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EnLiFT Model 1.0: A Livelihood and Food Security Model of a Forest-Farm System

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Abstract

This paper presents the concept, specification and calibration of a systems model for temporal simulation of a forest-farm livelihood system. The model has been developed to examine the level of food security of the forest-farm livelihood system in Nepal and to identify interventions to increase household income and food security. The model framework consists of five modules: annual crops, tree and understorey, livestock, community forest and Food Security Index. The household activities are categorized into the four aspects of food security: availability, access, use, and stability of supply. The model can be applied over 6 household types based on caste and wealth. This typology was derived from cluster analysis of data from a survey of 668 households in 6 villages in 2 mid-hill districts. An example is presented from simulation runs of one type of household – a capital-rich Janajati household for four selected agroforestry production scenarios. The simulation experiment reveals strong relative significance of the tree-understory module on household food security and the crucial importance of off-farm income and remittances from overseas.

Keywords: agroforestry, community forestry, forest and farm linkages, systems modelling

Introduction

The role of integrated forest-farm systems in ecological sustainability and food security has long been recognised (Swaminathan 1984). Initial research on agroforestry had focused on biophysical aspects of agroforestry systems particularly soil improvement, fertility management and crop yield (Nair 1998). The scope however of agroforestry research has broadened over the past two decades to cover economic and social aspects (Montambault and Alavalapati 2005) due to realisation of imperatives of social and economic aspects in advancing agroforestry adoption (Nair 1998; Rochelau 1998) to deliver the promise of eradicating poverty and hunger in developing countries (El-lakany 2004; Garrity 2004). Agroforestry as a science has become an inter- and multi-disciplinary endeavour integrating ecological/biophysical and social/economic/policy aspects to address livelihood and environmental issues (World Agroforestry Centre 2013).

Agroforestry has traditionally been the science and practice of incorporating trees, agricultural crops and livestock either simultaneously and sequentially on the same piece of land. With the increasing body of knowledge arising from agroforestry research, agroforestry is now described as a “dynamic, ecologically-based, natural resource management system that, through integration of trees on farms and in the agriculture landscape diversifies and sustains production and builds institutions" (World Agroforestry Centre 2013, p. 7). With this definition, agroforestry researchers are not only looking at systems where trees are integrated into agricultural cropping systems but are now looking at the interactions and interplay of 'off-farm trees' and forests with integrated tree-crop-livestock systems and the general livelihood and food security implications. Analysing agroforestry as a linked forest-farm system is indispensable because of the immense role of trees and forests on individual households livelihoods (McNeely 2004) as well as the environmental services trees and forests provide at the landscape level (Mbow et al. 2014a). For agroforestry to contribute to food security, social wealth and climate change mitigation, understanding the components and process flows in changing agriculture landscape is essential (Mbow et al. 2014b).

The crucial role played by linked forest-farm systems on livelihoods is prominent in Nepal. Nepalese agroforestry exhibits a heavy reliance of livestock on fodder trees as feed and on manure and forest litter for maintaining soil fertility (Amatya and Newman 1993; Garforth et al. 1999; Palikhe and Fujimoto 2010). Farmers cultivate maize, wheat and millet on their farms that are commonly terraced and bounded with fodder trees. Fodder trees stabilise the terrace risers and provide a major source of feed for livestock (Pandey et al. 2009; Amatya, 1990) constituting up to 70% of dry matter intake for large part of the year (Degen et al. 2010). The economic and ecological benefits of agroforestry are well documented in Nepal, (e.g. Amatya and Newman 1993; Gilmour and Nurse 1991; Malla 2000; Nuepane et al. 2002; Nuepane and Thapa 2001; Pandit and Thapa 2004; Acharya 2006; Regmi and Garforth 2010; Baral et al. 2013; Pandit et al. 2014). But these studies consider Nepali agroforestry systems as rather independent and self-sustaining systems of the landscape.

While the role of trees on farming and livelihoods is widely documented, the interplay of farm trees and tree resources outside farms (i.e. community forests in the context of household agroforestry system and stability) is understudied. The contribution of tree biomass from community forests to household needs is substantial. For example, Balla et al (2014) estimated an average of 528 kg to 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 is 27% (Adhikari et al. 2007). Timber demand by rural households in Nepal is generally met from community forests. Lamichhane (2009) identified the major domestic uses of timber in the midhills are (i) construction of house, for the households affected from natural hazards (flood, landslide and fire); (ii) making agricultural tools (plough, yoke, and handles of various tools); (iii) building new houses in the case of separation within families; (iv) repairing houses; (v) building and repairing cattle sheds; and (vi) public construction and developmental activities. Moreover, the availability and access of forest products from community forests has been found by Oli et al. (2014) to strongly dictate households' agroforestry practices in Nepal mid-hills.

Despite the inextricable link of forest and farm systems in most landscapes, most studies to date 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 WaNuLCAS (van Noordwijk and Lusiana 1999) and APSIM (Keating et al. 2003; Huth et al. 2003).The FALLOW Model developed by ICRAF/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 all great tools for evaluating agroforestry systems productivity using economic and ecological function indicators but do not capture the subtleties of livelihood processes in the forest-farm systems.

Inspired by WaNULCAS and FALLOW models, EnLiFT Model - a model of a linked forest-farm system, has been developed to explore agroforestry and community forestry technical and policy interventions that might improve livelihood and food security at household and landscape level. This paper presents the concepts and specifications of the EnLIFT Model and provides an example of the model calibrated for a typical household in the Nepal mid-hills. The next section provides an overview of the forest-farm system. Description and specification of the EnLiFT Model constitute the remaining portion of this paper. A short section is provided to conclude the paper with a brief outline on what the model has achieved and a short note of further modelling work.

Overview of the Forest-Farm System in Nepal and Choice of Modelling Platform

Livelihood and food security improvements are the major driving forces for development programs over the last few decades. The concept of livelihood is understood as comprised of capabilities and assets (material and social) required for a means of living (Chambers and Conway 1992). The first aim of any household's livelihood strategy is to achieve food security which the World Food Summit (FAO 1996) described as having access to sufficient, safe and nutritious food to maintain a healthy and active life at all times. Two general dimensions in understanding of 'livelihood' have emerged from the plethora of livelihood studies – these being 'materialist' and 'group centred' (Upreti et al. 2012). A 'materialist' understanding of poverty is concerned mainly with understanding poverty, development, vulnerability and coping strategies while a 'group-centred' approach is concerned with identity and exclusion/inclusion. The EnLiFT Model falls within the 'materialist' understanding of livelihood such that, it is concerned with examining allocation and management of resources of a farm-forest system that would provide the best livelihood outcome. The version of the model reported herewith is a household-level model but it is envisaged that a community-level model will be developed as a project sequel.

