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ARTICLE

Contribution of integrated forest-farm system on household food security in the mid-hills of Nepal: assessment with EnLiFT model

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ABSTRACT
About half of the households in the mid-hills of Nepal are severely food insecure, and the development of agriculture and forestry sectors could hold keys to reduce food insecurity and achieve other sustainable development goals. This paper presents results from a bio-economic model, Enhancing Livelihood from Improved Forest Management in Nepal (EnLiFT), that estimates a Food Security Index (FSI) across six household types in rural Nepal simulating selected agroforestry livelihood interventions. The FSI is calculated as the ratio between household expenditure capacity and household poverty threshold based on the national per capita poverty threshold. Market-oriented timber production shows strong potential to increase food security across all household types with greater benefits accruing to land-rich households. For land-poor households, remittances from household members working abroad remains the strongest route to their food security despite the underutilisation of agricultural land due to adult male labour outmigration. A drawback of market-oriented timber production is the long-term nature of timber production. As EnLiFT assumes that timber can only be harvested from Year 9, complimentary livelihood strategies are required to address food insecurity in the short term. Complimentary agroforestry interventions with the strongest potential to improve food security include combined high-yielding fodder production and commercial goat production, and production of non-timber forest products. Commercial vegetable production does not improve food security because of the high input costs. Currently, farmers in Nepal cannot yet fully obtain the financial benefits of agroforestry due to the complex and unsupportive forestry regulations surrounding harvesting and marketing of planted trees. While land-poor households are seen to rely on foreign remittances for food security, it is argued that policies encouraging use of remittances to promote agroforestry businesses is needed.

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trees on-farms; bio-economic model; household typology; agroforestry interventions; livelihoods

Introduction

It is well-recognised that forests and trees on agricultural landscapes provide rural populations goods and services necessary for sustenance of livelihoods (Sunderlin et al. 2005; Foli et al. 2014; Reed et al. 2017). In Nepal, trees and forest are prominent features of the food production and livelihood systems where farmers for generations have been heavily reliant of the goods and services they provided (Amatya 1990; Gilmour & Nurse 1991; Amatya & Newman 1993; Garforth et al. 1999; Malla 2000; Nuepane & Thapa 2001; Nuepane et al. 2002; Pandit & Thapa 2004; Acharya 2006; Lamichhane 2009; Pandey et al. 2009; Degen et al. 2010; Palikhe & Fujimoto 2010; Regmi & Garforth 2010; Baral et al. 2013; Balla et al. 2014; Pandit et al. 2014). With the increasing worldwide effort to curb hunger globally, the economic function of trees and forests in agricultural landscapes is highlighted anew in achieving sustainable development goals (McNeely 2004; World Agroforestry Centre 2013, p. 7; Mbow et al. 2014a; Mbow et al. 2014b; van Noordwijk 2019).

Nepal is a mountainous country where three quarters of its population is directly engaged in farming and agriculture-related livelihoods (CBS 2011a). Growing trees or managing natural tree regenerations is indispensable to the Nepali farming system (Neupane et al. 2002; Dhakal et al. 2012; Cedamon et al. 2017a). Like any other developing country, poverty and food insecurity remain challenges for Nepal where about a quarter of the population mainly consists of farming households below the poverty line (CBS 2011b; GoN 2018). There is certainly scope for agroforestry programs to help reduce poverty and improve food security as had been demonstrated elsewhere (Mbow et al. 2014b; Reed et al. 2017). However, there is a dire lack of empirical evidence on the suitability of agroforestry interventions to improve livelihoods and food security in this context.

According to the 2010–2011 Census, about 56% of households in the mid-hills Nepal receive overseas remittances (CBS 2011a). Overseas remittance account for about 31% of Nepal's foreign exchange and in 2016 was estimated at about USD 6 611 838 549 (World Bank 2019). Overseas remittance is also an effective household strategy in poverty alleviation and improving food security (Khatiwada et al. 2017; Regmi & Paudel 2017). However, remittances have a negative impact on the agriculture sector due to temporary labour outmigration causing socio-economic change in rural Nepal (Byg & Herslund 2016). They also have impacted socio-economic conditions in rural Nepal via the improvement of household income (Cedamon et al. 2017b). In the light of this socio-economic change, the formulation of agroforestry programs for poverty alleviation and food security should go beyond identifying agroforestry interventions and should also indicate which intervention is appropriate for specific household types to achieve livelihood improvement.

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While the economic benefits from trees on farms is widely documented, the impact of farm trees and tree resources outside farms, such as community forests, on livelihoods is less understood. The contribution of tree biomass from community forests to household needs is substantial in Nepal. For example, Balla et al. (2014) estimated an average of 528–2162 kg of forest litter per year is collected by a household in Mustang and Kaski districts in Nepal, respectively. Most of this forest litter is used as bedding material for livestock and later combined with manure to produce compost for application to field crops, while some forest litter is directly applied on field crops. The amount of fuelwood collected from community forests is estimated at 44% of the total household demand while fodder and grass are 27% (Adhikari et al. 2007). Timber demand by rural households is generally met from community forests. Lamichhane (2009) identified the major domestic uses of timber in the mid-hills are: construction of house, for the households affected from natural hazards (flood, landslide and fire); making agricultural tools (plough, yoke, and handles of various tools); building new houses in the case of separation within families; repairing houses; building and repairing cattle sheds; and public construction and developmental activities.

A systematic analysis is therefore required to understand the contribution of farm trees and community forests, or the 'linked forest-farm system', to household food security. There are no empirical measurements of the impact of agroforestry interventions on food security in this context. Modelling platforms already exist to analyse agroforestry and community forestry separately, and the focus has been on tree and crop interactions. Some well-known examples of these early models include Water, Nutrient and Light Capture in Agroforestry Systems (WaNuLCAS) (van Noordwijk & Lusiana 1999) and Agricultural Production Systems simulator (APSIM) (Huth et al. 2003; Keating et al. 2003). The FALLOW model developed by the World Agroforestry Centre simulates land-use decisions made by households where the system's performance is measured by carbon stocks, food security and biodiversity (van Noordwijk 2002). These models are useful tools for evaluating agroforestry system productivity using economic and ecological function indicators, but do not capture the subtleties of livelihood processes in the linked community forest-farm systems of a society like in Nepal.

Enhancing Livelihood from Improved Forest Management in Nepal (EnLiFT) is an action research project funded by Australian Centre for International Agricultural Research (ACIAR) from 2013 to 2018. It aimed to enhance livelihoods and food security from improved implementation of agroforestry and community forestry systems in Nepal. The project developed the EnLiFT model—a bioeconomic model inspired by WaNULCAS and FALLOW models, as a tool for assessing technical and policy interventions that might improve agroforestry and community forestry systems that will eventually enhance livelihoods and food security at household and landscape level. This paper presents results of simulations of the EnLiFT model for seven agroforestry interventions across six household types (defined in Cedamon et al. 2017b) found in the mid-hills Nepal. It employs a Food Security Index (FSI) that integrates subsistence and commercial outputs from both farm and community forest.

