Forest Gardening on Abandoned Agricultural Land Contribute to Ground Cover Change and Food Security

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Abstract

Various forest products such as nuts, mangoes, bananas, lime, silk from mulberry leaves, essential oil, timber, animal food, perfume from tree blossoms, mulch and biochar, possess high potential to increase rural income. However, farming families in Nepal can hardly afford the investment to create such productive ecosystems. Connecting to the global market through Carbon dioxide (CO_2)– certificates could serve to finance the creation of forest gardens. To test and demonstrate such approach, a project on 'building village economies through climate farming and forest gardening (BeChange)' has been implemented by 276 farming families in four districts (Tanhun, Lamjung, Gorkha and Kaski) of Nepal. Using Global Positioning System (GPS) point survey, household surveys, focus group discussions (FGDs), a triad group system, field observation and reports, the success of establishing privately owned forest gardens was assessed. A total of 42,205 mixed tree species such as *Michelia*, *Elaeocarpus*, and *Cinnamomum tamala* were planted on abandoned agriculture land of 276 families. The set-up and maintenance of the forest gardens was financed with advanced payments for the carbon sink services of the planted trees. Farmers who succeeded with tree survival rates above 70 per cent received an additional yearly carbon sink fee. This activity was linked to other income generating activities such as cultural eco-tourism, cinnamon leaf essential oil distillation, and intercropping of high value shade loving crops such as ginger, turmeric, and lentils. The outcomes of the project show significant improvements of the livelihood and food security in the project villages.

Keywords: Abandoned agricultural land, carbon sink, carbon financing, CO_2, forest garden certificate

INTRODUCTION

On foot-hills of the Himalayas, Nepalese people practiced organic agriculture for more than 2,500 years. By their own hands, they terraced slopes and channeled water. Farmers allowed trees to grow on the terrace faces and edges. There is a long history of Nepali farmers propagating trees on their land (Neupane *et al.* 2002; Pandit *et al.* 2018) and these traditional forest gardening systems have been well described by Amatya and Newman (1993) among others. The typical Nepali tree growing system on farmlands is mainly based on fodder trees for livestock. The resulting manure and forest litter were then used as mulching material to maintain soil fertility (Garforth *et al.* 1999; Neupane *et al.* 2002; Pandit *et al*. 2018). Farmers cultivate maize, wheat, millet and vegetable crops on their farms that are commonly terraced and bounded with trees. The livelihood, and thereby food security, of these people is highly dependent on their access to tree resources, either from their own land or from community forests. The fact that 42 of the country's 75 districts are reported to be food insecure (FAO 2010) indicates that there is significant room for improvement in the contribution of tree resources to livelihoods and ground cover change for improved ecosystem services (Schmidt *et al.* 2017). These forest gardens also provide subsistence products and environmental services such as soil amelioration and soil stabilisation (Gilmour and Nurse 1991; Malla 2000; Pandit and Thapa 2004; Regmi and Garforth 2010) and biodiversity conservation (Acharya 2006).

Despite these potentials, land around the villages has been abandoned. It lies uncultivated beneath the sun beckoning new development. Studies indicate that on average 37 per cent of arable land is abandoned in Nepal (Paudel *et al.* 2014; Ojha *et al.* 2017). The increasing land abandonment in Nepal has been posing multiple threats related to food insecurity, loss of rural livelihoods, reduction in crop production, loss of soil productivity, and damages the ecological landscape. More than 65 per cent of the rural people depend on agriculture for their livelihood and are thus in search of alternative options as subsistence farming is not able to meet the demand for food and income to sustain their families (Paudel *et al.* 2014; Schmidt *et al.* 2017). The implication of agricultural land abandonment is not limited only to the household level, but also impacts the national economy. For example, the Gross Domestic Product (GDP) contribution of agricultural sector was 33 per cent in 2011, though this figure decreased to 26 per cent in 2018 (CBS 2018) showing agricultural land abandonment as a major problem for the people, economy, and environment (Basnet 2016; Ojha *et al.* 2017).

The main reason behind this phenomenon is the lack of labor force in villages. As the production could not sustain people's livelihoods, around 400,000 young rural workers have migrated to foreign countries, mainly to Malaysia and Gulf countries in search for employment (FAON 2017). With this, the scale of agricultural land abandonment became one of the key development challenges in the recent decades (Paudel *et al.* 2014; Pandit *et al.* 2018). This paper primarily highlights on how farmers adapt their farming practices and how planting trees on abandoned farmlands may obtain environmental and livelihood benefits. This knowledge may help to inform policy makers about the potential of forest gardening to better support livelihoods of farmers under a range of socioeconomic circumstances.