The forest-farm system in the Nepal mid-hills is idealised in Figure 1. The farm-forest system is generally comprised of the food production system in private land and forest production on public land being aggregated at household level. While trees are common on private lands, availability of tree products varies between seasons and among household socio-economic status. At times when on-farm tree products are scarce, households make up the deficit from community forests creating the indispensable link of the farm and forest systems. As represented in Figure 1, community forestry contributes to food security through enhancing livelihood capital which is translated as 'purchasing power' in a strict economic sense. Figure 1 is a generic representation of the farm-forest system of a household in a community in the mid-hills of Nepal indicating the key components and areas for improvement. The text beside the arrows and boxes are issues of concern in analysing the flows and relationships. The model is implemented in Stella® software because of its capability as both a modelling too and a communication tool. The section that follows describes the concepts and formulation of the EnLiFT Model.

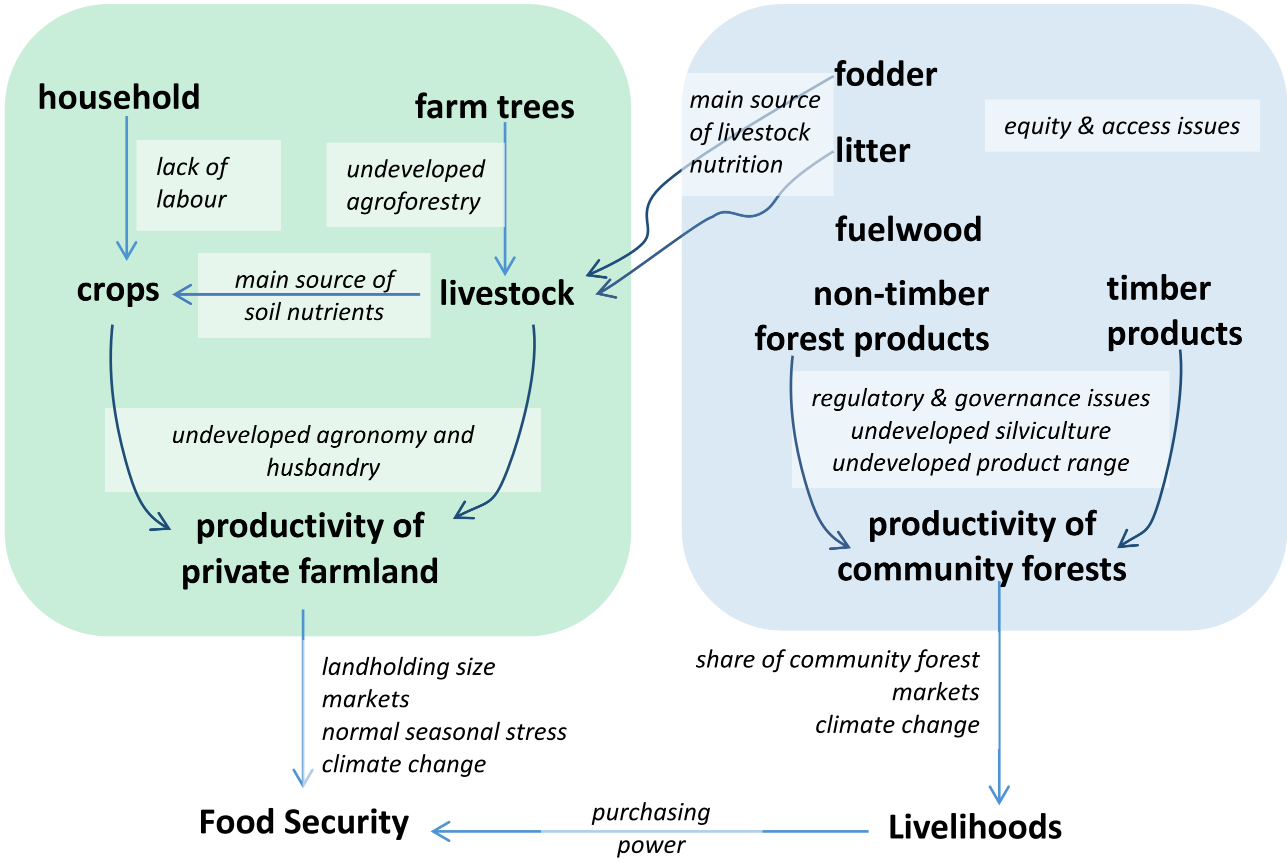

Figure 1. Idealised representation of the forest-farm system in the Nepal mid-hills including identification of areas for improvement.

Description and Specification of EnLiFT Model

Food security in the model

EnLiFT version 1.0 is a model designed with Stella® programming language that aims to simulate food security at the household level in agricultural landscape of the mid-hills of Nepal. The main aim of the model is to simulate resource allocation by farmers at the household and landscape levels with regards to their farming components, i.e. bhari (rainfed terrace), khet (irrigated terrace), kharbari (rainfed upland grazing area) as well as community forest. Thus, operating at a yearly basis was deemed to be more practical compared to simulating agricultural productions at a daily level. Household activities include:

- Cultivating annual crops with a maximum 4 different plots and 3 seasons per plot per year. Annual crop types can be different between seasons.
- Cultivating trees and understorey or adjacent crops in a maximum of 3 different plots and with a maximum 3 different kinds of tree species within the plot namely that for timber, fodder or non-tree forest product (NTFP, e.g. banana and broom grass), and 2 different types of understorey or adjacent crops (e.g. ginger and turmeric).
- Raising a maximum of 4 different types of livestock namely poultry, goat, cattle or buffalo and by sex type, and deriving income from selling the livestock into the market or their products such as milk, processed milk products, or eggs.
- Collecting products from community forests such as fodder and bedding materials for livestock, firewood for processing milk products or household activity (e.g. cooking), and buying trees for the timber.

- Obtaining income from other resource such as under-utilized land (UUL), remittance, pension, or skilled jobs and spending this money on food, non-food, education or health.

The model thus consists of five modules: annual crops, tree and understorey (agroforestry system), livestock, community forest and saving (Fig. 2). The household decisions can be categorized into the four aspects of food security:

- *Availability*: cultivation of annual crops, trees and understorey species and raising livestock to get yield and product;
- *Access*: part of the yield of annual crops and agroforestry systems (e.g. fruits), and livestock products such as milk and eggs are allocated for the household private consumption. In case of shortage, they can buy in the market;
- *Use*: the allocated product and those purchased from the market are used for private consumption;
- *Stability*: the model calculates the agricultural yields, livestock products, and the amount of savings every year along simulation time and the trend in the outputs can describe the stability of the household food security.