The aim is to answer the following questions: (1) Does household food security vary with household type? (2) Which agroforestry intervention/s contributes the most to food security and which household type? (3) What policies or programs are needed to advance the contribution of trees and forests to household food security? First, the conceptual framework underlying EnLiFT will be presented, then model structure and assumptions and simulations, followed by simulation results. The discussion of results will also reflect on what policies or programs are needed to advance the contribution of trees and forests to household food security.

Conceptual framework underlying the model

EnLiFT model—an estimator of a Food Security Index

The farm-community forest system in the mid-hills of Nepal is conceptualised in Figure 1. The comments in italics in the figure indicate some of the key issues and problems underlying the productivity of both farm and community forest. In the farm household, both subsistence and income generating livelihoods are based on annual crops, livestock and tree products (details given later). Livestock are key to subsistence nutrition and income generation. They are also crucial for soil nutrition of annual crops. Trees on-farm and in community forests are important sources of fodder and bedding material (litter) for these livestock. While off-farm labour, mainly due to outmigration, is a welcome source of household income, there is less labour for farm work, and the extra capital is rarely invested back into agriculture. Farming systems in the mid-hills are not well-developed in terms of commercial horticulture. The majority of households are still engaged in subsistence-level animal husbandry and agroforestry with opportunistic sale of surplus crops and livestock products. The community forest not only provides fodder and bedding material for livestock, but fuelwood for domestic energy needs. Within these forests there is also great potential for income generation from timber and non-timber forest products (NTFPs). Despite three decades of community forest proliferation throughout Nepal, the potential realisation of benefits has not been achieved due to poor silviculture and forest product markets, a restrictive regulatory environment, inefficient governance and equity issues within communities still stratified along caste lines.

The EnLiFT model was developed using Stella™ programming environment and operates on a yearly basis as agricultural production cannot be practically simulated at a daily time step. It links with an Excel™ file that contains the socio-economic production-related variables structured to generate household income and food security level. Figure 2 shows the modules within the model. Mulia et al. (2017) provide the description of the EnLiFT Model, describe in detail the Stella modelling principles and technique and the way to communicate between the Stella and Excel file.

The model simulates different household activities that represent the main pillars of food security: food availability (including generating cash income), access and utilisation. The activities include:

- Cultivating annual crops in different plots for several seasons per year, with options for different types of annual crops
- Maintaining tree-based systems with or without understorey; or intercrops in the same plot as a mixed-system or agroforestry. The tree species can vary, e.g.

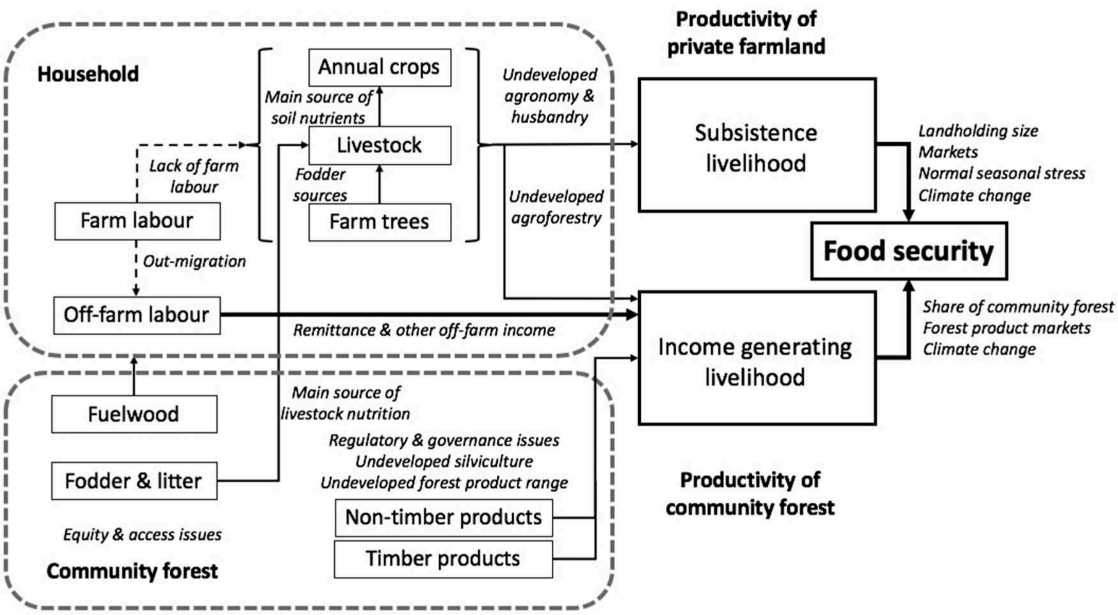


Figure 1. Conceptual framework of the forest-farm system in the mid-hills of Nepal, its contribution to household food security and identification of areas for development and research in italics

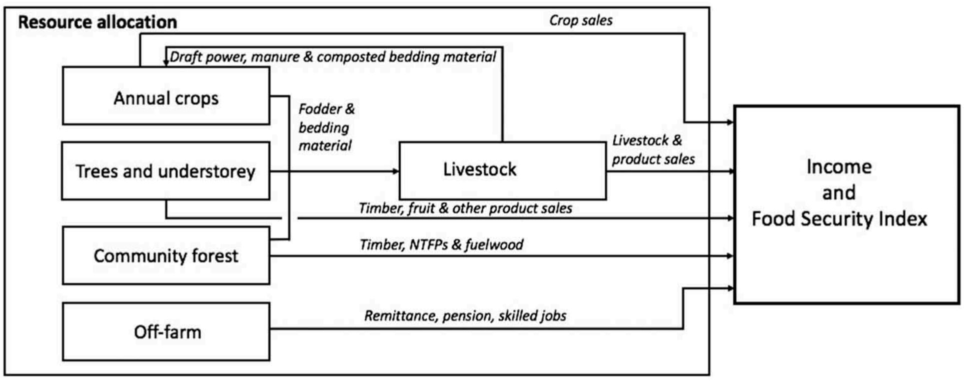


Figure 2. Flow and interaction between modules, or livelihood sectors, in the EnLiFT model version 1.0 constrained by household capital and allocation

those for timber, fodder or NTFPs, with various types of understorey or intercrops

- Raising different types of livestock, e.g. poultry, goat, cattle and buffalo, and deriving income from selling of their products (such as milk, milk-derived products or eggs)
- Collecting products from community forest such as fodder or bedding materials for livestock, firewood for cooking or processing milk product, or timber for construction
- Gaining income from non-farm sources such as remittance, pension or unskilled/skilled jobs
- Spending for food and non-food items, including education and health.

These household activities are represented in the model by the five modules namely: annual crops, tree and understorey, livestock, off-farm income and community forest, then an underlying resource allocation module which generates income and food security values.