METHODOLOGY

Various tools were used in this study. The process documentation by forming triad group was the most effective way for this study following the use of Global Positioning System (GPS) mapping, household survey, focus group discussion (FGD) and carbon accounting.

Establishment of the Triad System

A triad system was established in which three families form a group that is responsible for planting trees on their land. Families must communicate the recurrent tasks amongst each other, frequently patrol the plantations of each family, determine failure rates, and replant together. Each member of the triad is responsible for his or her two partners as well. Only if all three families can show tree survival rates of at least 80 per cent, following which they are entitled to receive the payment for carbon. If for example one family reaches 97 per cent, another 83 per cent, and the third achieves a 72 per cent tree survival rate, then the triad as a whole has failed and none of the families earns the premium.

If all three partners within the triad surpass the 80 per cent mark, each one of them receives the carbon bonus in accordance with the number of trees that are growing strongly on their own terraces. However, they have to commit within the triad to regrow the missing trees together. The project provided 100 per cent of the seedlings necessary for replanting if a triad has at least an 80 per cent survival rate. Triads that have not reached their 80 per cent have to pay for the new seeds by themselves, however following the successful re-plantation, they would receive the carbon premium for number of trees that survived. The intent of this system is not to distribute gifts, but rather to encourage accountability, promote self-responsibility and most of all, personal initiative.

Aimed at building confidence, simple agricultural trials in each village were established. With one pilot group per village, biochar-based fertilisers were manufactured, its use was demonstrated, and comparative tests were established. The results of highly improved harvests fostered trust and eventually understanding as to why something works better than what was done before. It also evoked curiosity of those who did not take part. As a group, however, with modest support provided in the form of seedlings, tools or daily wages these developments became possible.

GPS Mapping and Tree Growth Measurement

Every certified tree was accurately mapped and dated with a GPS-based smartphone application. However, in order to show the trees planted in a farm, plot wise mapping was carried out. In each of the plots, the number of trees planted were recorded and verified. At the end of the first and second year, tree height and trunk diameter at 10 cm above ground were measured. After the third year, trunk diameter was measured at the breast height (150 cm above the ground), the tree's general vigor and health were rated on a scale from 1 to 10, and a picture of each tree was captured. This monitoring system serves to ensure that Carbon dioixe (CO_2) certificates were issued only for trees that were actually growing well. Customers who bought CO_2 certificates will know where "their" trees are, how well they are growing, and how the biomass carbon is eventually sequestered. The goal is that the CO_2-subscribers will be able to follow the progress online on the growth of the forest garden that reclaims their CO_2 emissions and will also know which family does the work for them, forming a virtual alliance.

Household Survey

In order to assess the impacts of forest gardening project on food security and poverty alleviation, a sample of 121 HH heads from among 276 were interviewed. A range of 40 to 60 per cent HHs were sampled from these four villages (Table 1). This survey mainly identified the priority activity of farmers across each of the ethnic groups. This was helpful to investigate the food insufficiency among the HHs falling under the poverty trap at the end of the project intervention.

Table 1: Sampling of Households

Village/ Municipality	Brahmin/ Chhetri	Indigenous (Gurung, Magar & Tamang)	Dalit (shoe maker, iron smith and teller)	Total HHs	Sample HHs
1. Ratanpur, Bhanu Municipality	89	38	22	149	59 (40%)
2. Bandipur Rural Municipality	2	82	2	86	39 (45%)
3. Rainas Municipality	20	4	1	25	13 (50%)
4. Madya Nepal Municipality	13	2	1	16	10 (60%)
Total	124	126	26	276	121

Focus Group Discussion (FGD)

In each of the 17 communities of four target villages (Figure 1), at least one focus group discussion (FGD) was conducted. FGDs helped classification of HHs in terms of their focused activities such as (i) gender sensitisation and tree planting for increased productivity and carbon sequestration and (ii) Increased sustainable income through agroforestry and ecotourism for food security and poverty reduction.