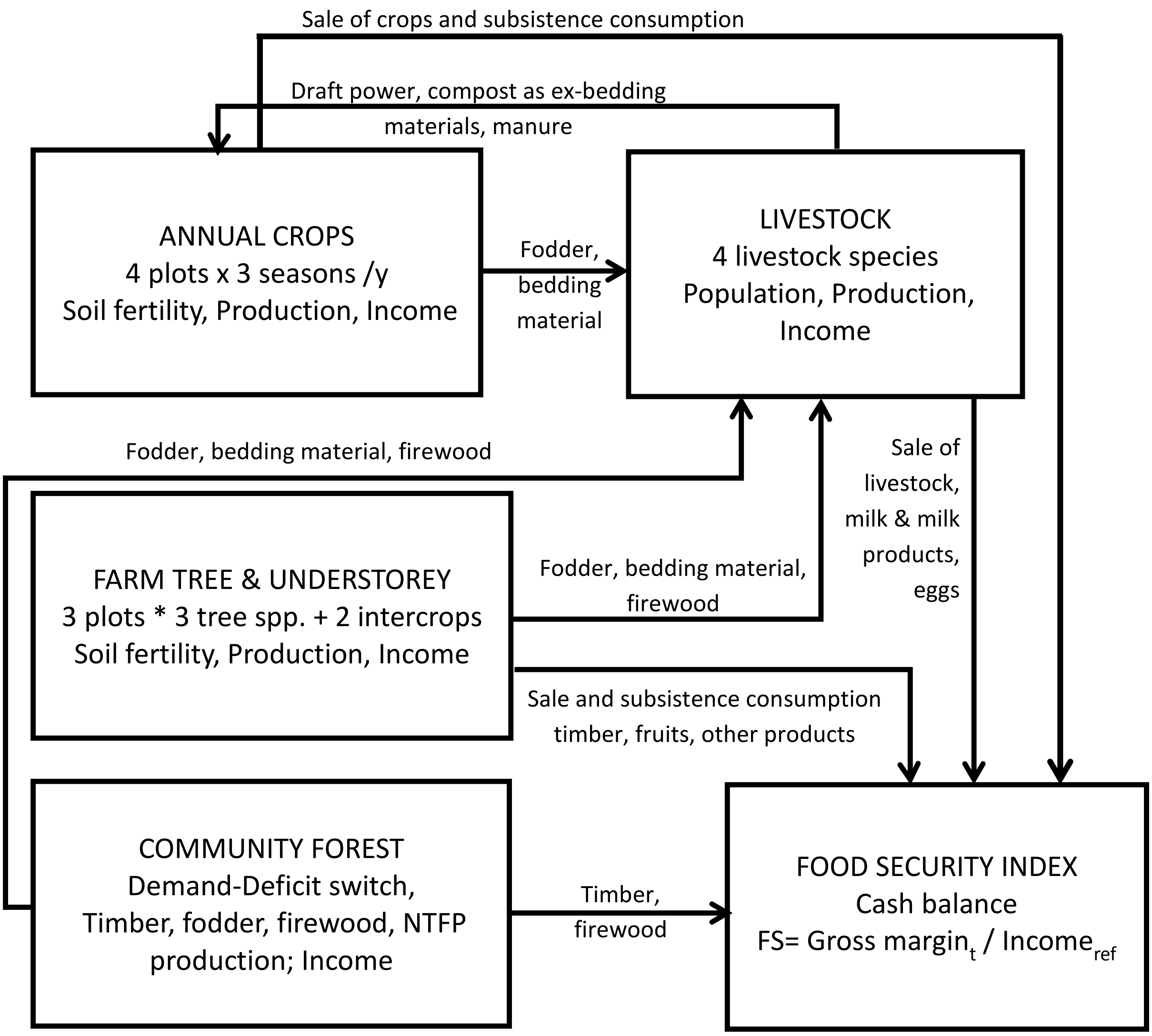

Figure 2. The five main modules of EnLiFT model version 1.0 and the interactions between modules

Dynamic aspect in the model

The model allows change in land allocation for components of the agroforestry system and product price (e.g. price of yield or fertilizer) across the year. The yield of tree and understorey components in the system varies across time depending on the growth stage. The model allows different plot areas, product prices and yields of perennial plants across 25 years (i.e. rotation for timber production). This dynamic aspect in the model allows users to design different scenarios related to land allocation, market mechanisms and plant productivity. Other dynamics in the model can include:

- Scenario of inflation in product price by a certain rate across the year;
- Introduction of higher quality propagules or improvements in planting or harvesting techniques can be translated as higher productivity of trees or understorey across a year or during productive periods of plant growth;
- Climate change modifies the pattern of plant growth. This can also be translated as a decrease or increase in plant productivity across year.

Annual Crops Module

There are a maximum of 4 plots of annual crops that can be simulated simultaneously by the model, and each plot can consist of a maximum 3 seasons per year. Key aspects of the annual crops module are soil fertility, production and income.

Soil fertility

Soil fertility in the plots of annual crops is modelled following the Trenbath principle (Trenbath 1984, 1989; van Noordwijk 1999) and measured in the scale of 1 to 5. The value depends on soil type (i.e. represented by inherent or maximum fertility of the soil type), natural soil recovery (i.e. recovery not because of fertilizer), and fertilizer application. Natural recovery is a function of maximum and actual soil fertility, and half-time recovery that is the time (in years) needed for the soils to achieve half of their maximum fertility:

$$\delta_{recov} = \frac{(fert_{max} - fert)^2}{(1+h_{1/2}) * fert_{max} - fert} \qquad (1)$$

One unit decrease in the soil fertility scale is equivalent to a production level ($yield_{pot}$, ton ha^{-1}) and to an amount of loss in organic matter (SOM_{ref}, ton ha^{-1}). Therefore, soil recovery by fertilizer input is the ratio between the sum of organic and inorganic fertilizer input (assumed to be equivalent with SOM) and SOM_{ref}. The soil fertility thus can be recovered naturally or by fertilizer application.

Actual soil depletion is a function of current soil fertility and constant depletion rate:

$$\delta_{dep,t} = fert_t * \varepsilon_i \qquad (2)$$

The default value for the constant soil depletion ε of soil type i is 0.2 and the default maximum soil fertility is 5. So, if current soil fertility is 5 (i.e. at maximum level) then the soil depletion is 1. It means actual yield will equal potential yield because:

$$y_{act,i} = y_{pot,i} * \delta_{dep} \qquad (3)$$

If the current soil fertility level is 4 while maximum fertility is 5 and ε equals 0.2 then soil depletion is 0.8. It means actual yield equals 80% of potential yield and so on.

The soil fertility dynamics in the crop plots is thus:

$$fert_{act,t+1} = \min(fert_{max}, \max(0, fert_{act,t} - \delta_{dep,t} + \delta_{natrecov,t} + \delta_{fertrecov,t})) \quad (4)$$

Productivity

The ploughing of the plot of annual crops is carried out by livestock (i.e. buffalo or cattle). Shortage in draft power from the household's livestock holdings is met from external sources by renting from neighbours. Crop growth is supported by both inorganic and organic fertilizer application as well as agrochemical products. Organic fertilizer comes from three sources namely a portion of leftover crop biomass, leftover bedding materials, and livestock manure. Another portion of crop residue will be used as fodder and bedding materials for livestock. Actual crop yield (ton ha^{-1}) depends on soil fertility and potential yield (i.e. achieved at maximum soil fertility) (Eq. 3). Crops produced are generally for household consumption, and in the case of a surplus, a fraction will be used for livestock feeding and the rest will be sold to the market. Food shortages are addressed by buying in the market or from neighbours.