(1) *Annual crops*: estimating production and net income gained from cultivating at maximum four plots of annual crops. Each plot can accommodate three seasons of annual crops
(2) *Tree and understorey*: estimates production and net income gained from cultivating at maximum three plots of tree-based or mixed systems with intercrops or understorey. Each plot can accommodate three different tree species and two understorey/intercrop species
(3) *Livestock*: estimates population and income gained from raising livestock. The model can simulate at maximum four kinds of livestock, e.g. poultry, goat, cattle and buffalo
(4) *Resource allocation*: allocates three kinds of household capital namely money, land and labour into different livelihood options based on household resource allocation strategy
(5) *Income and food security*: this module summarises incomes from on-farm and non-farm activities and estimates the household food security level.

Figure 2 describes the flow of product and activity between modules under the available household resources (land, labour and financial capital). In addition to the five main modules described above, the model also has a module that simulates the extraction of different products such as bedding materials, fodder, firewood or timber from a community forest in case the household experiences a shortage. It also has a module estimating income contribution from non-farm sources such as remittance, pension or skilled jobs.

Key model outputs

Farm income and farm productivity. EnLiFT produces an estimate of income (net of input cost except labour and land) from farming-related activities such as from annual crops, agroforestry (trees and understorey) and livestock sector. It also provides an estimate of total yield, marketable surplus and household consumption from each plot each year in 25 years.

Food and non-food expenses. EnLiFT estimates food deficit in Nepalese rupees given levels of food produce on-farm and the official national poverty threshold.

Food Security Index. The FSI is calculated as the ratio between household expenditure capacity and household poverty line obtained by multiplying the household size and per capita national poverty threshold which is NRS 19 261 (CBS 2011b). The household expenditure capacity is the total cash income that the households can generate from the different livelihood options and the money equivalence to their private consumption. Food Security Index below 1 can be interpreted as 'severely insecure' as the expenditure capacity is below the poverty line. Thus, FSI of 1–1.5 is deemed 'insecure' as the expenditure capacity is relatively close to the poverty line, 1.5–2 as 'secure', and greater than 2 as 'highly secure'. This food security level will vary across time depending on the household activities, performance of farming systems and income from other livelihood options.

Description of case study area

EnLiFT is simulated for rural households in Kavre and Lamjung Districts in the mid-hills of Nepal. Kavre district is located 40 km east of Kathmandu covering an area of 1396 km^2, and includes 80 720 households and total population of 381 937 (CBS 2014). The elevation ranges from 300 to 3000 masl. Lamjung district is 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 diverse geography and climate with elevation ranging from 300 masl to 6400 masl with about a quarter above 3000 masl. Kavre district is now under Province 3 and Lamjung district is under Province 4 in the new federal system of Nepal.

The household typology was derived through cluster analysis of 521 respondents of a household survey conducted in December 2013–January 2014 in these districts (see Cedamon et al. 2017b for more details). The household types and their relative percentage of the sample population are:

Type 1: resource-poor Brahmin/Chhetri (17.3%)
Type 2: resource-poor Janajati (18.0%)
Type 3: resource-rich mixed-caste (3.3%)
Type 4: resource-rich Brahmin/Chhetri (24.0%)
Type 5: resource-rich Janajati (23.2%)
Type 6: resource-poor Dalit (14.2%).

All household types except Type 3 exist in all survey villages albeit at varying distribution indicating intrinsic social differentiation or ethnic diversity (or homogeneity) of a village. These household types are regrouping of the three major castes in the mid-hills of Nepal namely: Brahmin/Chhetri, Janajati and Dalit. The Brahmin/Chhetris are high and 'ritually pure' caste while Dalits are low and 'ritually impure untouchable' caste. Janajati is the general term used to signify people from the several Tibeto-Burman ethnic groups.

Description of the baseline forest-farm system

The forest-farm system that best represents a baseline or business as usual scenario for the mid-hills Nepal is shown in Figure 3. For simplicity reasons, land parcels in any village are categorised as Khet (Plot Type 1), Bari (Plot Type 2) and Khar Bari (Plot Type 3). The descriptions of these plot types are provided on Figure 3. Any household may own multiple parcels of land in each of these plot types. Although not shown in Figure 3, community forests provide substantial amount of timber, fodder and firewood to households. Noteworthy is the recent decline of firewood use in the case study due to use of liquified petroleum gas (LPG) for household cooking. The model input parameter for quantity of firewood represents the average firewood demand of households with LPG being used in household cooking. The livestock system is stall-fed where feed is derived from on-farm fodder trees, community forests and annual crop residues and bedding materials are obtained mainly from community forests.

Within each of these plots, the baseline spatio-temporal scenarios for trees, annual crops and NTFPs are shown in Figure 4. The allocation of land to trees and understorey on each plot type are as follows:

- Khet: 90% annual crops, 10% tree/understorey
- Bari: 80% annual crops, 20% tree/understorey
- Khar bari: 50% trees and 50% understorey.

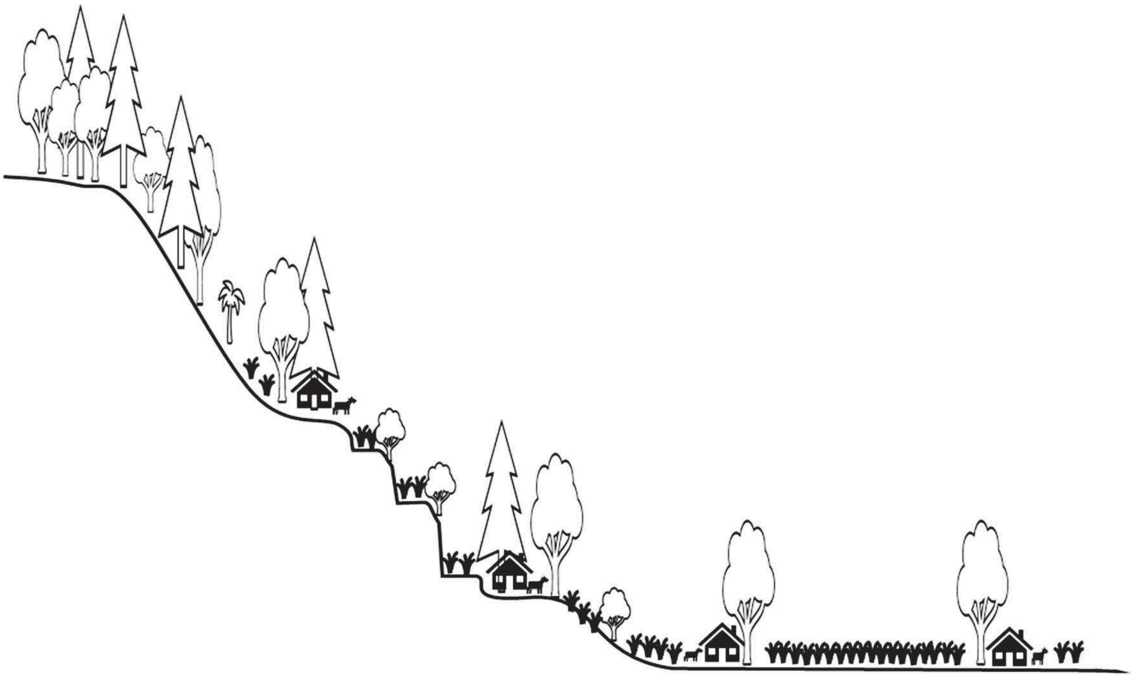
The area of kitchen garden is approximately 100 m^2 located in the homestead. On Khet under cultivation, current farming practice limits growing of valuable fodder trees on bunds and farm borders. Additionally, households have access to community forests for some of their timber, firewood, fodder/grasses and leaf litter needs.