Carbon Accounting

Every tree stores in its trunk, roots and branches a certain amount of carbon that has been extracted as CO_2 from the atmosphere. The stored carbon

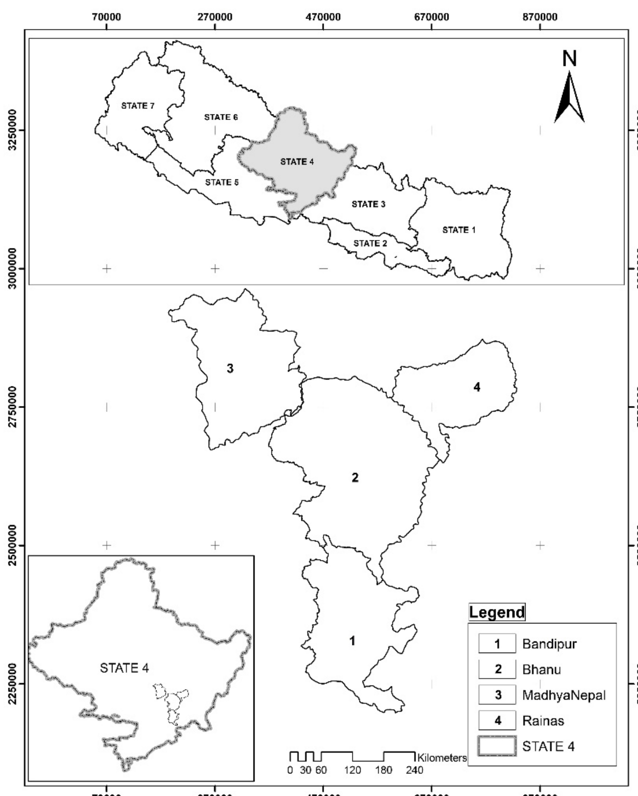

Figure 1: Map of Project Area

within a particular tree can be calculated from the volumes of the trunks, branches and main roots and their material densities, using an average carbon content of 50 per cent by weight (Toensmeier 2016).

A catalog of tree species including every tree's average annual increase in height, trunk diameter and volume as well as carbon uptake of the trunk, branches and roots was initially assembled from literature references. As the data accumulates every year, the calculations will accordingly become increasingly accurate and adapted to the location. About 80 per cent of the biochar carbon applied to the soil is stable for a period of several centuries (Zimmerman and Gao 2013; Lehmann *et al.* 2015).

Currently, the catalog features 58 tree species and varieties where the average growth and carbon accumulation rates are known in the given climate conditions. When farmer families in Nepal plant 583 trees from this catalog in one hectare (ha) of abandoned rice terraces, calculation of how much carbon is effectively pulled from the atmosphere as CO_2 over the first 10 years, 20 or 100 years can be done. For example, over a period of 20 years, a Cinnamon tree extracts 70 kilograms (kg), *Michelia champaca* extracts 380 kg and a frequently coppiced Melia tree can extract 558 kg (Table 2). A diverse mix of 600 fruits, nuts, fodder, oil and timber producing trees per ha results in 22 t C (81 t CO_2) being pulled from the atmosphere over the course of the initial 10 years. The formula used to calculate the volume of the tree is (πr2xHeight x0.5)/4 (Table 2). The average CO_2 removal of six mixed tree species is 336 t/ha.

Table 2: Methodology for Converting Stem Volume into CO_2

Tree species	Stem volume (πr2*Ht*.5)/4	wood density kg/m3	Trunk Biomass	branch biomass (44%)	Root biomass (12%)	leaf biomass (12.5%)	Total biomass over 20 years/ tree (kg)	Total C/ Tree (kg)	CO_2 removal per tree (Kg)	No of tree/ ha	Total carbont/ ha
Pinus roxburgii	0.707	327	231.03	101.65	27.72	28.88	389.28	182.96	670.86	400	268
Michelia champaca	1.202	400	480.81	211.56	57.70	60.10	810.17	380.78	1396.19	278	388
Melia azedarach	1.256	560	703.36	309.48	84.40	87.92	1185.16	557.03	2042.43	400	817
Cinnamomum tamala	0.188	510	96.08	42.28	11.53	0.00	149.89	70.45	258.31	625	161
Emblica officinalis	0.097	680	66.06	29.07	7.93	8.26	111.31	52.31	191.82	625	120
Ficus benjamina	0.721	490	353.40	155.49	42.41	44.17	595.47	279.87	1026.20	156	160
Saraca ashoka	0.188	496	93.45	41.12	11.21	11.68	157.46	74.00	271.35	1600	434
Total (avg)										**583**	**336**

A considerable part of the carbon that has been accumulated by trees must remain bound for time span well exceeding 100 years. To demonstrate this, we consider how the ecosystem processes absorbed carbon and how farmers may utilise it. Even though the gross photosynthesis (Gp) is almost double in a tropical rain forest compared to a temperate deciduous forest, a much bigger percentage is retained as soil organic matter (SOM) in the temperate forest, resulting in a net annual C storage in above and below ground biomass and SOM being about 6t/ha/y for both forests. Figure 2 depicts the C flows in a hectare of forest.