Every year, a fraction of crop yield will be used for the seeds to cultivate in the subsequent year. If the requirement is greater than the supply from the fraction of crop yield, the shortage will be fulfilled by buying seeds in the market. Seed preparation cost covers the costs to appropriately prepare seeds for cultivation.

Income from annual crops

Production cost (NRs per ha) is the sum of the cost of buying seeds, seed preparation, inorganic fertilizer, agrochemicals, renting cost for the shortage of draught power, buying organic fertilizer in the case of shortages, labour cost, 'other' costs, as well as buying crop products in case of shortage for private consumption. Total production cost (NRs ha^{-1}) is the production cost multiplied by area of annual crops (ha). Revenue (NRs) comes from selling of crop yield, seeds, manure, and renting surplus of draught power. Total income (NRs) of cultivating annual crops is the revenue from all crop plots minus the total production cost of all plots.

Tree-Understorey Module

There are a maximum of 3 plots to simulate for three tree species and two understorey or intercrops. The three tree species in one plot of the module is based on the fact that the local householder usually plants three different kinds of tree for different functions such as that for timber, fodder or NTFP.

Soil fertility

The model assumes that soil fertility is stable across time due to the presence of trees which provide a SOM (soil organic matter) balance through aboveground litter fall and belowground root decay. Therefore, soil fertility and its recovery (both natural and due to fertilizer application) are not simulated. It is assumed fertilizer application in the tree-understory module of the system is not necessary

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Productivity

Tree and understorey propagules are supplied by buying from the nursery/market. In the case of natural tree regeneration, decisions to retain and grow these trees are similar to planting trees, and hence the cost of each tree is taken to be the same as that of purchased propagules. Not like in the case of annual crops, the householders do not produce seeds/propagules by themselves. Yields from tree components are fruits (ton ha^{-1}), timber (m^3 ha^{-1}), bedding materials (ton ha^{-1}), fodder (ton ha^{-1}), and firewood (ton ha^{-1}). They will be allocated for personal use based on demand or otherwise sold to the market in case of surplus. For timber, in the case of shortage, the householders will fulfil a part of the shortage from purchases in the market or they will buy a tree in the community forest. Similarly for fodder, firewood, and bedding materials, in the case of shortages, the householders will collect from the community forest and the rest will be purchased from neighbours. The products of the understorey are expressed in terms of yield (ton ha^{-1}) and bedding material (ton ha^{-1}).

Income from tree and understorey

Production cost (NRs) in multi-storey systems includes labour and 'other' costs for cultivating trees and understorey. Revenues (NRs) come from fruit and timber selling minus any costs for buying these two products in the case of shortages. Revenue from cultivating understorey comes from its yield minus costs for buying propagules. Total income will be total revenue minus total cost.

The Livestock Module

This module simulates productivity and income gained through raising a maximum of 4 types of livestock namely poultry, goat, cattle and buffalo.

Population

The model applies a threshold of livestock population (animal unit) that should be met but when livestock population falls below this threshold they are replaced by purchases from the market. In the case of the population being above the threshold, a fraction of the livestock population will be sold to the market. The population increases due to annual birth rate and decreases due to annual mortality rate. For feeding, the livestock need fodder (ton $animal^{-1}$) and plant residues (ton $animal^{-1}$). For the stable, they need bedding materials (ton $animal^{-1}$) from the plot of annual crops and AF system.

Production

The products from raising the 4 types of livestock include manure (ton $animal^{-1}$), draught power (draught power unit $animal^{-1}$) from the male cattle and male buffalo, eggs from poultry (kg $poultry^{-1}$), milk (litre $animal^{-1}$) from cattle and buffalo, and the processed milk-product or curd (kg/litre of milk). A fraction of milk will be used for private consumption.

Income from livestock

Total production cost (NRs) consists of labour for collecting fodder and bedding materials or in the case of shortages of feed and fodder purchases, production costs for processing milk into curd, and the costs of buying new livestock. Total revenue (NRs) comes from selling livestock and their products (i.e. eggs, milk, processed product from milk), and surplus in bedding materials and draught power.

Fodder and firewood

Fodder supply comes from trees in the tree-understory and community-forest and annual crops modules, whereas firewood is collected from the tree-understory module. In the case of shortages, a fraction of the required fodder and firewood will be provided by collecting in the community forest, and the rest is purchased from the market. Fodder will be used to feed all livestock except poultry. In the case of surplus, remaining fodder will be sold to the market. Firewood supply is used for household activity (e.g. cooking) and to process dairy products from cattle or buffalo milk. If demand has been fulfilled, surplus firewood will be sold to the market.

Community Forest Module

When the demand is greater than the supply of fodder, firewood, or bedding materials, the householders will collect a fraction of the deficit in the community forest for free, and the rest is purchased from the market. For timber, they will buy a tree and collect the timber later. The model takes into account the cost of harvesting fodder, firewood, bedding material and timber from the community forest.

Food Security Index Module

The Food Security Index generated by the model is based on the gross margin of the household. Income is obtained from sales of annual crops, tree products, and livestock and their products, and off-farm sources such as remittance, pension, and skilled jobs. Expenses are incurred in buying items necessary for agricultural activities, but also to buy other food rather than staple food, for health, education and other 'non-food' items. The calculation of the Food Security Index is shown in Equation 5. The reference household income, the reference income, $Income_{Ref}$ is the poverty line set by Nepal and other agencies and defined as the minimum income the household requires to ensure food sufficiency for all members of a family for one year (NRs). The poverty line set by the World Bank for 2015 is US$1.90 per person per day or NRs70,000 (assuming exchange rate of 100NRs =US$1) while the Nepali poverty line is NRs 19,261 per person per year.

$$FS_t = \frac{Gross\ Margin_t}{Income_{Ref}} \qquad (5)$$

If $FS_t \leq 0$ then the level of food security is 'very insecure', $0 < FS_t \leq 1$ means 'insecure', $1 < FS_t \leq 2$ means 'secure', $FS_t > 2$ means 'very secure'. If the expense for education and 'non-food' category are set to be 0 then the calculation of food security index in the Eq. 1 does not involve those two variables.