Model parameterisation and calibration

Input parameters were obtained from the EnLiFT Baseline Survey (Tamang et al. 2014; Cedamon et al. 2017b), farmer focus group discussions, key informant interviews and expert interviews conducted between 2014 and 2016.

The following parameters are constant for all household types in the baseline scenarios:

- Number of working days per year (days): 275 (derived from expert opinion)
- Annual per capita consumption for maize (flour, kg): 35.8 (Kc et al. 2015)
- Annual per capita consumption for rice (milled, kg): 67.1 (OECD/FAO 2015)
- Remittance income: nil
- Pension income: nil
- Income from labour jobs: nil
- Community forestry income given to households: nil
- Fraction of saving allocation for food expenses: 0.25 (derived from focus groups)



Slope	Very steep, ploughing not possible	Moderate to steep, ploughing by animal possible, terrace might have been constructed	Flat, ploughing by animal or tractor possible, bunds might have been constructed
Irrigation	Rainfed	Rain fed	Rain fed/irrigated
Land use	Trees, woody shrubs, grasses, wild NTFPs, grazing, animal barn	Cereals, fruits, vegetables, oilseeds, multi-purpose trees, planted NTFPs, settlement, stall-fed livestock	Cereals, fruits, vegetables, oilseeds, multi-purpose trees, planted NTFPs, settlement, stall-fed livestock
Cropping season	Cropping not practiced	2 cereal crops	2–3 cereal crops, 2cereal crops + vegetable
Plottype	3-K har bari	2-Bari	1-K het

Figure 3. Description of the land parcels in the mid-hills of Nepal that are used as plot types in EnLiFT model

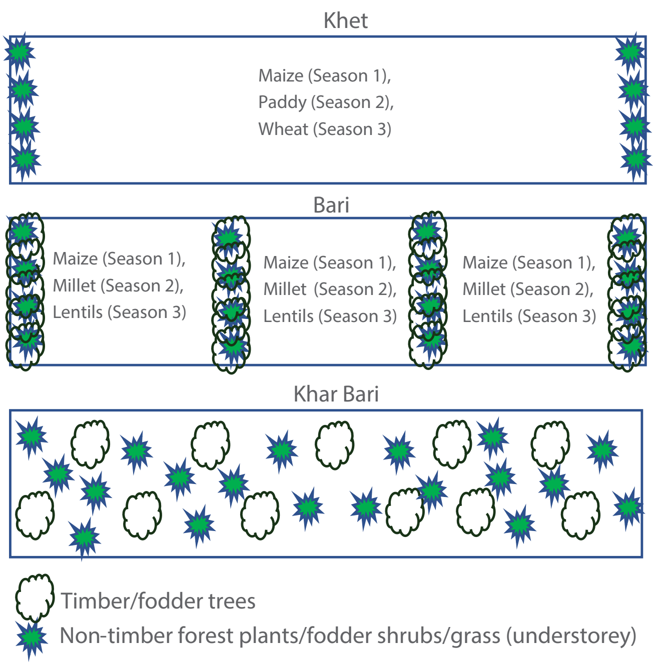


Figure 4. Typical spatio-temporal pattern of trees and annual crops in the mid-hills of Nepal

- Fraction of saving allocation for non-food expenses: 0.25 (derived from focus groups)
- Annual poverty threshold per capita (NRS): 19 261 (CBS 2011b)

The values in Table 1 are defined for simulations of the baseline scenarios for each household.

Livelihood scenarios

EnLiFT was run for 42 simulations for the six household types over the following seven scenarios.

(1) Baseline
(2) Open-planted tomato in khet replacing maize (commercial vegetable production scenario)
(3) High-yielding fodder trees for livestock holding at baseline scenario
(4) High-value market-oriented timber production
(5) High-value timber plus market-oriented NTFPs
(6) High-yielding fodder trees for commercial goat production
(7) Baseline with remittance income from household member working abroad.

Table 1. Landholding, household size, proportion of active labour, pension and expenses (health, education), assumed initial capital

Household Type	Median land area (ha) Khet	Bari	Khar Bari	Annual Pension (NRS)	Family Members (person)	Active Labour fraction	Initial Capital (NRS)	Health Expenses (NRS)	Education Expenses (NRS)
Resource-poor Brahmin/ Chhetri	0.31	0.31	0.15	Nil	5.6	0.74	125 036	35 000	29 250
Resource-poor Janajati	0.31	0.25	0.1	Nil	5.8	0.71	115 782	50 000	29 250
Resource-rich mix caste	2.09	0.31	0.51	Nil	5.9	0.77	171 152	53 000	40 000
Resource-rich Brahmin/Chhetri	0.31	0.31	0.2	30 000	6.9	0.77	274 279	32 000	29 250
Resource-rich Janajati	0.3	0.23	0.15	54 000	6.6	0.78	225 816	33 000	29 250
Resource-poor Dalit	0.17	0.15	0.1	Nil	5.8	0.73	135 039	33 000	29 250

NRS, Nepalese Rupees.

The aim of these simulations was to identify which scenario is best for each household type and the leverage that Scenarios 2–7 may bring to each household type. Table 2 shows the suites of tree, crops and livestock representing these scenarios. Scenario 5 introduces a high-value timber tree increasing the fraction of timber trees from 50% to 100% representing tree plantation. While Scenario 3 represents improved fodder production to serve the number of livestock found on a baseline farm, Scenario 6, simulates commercial goat production (in addition to buffalo and cattle at baseline levels) given the limits of land and labour.

Results

Estimated net revenue of household groups by livelihood sectors (annual crops, trees and understorey, livestock, off-farm activities)

The estimated net annual revenue from annual crops, trees and understorey, livestock and off-farm activities for the seven livelihood scenarios by each household type is presented in Table 3. It was found that all household groups showed increase in revenues in annual crops sectors under intensive horticulture production, i.e. cultivating tomatoes on Khet land replacing maize, however, the resource-poor Dalit household group showed a marked increase of 11-fold. In the livestock sector, increasing fodder yield showed 15% increase on livestock revenue in resource-rich mix caste group while all other groups are insensitive to this change. High-yielding fodder production and commercial goat production, however, resulted in marked increase of revenue in the livestock sector ranging from NRS 46 000 to 101 000 or an increase of 28–167%; the resource-poor Brahmin/ Chhetri and Janajati being the groups showing considerable increases in revenue. The incremental revenues across household groups under the high-yielding fodder and commercial goat production scenario showed huge variation indicating sensitivity of food security levels of household groups to commercial goat intervention.

