under-utilised land; (2) develop a suite of tree and groundcover species that can be readily integrated within existing terrace-riser agroforestry practices that improve subsistence production and opportunities for cottage industry; (3) acknowledge the different livelihood capitals of resource-poor and resource-rich cultural groups and promote terrace-riser and woodlot agroforestry systems respectively to these groups; and (4) develop high-value fodder production systems for commercial livestock on terrace-riser agroforestry, and also for non-terraced, non-arable land.

Other knowledge and advocacy is required to support these interventions. While abandoned agricultural lands are spontaneously developing into under-performing agroforests, there is little knowledge about the quantity and quality of this emerging forest resource. There is also a policy vacuum concerning the development of both agroforestry and under-utilised land in Nepal (Gilmour et al. 2014). Supporting research could include silviculture trials to examine optimal spatial and temporal arrangement of trees, crops and livestock on terrace-based and woodlot agroforestry. Policy and regulatory barriers to the sale of farm-grown timber also requires attention to remove disincentives in farm-tree growing.

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