Developing a Household Typology for Nepal Mid-Hills

The farm households of the Mid-hills of Nepal are heterogeneous in terms of socio-economic conditions and rigid caste differences. As the EnLiFT Model simulates food security at the household level, a typology of these different households is required to allow scaling-up of the model to the community or district level. A survey of 668 households in six selected village development committees in Kavre and Lamjung Districts was undertaken to provide baseline data. The survey data was compiled in SPSS version 21, where a two-step cluster analysis was undertaken using the following criteria that had had been identified by a panel of experts from the EnLiFT Project:

Categorical variables

- Caste (Brahmin/Chhetri, Janajati, Dalit)
- Has family member abroad (Yes, No)

Continuous variables

- Total household income (NRs)
- Total landholding (m^2)
- Total under-utilised land (m^2)
- Livestock holdings (Animal units)
- Active labour force (≥ 15 years old)

- Relative tree density

The six household typologies obtained from cluster analysis are:

Group 4: resource rich Brahmin/Chhetri
Group 5: resource rich Janajati
Group 2: resource poor Janajati
Group 1: resource poor Brahmin/Chhetri
Group 6: Dalit low caste household
Group 3: resource rich caste independent

The characteristics of these household types are shown in Table 1. Group 4 households comprise around a quarter of the respondents and these households have the highest reported income. The resource rich Janajati households (Group 5) are ranked second in terms of household income but their landholdings, livestock holdings and tree holdings are generally lower than resource rich Group 4 Brahmin/Chhetri. Groups 2, 1 and 6 are generally the resource poor households which comprise nearly half of the total respondents. Group 3 represents a small number of households that own five to ten times more land than any other household grouping, nearly six times more livestock than any other grouping, and nearly ten times more trees than the average tree holdings. Household income for Group 3 is, however, only just about the average household income in the mid-hills.

Table 1. Key characteristics of six household typologies

Household Variable	Group 4	Group 5	Group 2	Group 1	Group 6	Group 3
Ethnicity class	Brahmin/ Chhetri	Janajati	Janajati	Brahmin/ Chhetri	Dalit	Mix caste*
Proportion of households (%) with foreign worker	100	100	100	100	56.8	52.9
Area of landholding (ha)	0.83	0.78	0.66	0.79	0.37	4.10
Average under-utilised land are (ha)	0.12	0.15	0.08	0.10	0.06	0.76
Average tree density (trees per ha)	191	81	140	109	126	2,180
Average household income (NRs)	274,279	225,816	115,782	125,036	135,039	171,152
Livestock holding (animal unit)	2.49	2.38	2.44	2.85	2.38	12.25
Average persons per household in active labour force (person)	5.34	5.12	4.1	4.17	4.22	4.53
Proportion of survey respondents (%)	24	23.3	18	17.3	14	3.3

* Group 3 comprised of 47% Brahmin/Chhetri.

Model calibration and evaluation for a typical household in Nepal mid-hills

Thirty-six (36) case study interviews were conducted in six sites in the Kavre and Lamjung Districts to collect data to parameterise the EnLiFT Model. At each site, six households were interviewed representing the six household types. The averages were obtained for the six sites to derive parameter values for the EnLiFT Model. This section presents calibration of EnLiFT Model for Group 5 households and the sensitivity of parameter values were evaluated by a panel of agroforestry and community forestry experts in Nepal.

Model inputs

Stella® communicates with an Excel® file that contains all the necessary inputs to the model. A “Summary” worksheet and “StellaLinks” worksheets are created on excel input file as compilations of derived parameters for an initial year and succeeding 25 years respectively. The formulation of the EnLiFT model is generic for all household types such that systems components that may not be present in other household types or such agroforestry regime is not applied, values are kept zero. This approach is efficient for investigating scenarios for potential systems interventions – which may include agroforestry innovations or better timber policies.

For the EnLiFT Model to function, equations are defined for all relationships defined in every module of the model. Values used in these equations are obtained from the Excel input file. These equations are generic for the model and need not be redefined for new household types or scenarios. This makes the modelling work easier considering there are about 500 equations defined for the current version of the model.

Model Application

The EnLiFT Model 1.0 was tested for 'resource-rich Janajati' households (Group 5) of which inputs and outputs were validated by Nepali community forestry and agroforestry experts and practitioners. The purpose of model validation is to see if the model generates outputs that are expected given the model input. Simulations were run for four scenarios of agroforestry activities namely subsistence-based agroforestry (baseline scenario), expansion of multistorey cropping to bhari land, a supportive timber-policy scenario and intensified fodder production. Results were obtained using specific data sets from case study households.

Subsistent agroforestry livelihood system (baseline scenario)

The EnLiFT Model 1.0 can predict the yield and consequent net revenues for each of the four agroforestry system components given available resources and management regime. The net revenue or savings is summed-up at the household level to include non-farm income and expenses. The results presented here are first approximations for a long-term livelihood performance based on subsistence agroforestry production on khet, bhari and kharbhari lands in Kavre Districts in Nepal. The household practice of rotating maize, rice and wheat crops on 0.27 ha of khet land, and planting 0.32 ha of bhari land to maize, millet and lentils are modelled. The total area occupied by trees on khet, bhari and kharbhari is 0.05 ha, 0.08 ha and 0.5 ha, respectively. The initial livestock holding of the household is provided in Table 2 in which the household generally have the typical domesticated animal of a Nepali household except for female cows. The household receive annual foreign remittance for the first five years of simulation.

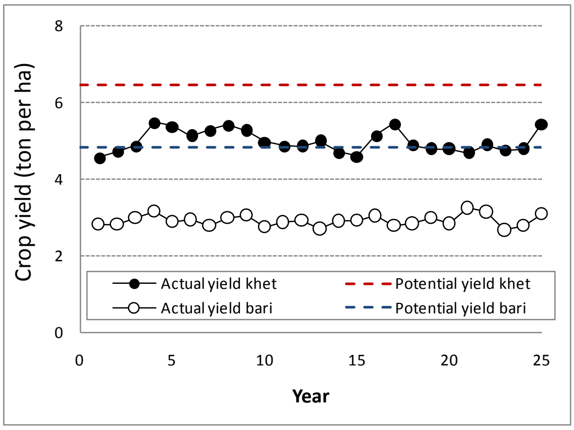
Table 2. Livestock holding values used for the EnLiFT Model for baseline scenario

Livestock type	Initial population (number of heads)	Minimum number to keep annually (number of heads)
Male poultry	10	2
Female poultry	7	3
Male goat	3	1
Female goat	3	2
Male cattle	2	2
Female cattle	0	0
Male buffalo	2	1
Female buffalo	2	2

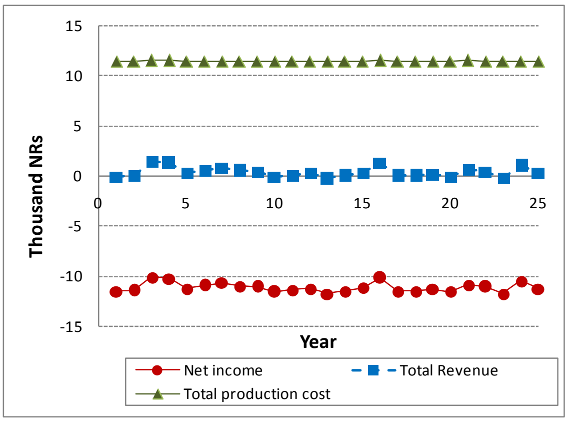
For the baseline scenario, the yield and revenue of annual crops are presented in Figure 3. As expected, the actual yield of annual crops on *bhari* land is considerably lower than *khet* land however these yields are on average 60% and 76% of the potential yield of these land types. The revenue from annual crops is predicted to be negative indicating a high cost of farming inputs. The livestock income fluctuates between -15,000 to +13,000, but on average is about

-1,000 NRs. These fluctuations somehow follow fluctuations in buffalo milk production. Timber products are for household consumption only.