The impact of marketing planted trees on farms (tree and understorey sector) was found to be substantial across household groups. In the baseline scenario, the model is forced to commercial zero timber harvest based on the assumption that current timber regulations are

Table 2. Suites of crops, timber and fodder trees and understorey for seven livelihood scenarios

	Khet land						Bari land						Khar bari land		
	Crops			Trees and understorey			Crops			Trees and understorey			Trees and understorey		
Scenario	S 1	S 2	S 3	Timber	Fodder	NTFP	S 1	S 2	S 3	Timber	Fodder	NTFP	Timber	Fodder	NTFP
1	Maize	Paddy	Wheat	-	-	-	Maize	Millet	Lentil	Chilaune	Ficus	-	Chilaune	Ficus	-
2	Tomato	Paddy	Tomato	-	-	-	Maize	Millet	Lentil	Chilaune	Ficus	-	Chilaune	Ficus	-
3	Maize	Paddy	Wheat	-	Kimbu 664 sph	-	Maize	Millet	Lentil	Chilaune	Ficus	-	Chilaune	Ficus	-
4	Maize	Paddy	Wheat	-	-	-	Maize	Millet	Lentil	Uttis 1111 sph	-	-	Uttis 1111 sph	-	-
5	Maize	Paddy	Wheat	-	-	-	Maize	Millet	Lentil	Uttis 556 sph	-	Cardamom	Uttis 556 sph	-	Cardamom
6[a]	Maize	Paddy	Wheat	-	Kimbu 664 sph	-	Maize	Millet	Lentil	Chilaune	Kimbu 1111 sph	-	Chilaune	Kimbu 1111 sph	-
7+	Maize	Paddy	Wheat	-	-	-	Maize	Millet	Lentil	Chilaune	Ficus	-	Chilaune	Ficus	-

[a]goat production only; [b]with remittance
NTFP, non-timber forest products
1. Baseline
2. Open-planted tomato in khet replacing maize (commercial vegetable production scenario)
3. High-yielding fodder
4. High-value market-oriented timber production
5. High-value timber plus market-oriented NTFPs production
6. High-yielding fodder for commercial goat production
7. Baseline with remittance from household member working abroad
Scientific names of local plants and trees
Kimbu (*Morus alba* L.)
Millet (Finger miller) (*Eleusine coracana* Gaertn.)
Uttis (*Alnus nepalensis* D.Don)
Ficus species (mainly *Ficus nemorales* Wallich ex Miquel and *Ficus hespida* L.f.)
Cardamon (*Amomum subulatum* Roxb.)
Chilaune (*Schima wallichii* Chois)

Table 3. Sectoral annual net income (in thousand Nepalese Rupees, NRS) of household types by agroforestry system scenario

Scenario	Household type	Annual crop income (1000 NRS)	Tree and under-storey income (1000 NRS)	Livestock income (1000 NRS)	Off-farm income (1000 NRS)
1 Baseline	Resource-poor Brahmin/Chhetri	9.27	−0.181	20.21	0
	Resource-poor Janajati	24.11	−0.066	21.83	0
	Resource-rich mix caste	7.99	−0.256	32.92	0
	Resource-rich Brahmin/Chhetri	31.56	−0.118	65.88	0
	Resource-rich Janajati	13.02	−0.001	62.63	0
	Resource-poor Dalit	−1.23	−0.058	28.14	0
2 Open-planted tomato in khet replacing maize (commercial vegetable production scenario)	Resource-poor Brahmin/Chhetri	14.07	−0.181	19.2	0
	Resource-poor Janajati	24.99	−0.066	19.39	0
	Resource-rich mix caste	23.22	−1.69	33.24	0
	Resource-rich Brahmin/Chhetri	38.87	−0.118	64.44	0
	Resource-rich Janajati	19.95	−0.01	65.12	0
	Resource-poor Dalit	10.02	−0.059	28.98	0
3 High-yielding fodder scenario planted on terrace risers on khet	Resource-poor Brahmin/Chhetri	9.77	−0.143	19.42	0
	Resource-poor Janajati	23.35	−0.113	20.77	0
	Resource-rich mix caste	9.53	−0.256	37.93	0
	Resource-rich Brahmin/Chhetri	31.44	−0.166	65.23	0
	Resource-rich Janajati	13.08	−0.012	62.12	0
	Resource-poor Dalit	−1.15	−0.047	28.3	0
4 High-value market-oriented timber production scenario	Resource-poor Brahmin/Chhetri	10.56	197.51	20.72	0
	Resource-poor Janajati	20.4	73.66	30.83	0
	Resource-rich mix caste	9.01	266.32	35.57	0
	Resource-rich Brahmin/Chhetri	33.62	134.42	66.35	0
	Resource-rich Janajati	12.8	140.01	62.25	0
	Resource-poor Dalit	−1.21	63.84	28.24	0
5 High-value timber plus market-oriented NTFPs	Resource-poor Brahmin/Chhetri	11.72	188.05	20.88	0
	Resource-poor Janajati	20.71	65.59	30.05	0
	Resource-rich mix caste	9.64	259.75	34.39	0
	Resource-rich Brahmin/Chhetri	32.91	122.66	63.08	0
	Resource-rich Janajati	14.56	135.09	64.43	0
	Resource-poor Dalit	−0.92	55.28	28.27	0
6 High-yielding fodder for commercial goat production scenario	Resource-poor Brahmin/Chhetri	28.34	−0.004	53.94	0
	Resource-poor Janajati	22.97	0	51.78	0
	Resource-rich mix caste	21.09	−4.6	73.08	0
	Resource-rich Brahmin/Chhetri	33.99	−0.003	84.01	0
	Resource-rich Janajati	21.31	−0.003	101.15	0
	Resource-poor Dalit	0.059	−0.001	46.5	0
7 Baseline with remittance income	Resource-poor Brahmin/Chhetri	10.81	−0.18	19.88	111.15
	Resource-poor Janajati	18.93	−0.07	30.34	113.82
	Resource-rich mix caste	10.43	−0.26	31.13	106.46
	Resource-rich Brahmin/Chhetri	31.73	−0.118	64.72	131.03
	Resource-rich Janajati	13.42	−0.01	64.03	130.43
	Resource-poor Dalit	−0.92	−0.058	28.47	108.94

1000 NRS = 9.56 USD; 19 March 2018. NTFP, non-timber forest products.

complex and time-consuming, discouraging farmers to enter the timber market. When the run was simulating commercial timber harvest, farmers could generate additional income from NRS 63 000 to NRS 266 000 in which household groups with larger landholdings are expected to earn higher income from trees. Cultivation of a NTFP under trees like cardamom, reduces income from this sector of 2–13% due to the high labour cost.

Food security of households at baseline scenario

The model estimated that four out of six household types representing more than half of the rural population have FSI of 1 or lower under the current forest-farm livelihood system (baseline scenario) indicating these household types are 'severely food insecure' (Fig. 5). These households are the resource-poor Brahmin/Chhetri, Janajatis and Dalits, and the mix resource-rich households. Under the baseline scenario, the model estimated that Dalit households have a negative net annual income from annual crops indicating food (mainly cereal) deficit. The trees and understorey component also show negative annual net income indicating that this system does not generate income. However, these components generate materials for input into annual crops and livestock sectors, and therefore some portion of outputs from crops and livestock can be attributed to trees and understorey. Livestock improvement shows a positive annual net income indicating significant marketable surplus; the rich households showing two to three times higher net livestock income compared to the resource-poor households.