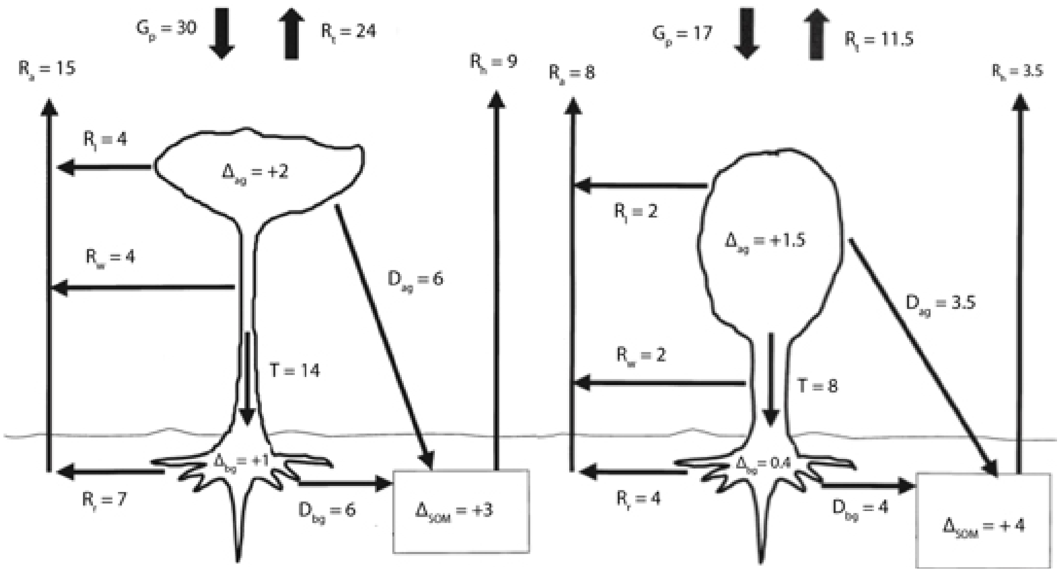

Figure 2: Estimated Annual Total C Flows in Tonne/ha/yr in (a) a Tropical Rainforest (Amazonia) and (b) a Temperate Deciduous Oak-hickory Forest (Tennessee, US)

Gp = Gross photosynthesis; Rt = Total respiration; Ra = Autotrophic respiration; Rh = Heterotrophic respiration; Rl = Leaf respiration; Rw = Above ground wood respiration; Rr = Root respiration; Dag = Above ground litterfall & mortality; Dbg = Below ground detritus & exudation; T = C transfer below ground; Δag = Above ground biomass growth; Δbg = Below ground biomass growth; ΔSOM = SOM matter growth.

Source: Malhi *et al.* (1999)

RESULTS

Tree Planting

One year after the initial forest gardens were planted, the results were quite variable. While some families had kept 95 per cent of their trees alive during the first year and replanted the remaining 5 per cent all on their own, others only showed tree survival rates of 30 per cent or lower. Most plantations reached success rates of 60 to 70 per cent. Although that is more than twice as much as in other reforestation projects within the same country, there was certainly much room for improvement.

Since the summer of 2015, over 42,502 trees have been planted in cooperation with 276 farming families (Table 3); 49 ponds have been put into place; and five villages are now housing tree nurseries. While only 60 per cent of the planted trees survived in the first year and 60 tons of CO_2 have been extracted from the atmosphere, the survival rate for the second year and third year reached 70.25 per cent and 77.5 per cent, respectively. In the fourth year, survival dropped significantly to 53 per cent. The reason behind this was that the triad system was not possible for scattered HHs and in collective plantation. The introduction of triads improved the success of the plantings, but surprisingly only 8 out of 29 triads succeeded in receiving the carbon bonus at the end of the second year. However, seven out of the eight triads that succeeded had participated already in the first year; experience, apparently, played an important role both for the cultivation of the forest garden as well as for social interaction within the triad. This system works only when the community HHs remains in proximity.

Table 3: Number of Villages, Beneficiary Households and Total Trees Survived by Year

Village/ Municipality	First two year period				Second two year period			
	2015/16		2016/17		2017/18		2018/19	
	No of villages	No of HHs	No of villages	No of HHs	No of villages	No of HHs	No of villages	No of HHs
Ratanpur, Bhanu	1	40	2	66	8	143	2	149
Bandipur	0	0	1	20	1	75	1	86
Madya Nepal	0	0	0	0	0	0	1	25
Rainas	0	0	0	0	0	0	1	16
Total	**1**	**40**	**3**	**86**	**9**	**218**	**5**	**276**
Trees planted	**10442 (60%)**		**9838 (77.5%)**		**11946 (87.6%)**		**10276 (53%)**	