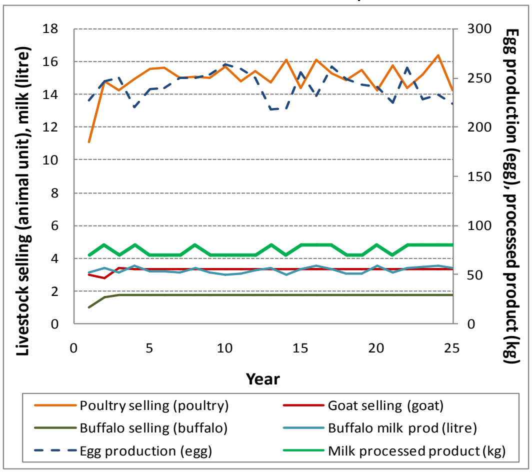
But why households are still engaged in crop production? As shown Figure 3, the combined tree and understorey has positive annual revenue of over NRs 20,000. This illustrates how food security of a mid-hills household is strongly supported by the tree-understory components of the agroforestry system. The extent to which the total household income is driven by off-farm income and foreign remittance is illustrated when the household stops receiving foreign remittance in year 6. This drop in household income consequently affects the annual household savings which defines the food security level of the household. The revenue and savings of subsistence-based agroforestry livelihood systems predicted by the EnLiFT Model suggested the significant role of trees and understorey in the livelihood system and the strong influence of foreign remittance in determining the household food security.



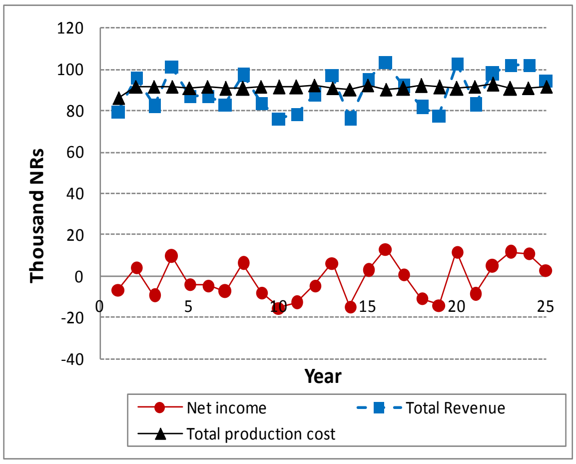
Yield of annual crops



Cost and revenue of annual crops



Yield of various livestock products



Cost and revenue of livestock

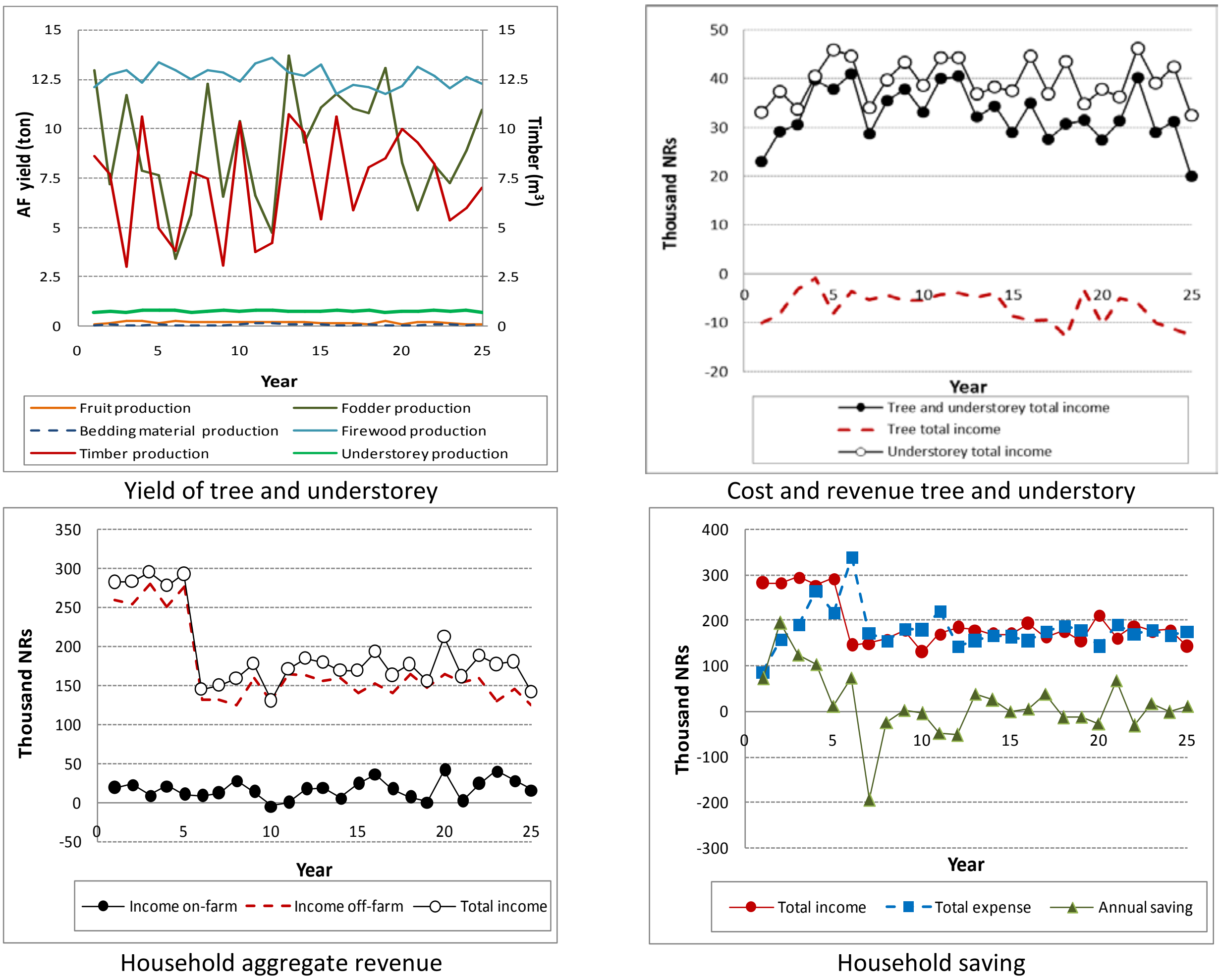


Figure 3. Yield, cost and revenue of agroforestry components and predicted household income and savings predicted by EnLiFT Model 1.0.