Food security level under commercial vegetable production scenario

The food security of households under a commercial vegetable production scenario was investigated via open-cultivated tomato on khet land replacing maize and wheat in the dry season. The model estimated that the FSI across households with commercial tomato production scenario is lower compared to the baseline scenario (Fig. 5). The FSI of all but the resource-rich Brahmin/Chhetri are below 1 indicating that the household expenditure capacity is below its minimum requirement represented by the poverty line. Although Table 3 shows that the net annual income from annual crops in tomato production scenario is increased across all household types, this income increase does not have an impact on food security due to the food production potential foregone from maize and wheat. The household FSI is reduced by about 10–25% of FSI; the poor households showing severe food deficits. The performance of livestock component is not affected by the change of crop in the khet land although crop residues from annual crops for livestock may have been reduced due to replacement of maize and wheat.

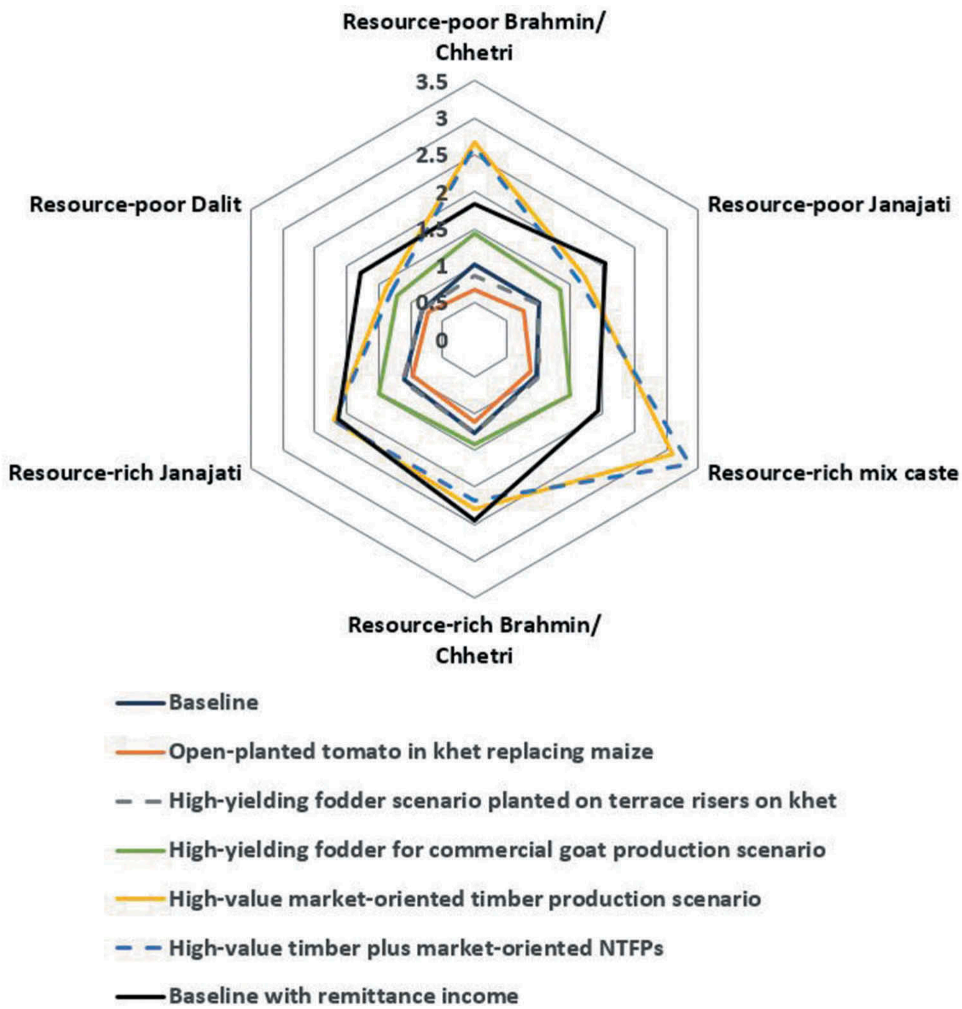


Figure 5. Radar chart of food security indices of household types for seven livelihood scenarios

Food security level under high-yielding and fast-growing fodder agroforestry system

Given that livestock considerably contributes to household income and therefore to food security, production of high-yielding fast-growing fodder crops was simulated to examine their role in household food security. Fodder production on terrace risers on khet land was simulated which found that the FSI of all household types for high-yielding fodder production scenario is almost at the same level as the baseline scenario (Fig. 5). This also means that the households have sufficient fodder supply for their current livestock production level, and that planting high-yielding fodder on terrace riser as a sole strategy is not a viable livelihood strategy. This could be due to (1) sufficient fodder supply of baseline scenario for their current livestock production level and (2) the lack of market for surplus fodder. As the FSI of household under high-yielding fodder production scenario is similar to the baseline scenario, food security of most household types is 'very food insecure'.

Food security level of households under commercial goat production

In contrast, commercial goat production simulations show that high-yielding fodder and commercial goat production could significantly increase FSI. The FSI under commercial goat production ranges from 1.2 to 1.5 (Fig. 5). Although this FSI level is still considered 'food insecure' because it is still around the FSI of 1, this is a great improvement from the baseline scenario. This improvement in food security obviously comes from livestock income with 18 000 NRS to 40 000 NRS increase from the baseline scenario. Additionally, it is worth noting that the FSI under commercial goat production is comparable across household types.

Food security level under timber production with supportive timber market policy

Due to increasing trend of tree growing on previously cultivated rainfed lands and grassland (khar bari), the EnLiFT model was used to examine the food security contribution of this system compared with other forest-farm livelihood intervention scenarios. The model showed that Uttis (*Alnus nepalensis*) tree crops (a fast-growing native broadleaf agroforestry tree species) generates high income to households (Table 3) and thus raised the FSI by two- to three-fold (Fig. 5). Uttis is one of the tree species that is traditionally grown on farms for which harvesting and marketing are relatively easy compared to other agroforestry tree species. This scenario demonstrates how a supportive policy environment for harvesting and marketing timber products from private forests could increase the revenue and food security functions of trees on forest-farm systems in Nepal. As shown in Figure 2, despite the general increase of FSI brought about by timber production and marketing, household types with small areas of bari and khar bari lands (resource-poor Janajati and Dalits) did not have a comparable food security response compared to household types with larger land areas suitable for timber production.