Expansion of multi-storey cropping on bhari land (AFE scenario)

The EnLiFT Model 1.0 was run to simulate the livelihood performance whereby the annual crops on bhari land is replaced with fodder trees (Pakhuri, *Ficus globerrima*), banana, and ginger and turmeric as understorey crops – a scenario for intensified fodder-based multi-storey cropping. With change from annual cropping to multi-storey cropping, the area under trees is now 0.4 ha from 0.08 ha and the proportion of area planted to understorey is now increase to 14% from 10%. Like the baseline scenario, timber products are for household consumption only. All other livelihood activities are similar to the subsistence scenario including remittance income. Because it is assumed that timber is only for household consumption, the focus of investigation under this scenario is the change to income from understorey crops – i.e. ginger and turmeric. The EnLiFT Model predicted an increase of income from understorey by nearly two and a half times (from 39,000 NRs to 91,000 NRs). This increase of income from understorey alleviated the household savings particularly in the year when foreign remittance is cut-off but the expansion of multi-storey cropping to bhari land. While an increase on average annual household savings under an agroforestry expansion scenario has been predicted to be about 19,000 NRs, this is slightly higher than the baseline scenario of about 16,000 NRs. Expansion of agroforestry systems does not necessarily propel the household from poverty.

Expansion of multi-storey cropping on bhari land with supportive policy for AF timber marketing (AFE-TP scenario)

The livelihood outcomes of agroforestry systems in Nepal is not only affected by household decisions but with institutional and policy arrangements as well. In the previous two scenarios, the household is not able to sell timber products because of a restrictive timber policy. The EnLiFT Model was run to test its capacity to handle policy-based scenarios. In the previous scenarios, the timber market prices were set to zero which forces the model not to sell. In simulating a supportive timber marketing policy, the household is assumed to have mature timber trees, of which a fraction will be ready for harvest. The timber market price (in real value terms) for Uttis (*Alnus nepaulensis*) and Pine (Pinus sp.) is 14,814 NRs m^{3-1} while for Chilaune (*Schima wallichi*) 18,518 NRs m^{3-1}. The annual income from timber and the annual household savings for the three baseline, AFE and AFE-TP scenarios are presented in Figure 5. It is predicted that household savings under the AFE-TP scenario is generally higher than baseline and AFE scenarios, indicating the role of trees as safety nets. However, there are two points in the simulation (i.e. year 11 and 23) in which extreme plunges of household savings had been predicted. This is because households tend to spend their money on buying more and higher quality (hence expensive) food from 'preceding year's savings', however the income from that year does not replenish the savings account resulting in negative savings. This represents a typical household spending pattern in rural Nepal.

Expansion of multi-storey cropping on bhari land with supportive policy for AF timber marketing and livestock expansion (AFE-TP-LE scenario)

When multi-storey cropping is expanded to bhari land, fodder supply is increased and the incremental revenues from this expansion can be used to expand the livestock enterprise. The EnLiFT model was calibrated to simulate a livestock expansion scenario of keeping one more female buffalo for milk and processed milk products. As shown in Figure 6, the income of this livestock enterprise is increased by on average 70 fold compared to baseline scenario, however similar to the supportive timber market scenario, there are years where annual savings drop dramatically indicating higher risks with enterprise expansion.

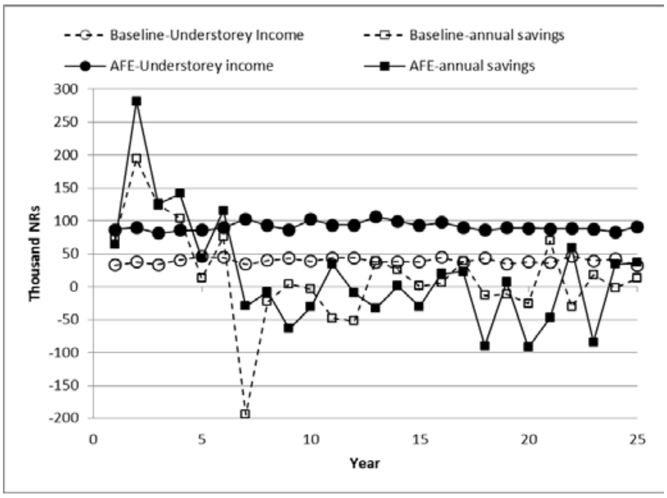


Figure 4. Predicted income from bhari land and savings under baseline (dotted line) and agroforestry expansion (AFE, solid line) scenarios

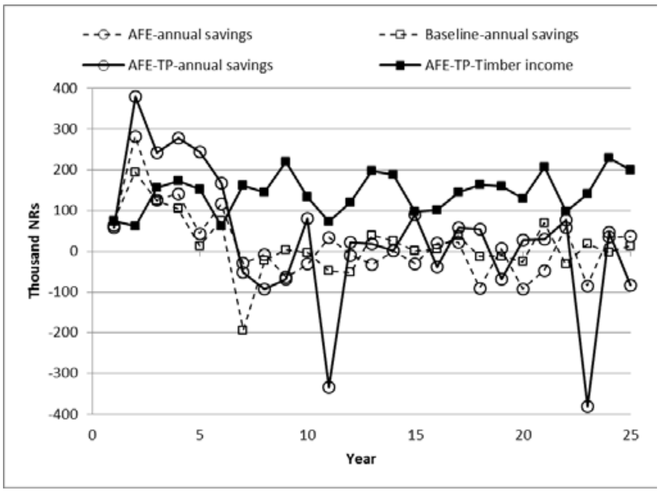


Figure 5. Predicted income from bhari land and savings under baseline (dotted line) and agroforestry expansion (AFE, solid line) under supportive timber marketing scenario

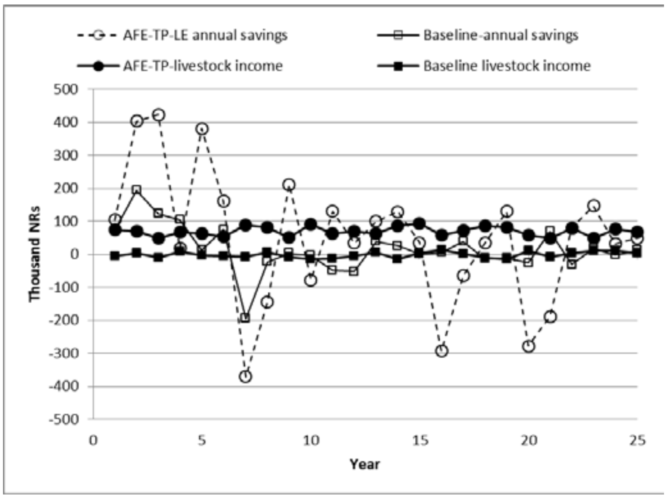
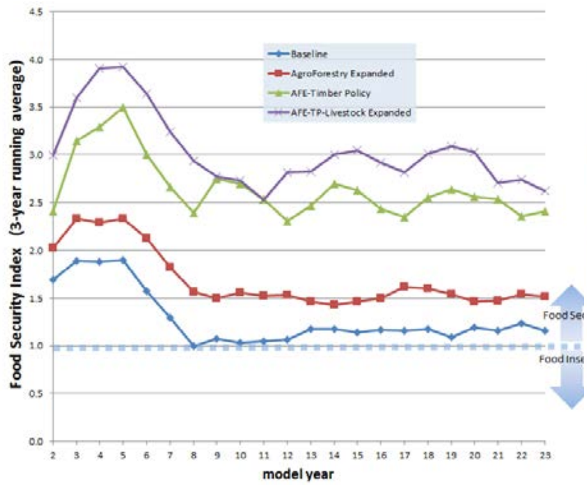


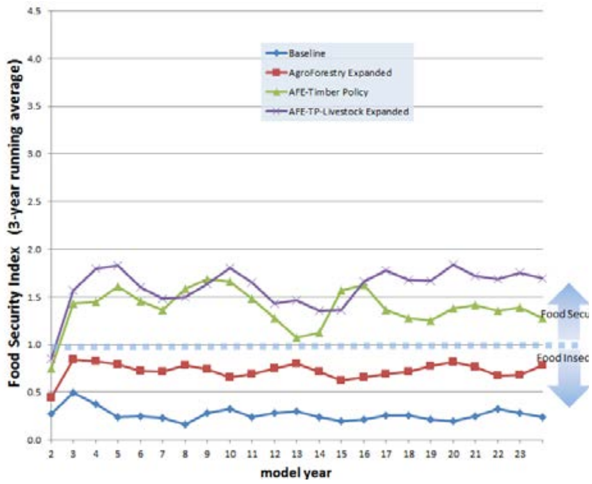
Figure 6. Predicted annual savings and livestock income under baseline scenario (square) and annual savings and livestock income under agroforestry expansion, supportive timber market policy and livestock expansion scenario (circles).

Estimating food security index for four agroforestry production scenarios

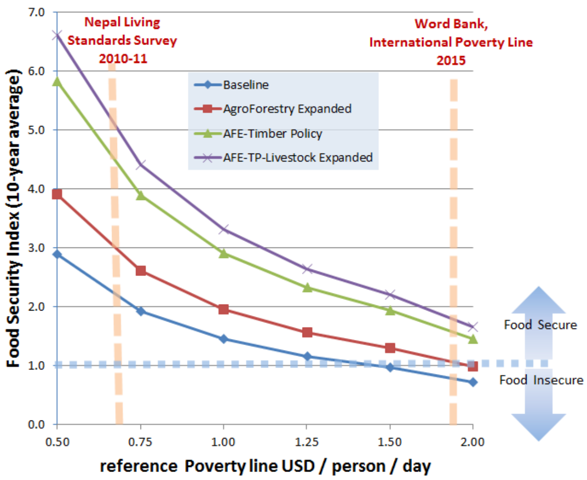
The EnLiFT model estimated the food security index (FSI) for the four agroforestry production scenarios with and without remittances or pensions. The three-year running average of the FSI and the ten-year average of FSI at various poverty lines are shown in Figure 7. The EnLiFT Model showed that resource rich Janajatis (Group 5) are generally food secure when they are receiving remittance and pensions. When these households are not receiving remittances and pensions, they are food-insecure throughout the modelling period under baseline and agroforestry expansion scenarios. They then become food secure under timber market policy and livestock expansion scenarios indicating the importance of improving timber market policy and expansion of livestock enterprise when the households are not receiving remittance or pension. The FSI at varying levels of reference poverty lines showed that resource-rich Janajati's are food insecure under the baseline scenario when they are not receiving remittances or pensions in all levels of reference poverty lines but food secured for all scenarios when reference poverty line is below US $1.25 per day per person. Resource-rich Janajatis are generally food secure on other scenarios except the baseline. Figure 7 shows the sensitivity of FSI to reference poverty line signalling caution for selecting appropriate reference income for determining food security.



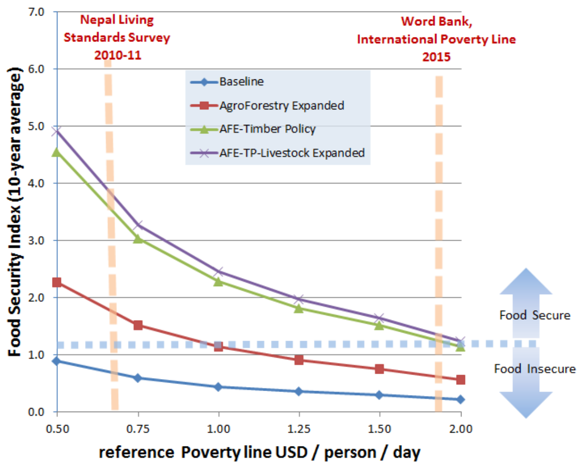
Resource-rich Janajati household receiving remittance / pension income



Resource-rich Janajati household not receiving remittance /pension income



Resource-rich Janajati household receiving remittance / pension income



Resource-rich Janajati household not receiving remittance /pension income

Figure 7. Three-year average of food security index and FSI at various levels of reference poverty lines for four model scenarios.

Concluding Comments and Future Modelling Work

The rationale of the EnLiFT model is to estimate the impact of technical and policy interventions to improve the livelihood and food security of households in the mid-hills of Nepal. Before any interventions can be conceived, the model helps identify the 'leverage' points of the livelihood system with scientific confidence. This is difficult when livelihoods are derived from community forests and privately-held agroforestry systems, as well as off-farm income and remittances from overseas. Most analyses to date have just considered the agroforestry and community forest separately. The EnLiFT Model is therefore a first attempt to holistically analyse the mid-hills livelihood system.

This paper has summarised the concept and specifications of the EnLiFT Model. The process of developing the model has involved a series of workshops and consultations of community forestry and agroforestry modelling experts in Nepal and abroad. This initial output of the model calibrated for a typical mid-hills household has been validated by Nepali community forestry and agroforestry scientists and practitioners. Model simulations for the four scenarios presented in this paper shows the capacity of the model to answer both technical and policy questions. The household level model (EnLiFT Model 1.0) is the building block of the community-level model where simulations of socially, economically, ecologically and politically acceptable interventions are plausible. The community-level EnLiFT Model, which is currently under construction, will serve two main purposes: (1) assess the community level food security given available resources – land, labour and capital to household and (2) evaluate the impacts of an improved community forestry management and policy regime.

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