Food security level under timber production and non-timber forest products with supportive timber market policy

Non-timber forest products are another promising system trialed by some farmers in the mid-hills, particularly when tree canopy is present. The EnLiFT model was used to investigate the additional contribution planting cardamom under Uttis has on household income and food security. Figure 5 shows that NTFP production combined with timber production has a similar economic performance to timber production scenario. This could be due to the relatively high capital outlay and operating costs for NTFP cultivation and processing. However, NTFPs could serve as a safety net when timber harvesting or marketing policy is not favourable to private forestry.

Food security levels with remittance

With the increasing trend of labour outmigration and importance of remittance economy in rural areas, investigating remittance income on household food security in inevitable in investigating agroforestry options for different household types. Based on the marginal increase of food security index due to remittances, Figure 5 shows that remittances can make all households 'highly secure' achieving a food security index of 1.79–2.45. Additionally, the FSI are comparable among household types.

Annual food security profile under remittance and market-oriented timber production scenarios

The FSIs reported above are averages over 25 years. Figure 6 presents three-year moving average of FSI across the six household types for three livelihood interventions unraveling important insights of annual food security profile of selected agroforestry or livelihood interventions. First, the food security level of all households in the baseline scenario is generally stable in which a majority of the rural population is showing severe food insecurity. Second, the pattern of household food security from year to year is mirrored under the remittance scenario although at much higher scale, i.e. more than 1.5 FSI. Third and most importantly, the food security of all household types under the market-oriented timber production scenario only starts to improve at Year 10 when trees have attained marketable sizes. Although this is not surprising, it is important to note that timber-based interventions could have an important contribution to food security in the medium and long term. Conversely, it is also important to note that agroforestry or other tree-based interventions like fodder production or NTFP production, could be suitable supplementary livelihood activities to timber production prior to commercial timber harvest.

Discussion

Promising agroforestry interventions by household type

The household types considered in the EnLiFT model differ largely on their household assets, particularly land and human capital which has important implications for household food security. The impact of agroforestry interventions

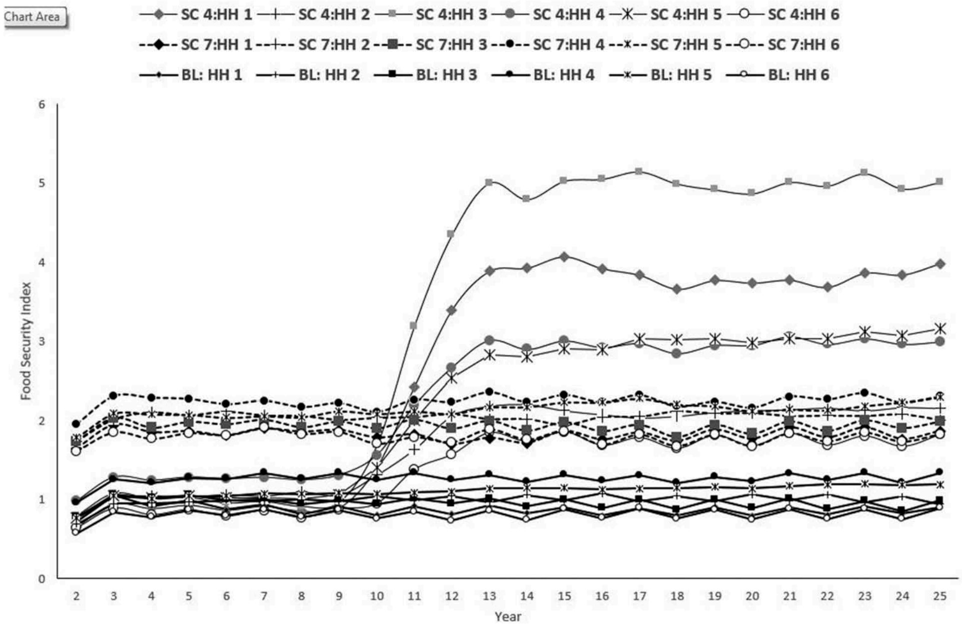


Figure 6. Three-year moving average of food security index of six household types under *market-oriented timber production scenario* (SC 4, represented by solid line), *with remittance scenario* (SC 7, represented by broken lines) and *baseline scenario* (BL, grey lines)

on the food security level is compared among the six household types. The model showed that planting high-yielding fodder for commercial goat production and market-oriented timber production are agroforestry interventions that could greatly improve food security of rural households. The mixed caste group and resource-poor Brahmin/Chhetri group showed the greatest improvement in food security from market-oriented timber production scenario followed by the resource-rich Janajati group. The FSI of the resource-poor Brahmin/Chhetri group is highest under the market-oriented timber production scenarios surpassing the FSI of foreign remittance scenario. While a slight improvement of food security was observed under market-oriented timber production scenario in Dalit groups, they remained food insecure. This is because improvement of food security is directly related to the area of landholdings and that Brahmin/Chhetri households traditionally have large landholding and Dalit have small landholdings.

The EnLiFT model showed that intensive horticulture has the lowest impact on household food security across all household types (FSI below 1 indicating severe food security). This is contrary to the findings of Pandit et al. (2018) that market-oriented agroforestry interventions, including tomato, banana and ginger, improve food security in the study site. Pandit etal. (2018) concluded that 17% of households became food secured through market-oriented agroforestry systems because of 58% increase of farm income. Their calculations of overall household income and food security included off-farm income. They estimated an average before and after annual farm income of NRS 44 817 and NRS 70 622, respectively, and average before and after annual off-farm income (including remittance) of NRS 75 578 and NRS 76 300, respectively. In comparison, the EnLiFT model which did not include off-farm income in the estimation of food security, estimated an average annual income of NRS 60 248 from intensive horticulture scenario. Pandit et al. (2018) confirm that farm income alone from intensive horticulture production is not sufficient to improve household food security. Moreover, given that nearly half of rural households rely on off-farm work and remittances for their livelihoods, it is important to note the EnLiFT model baseline scenario represents the food security context of the other half of rural households that does not receive off-farm income or remittances.

Improving food security in rural Nepal through trees

The EnLiFT model showed that the trees and understorey component of the forest-farm system have important role to play in improving food security. The model has demonstrated that planting of high-yielding fodder for animals raised under the traditional system does not improve food security. When the goat herd at the baseline scenario is increased to 20 heads to represent commercial goat production, and when fodder production is expanded to bari and khar bari land, the food security level across households is increased from FSI of 1–1.4. Although on average the improvement of food security from intensifying fodder production and increasing goat herd is relatively a mild increase, that is from level of 'severely insecure' to 'insecure', this increase is a great achievement particularly for the low-caste (Dalit) household group (from 0.8 to 1.2 FSI).

It was found that among agroforestry interventions assessed by the EnLiFT model, commercial timber production showed the greatest increase in food security from average FSI of 1 to average FSI of 2.2. This increase is due to rationalisation of current timber market regulations allowing sale of timber products. Current regulations and operational procedures are complicated with high transaction costs discouraging farmers from accessing higher-value timber market. However, if existing timber regulations and administrative procedures are improved, this will greatly improve food security of tree farmers. Additionally, the model assumes a competitive market for timber products and that purchase of food is of highest priority in the disposal of timber revenue. The FSI of 2.67 and 3.1 by resource-poor Brahmin/Chhetri and resource-rich mix caste, respectively, under the market-oriented timber production scenario demonstrates the potential of agroforestry in improving food security.

Household access to community forestry plays an important role in augmenting the impact of planted tree sales on household food security. Most households rely on community forests for their domestic needs for timber, firewood and forest litter. Planted trees and managed natural regrowth, therefore, serve as reserves when contingencies arise; such as unexpected need for cash, when a household member is unable to go to the forest due to ill health or other family circumstances, or when desired products are not available from the nearby community forest. Under the market-oriented timber production scenario, where faster growing tree species (*Alnus* spp.) replace the slow growing managed natural regeneration (like *Schima wallichii*), the total annual available timber is almost 75–100 times more than the household timber demand; a considerable quantity of commercially available surplus timber. This timber, however, only became available from Year 10 onwards hence timber requirement of the household before this period is assumed to be satisfied from the community forest. Therefore, community forests play an important role in satisfying household subsistence demand for timber. Similarly, Oli et al. (2014) found that availability of and access to forest products from community forests strongly dictates households' agroforestry practices in the mid-hills of Nepal.

Impact of remittances on food security

The effect of remittances on the macro and micro economy of Nepal is starting to be known, but the impact of remittances on household food security has not yet been measured. The EnLiFT model revealed that foreign remittance provides the highest FSI for resource-poor Janajati and Dalit, and resource-rich Brahmin/Chhetri. For resource-poor Janajati and Dalits, foreign employment is the most effective way to improve household food security. It is interesting to note that foreign remittance has considerably greater impact on food security of resource-rich Brahmin/Chhetri than their resource-poor counterparts. This is because resource-rich Brahmin/Chhetri have generally better education and are likely to get higher paying professional jobs overseas than resource-poor Brahmin/Chhetri. For the resource-poor Brahmin/Chhetri and resource-rich mix caste groups, their food security level is much lower under foreign remittance scenario than the market-oriented timber production scenario.

The analysis of impact of overseas remittances on household food security points out the reality that for some household types, foreign employment is the only means to get out of poverty, particularly in the shorter term. The annual food security profile showed that remittances can have an almost instant improvement on food security and is stable for the whole 25-year modelling period. However, the reality is that the period of foreign employment does not last long for many labour migrants. The EnLiFT model shows how remittance can be an important poverty alleviation strategy in the short-term, but land-based interventions including agroforestry appear to have better long-term food security outcomes. CBS (2011a) reported that although 79% of remittance income is used for daily consumption, only 2% is used in capital formation. A financial mechanism should be put in place to help labour migrants improve their financial health and increase their capacity in capital investments that will improve and stabilise their food security situation. An obvious adverse result of labour outmigration is abandonment or under-utilisation of agriculture land (Ojha et al. 2017) which could have severe economic as well as environmental consequences, particularly for households of unskilled labour migrants. Policies incentivising labour migrants investing in agriculture, agroforestry or forestry-related activities as well as improving regulations on land leasing and land sharing could help address the twin problem of poverty and environmental degradation in the long term.

Policies are needed to encourage the use of remittances to promote agroforestry businesses that can enhance food security. The government needs to recognise the opportunity to promote agroforestry-based entrepreneurship amongst returning migrants and initiate schemes by targeting the investment of these returnees into agri-business activities. In order to promote investment of remittances in agroforestry enterprises, there is a need for the government to provide adequate incentives in the form of tax exemption or security for investment for migrant workers to invest in agro-based activities in Nepal. The practice of micro-finance could help support poorer groups to access and use these remittances and engage in agroforestry activities, where government and NGOs could offer services such as training, advice and marketing assistance. Moreover, remittances could be a seed and working capital for establishing and running agroforestry enterprises. In fact, many returned migrants have been informally doing these activities, but this has not been properly supported and recognised. The remittances can provide such credit, thus supporting the growth of agro-enterprises. Many migrants who are working overseas may like to invest in such enterprises and the government policy could enable such investors which could generate income and employment to many people in Nepal, while providing good return to investment.

Limitations of the EnLiFT model

The EnLiFT model elucidates the forest-farm dynamics of an average household in any of the six household groups in mid-hills Nepal identified by Cedamon et al. (2017b). Although the current model can integrate the contribution of community forest to household's food security through provision of subsistence forest products to livelihoods, the direct financial benefits from forest management is not modelled. This is due to the lack of information on the level of financial benefits and mechanisms for cash transfer from community forest user group to households in return to their efforts in forest management. When information on direct financial benefits of households from community forest management becomes available, further parameterisation of the EnLiFT model will be required to measure the impact of improved community forest management on household income and food security.

The definition of 'food security' used in the model is necessarily very simplistic and based on economic access to food in annual time steps. More comprehensive definitions include physical and social access, the seasonality of access and the nutritional quality of the food accessed (see for example GoN 2010). To build and characterise a model to reflect such complexity was beyond the resources and remit of the EnLiFT project. We maintain that a relatively simpler model with clear boundaries and verifiable parameters is more useful than complex models with vaguely characterised parameters.

The range of simple FSIs this model estimates fall within common sense expectations for the case study area; there are no unexpected outliers. However, if the model is to be applied in other provinces then it will need further characterisation to represent different socio-economic and biophysical conditions.

Conclusion and policy implications

This study highlighted the wide disparity in food security between the rich household types and poor households. It is estimated that more than half of rural households currently suffer severe food insecurity due to inadequate food produced and insufficient off-farm income. However, the model showed that some agroforestry interventions could improve household food security. These interventions are market-oriented timber production and production of NTFPs, high-yielding fodder and commercial goat production and remittances from foreign employment.

Of particular value is how the model distinguishes which agroforestry or livelihood intervention benefits which household type the best. For example, commercial timber production with a supportive policy for timber harvesting and marketing will provide the best food security impact for land-rich households (resource-rich mix caste, resource-poor Brahmin/Chhetri and resource-rich Brahmin/Chhetri groups). But resource-poor household types (resource-poor Janajatis and Dalits) with little land, remittances from overseas employment will remain as having the greatest effect on improving food security. Commercial goat production with intensive fodder production also has a promising role in improving food security, although not as strong as remittances and commercial timber production. Importantly, commercial vegetable production coupled with a modest increase in on-farm fodder supply will not markedly improve food security levels for any household type.

Drawing from the modelling work undertaken on the contribution of forest-farm systems to food security in the mid-hills of Nepal, this paper argued that timber trees on farms could improve food security level across all household types in rural areas provided they have access to under-utilised land (of which there is a considerable area). The requirement, however, is to improve policies and regulations affecting timber harvesting and marketing. In Nepal and many developing countries, existing forestry regulations are unsupportive of harvesting and marketing of timber grown by farmers. In Nepal particularly, there is need to simplify and reduce the length of time needed for processing permits to harvest and transport of farm-grown timber. There is also a need to push for an agroforestry policy in Nepal that will encourage the use of remittances in the development of agroforestry entrepreneurship in addition to the focus on research, development and investment in the context of the newly formed federal government institutional arrangements.

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