Impacts on Food Security

As an inclusive development strategy, poor and socially excluded indigenous ethnic community people (*Gharti* and *Dalit*) have been prioritised to work in this project. The indigenous castes, *like Gharti*[1], *Gurung*[2] and *Magar*[3] have already been influential to communicate climate friendly messages to other groups of people in all areas. They are among the poorest of the poor, and of the total 65 HHs of these three groups (*Gharti, Gurung/Magar and Dalit*) sampled, almost all 54 (83%) had food sufficiency for three months per year until the start of the project (Table 4), but now this figure has dropped to 34 HHs of which 14 HHs shifted to 4-7 months and 6 to 8-12 months food sufficiency level. If we see impact on *Dalit* families, of the total 18 *Dalit* families who were under extreme poverty (food sufficient for 3 months),

1 *Ghartis*, (or Bhujel) are considered an offshoot of the Indian Chettri who, due to poverty, served royal families and upper classes of people as bonded laborers and water-carriers.

2 *Gurungs* are the ethnic groups of Nepal. *Gurungs* are one of the Gurkha tribes.

3 *Magars* are the third largest ethnic groups of Nepal. They are also Military tribes.

six HHs shifted from three months food sufficiency to second level (4-7 months), and two HHs shifted to third level (8-12 months) (Table 4). Similarly, *Gharti* and *Gurung* families' food sufficiency level has also increased. This is attributed mainly because of goat and fodder tree support, eco-tourism and home stay programs. People visit the area to observe forest gardens in these areas. The BeChange project targeted these four ethnic groups to increase their income, well-being and status. *Brahmin* and *Chhetri*[4] are targeted for sensitisation activities that benefit the poor and most disadvantaged.

Table 4: Outcomes Achieved through Implementation of Priority Activities by Caste and Ethnicity

Activity	Ethnicity	Food sufficient households (HHs)			Total
		Up to 3 months	4-7 months	8-12 months	
Gender sensitisation and tree planting for increased productivity and carbon sequestration	Brahmin	24 (19)	9 (4)	5 (1)	38
	Chhetri	10 (7)	4 (2)	4 (1)	18
	Sub-total	**34 (26)**	**13 (6)**	**9 (2)**	**56**
Increased sustainable income through Agroforestry & ecotourism for food security & poverty reduction	Gharti	7 (3)	1 (3)	1 (1)	9
	Gurung/Magar	29 (21)	4 (5)	2 (3)	35
	Dalit	18 (10)	2 (6)	1 (2)	21
	Sub-total	**54 (34)**	**7 (14)**	**4 (6)**	**65**
	Total	**88 (60)**	**20 (20)**	**13 (8)**	**121**

DISCUSSIONS

Success of Tree Planting Vested on Carbon Payment

Forest gardens have the advantage over traditional crops in that the former requires less effort for cultivation (Pandit *et al.* 2018). Such gardens would provide potential for the remaining women and elderly in the village to return fallow fields to cultivation. The amount of work required can be adjusted to suit the villagers' physical capacities and motivation. Over time, the outcome and success (Table 4) can be used to re-attract the lost sons and fathers (Schmidt *et al.* 2017).

While the necessary investments in seeds, plantation, water retention, watering, etc. would not have been possible for the farmers without CO_2 certificates, it is anticipated that the yield from trees after just five years is going to be fifteen times as high as the certificates themselves. The trees will continue to draw CO_2 from the atmosphere, but the farmers will no longer depend on global trade for additional income. That does not mean that they will no longer be rewarded for their services to the global climate, nevertheless, they will not have to depend on it anymore. Therefore, after three years, the initial planted tree carbon money was stopped

4 *Brahmins*, or *Bahuns* as they are called in Nepal, represented the priestly caste of Nepali society, and *Chhetris*, or *Kshatriyas* as they are called in Hinduism, were the ruling-warrior caste. *Brahmin* and *Chhetris* live across the middle segment of Nepal, occupying the rich, fertile farmland of the Himalayan foothills

and only second year and third year carbon money is being granted now. From next year on-wards, the second year planted tree carbon payment will be discontinued.

Vegetal Carbon as Income and Commodity

There is a way that could make the investments and efforts of the first three years viable for every farming family – not through subsidies or donations, but by connecting farmers to the international carbon market. The planted trees not only promise profits from their fruits, seeds, leaves, woods, oils, resins and medicine, but they also absorb CO_2 from the atmosphere and store carbon within their wood, leaves, and roots, and also in the soil.

With the increased pressure to limit climate change to the level of 1.5°C, as has been agreed at the United Nations Convention on Climate Change (UNFCCC) Conference of Parties (COP) 21 held in Paris, worldwide management of carbon is vital. The equilibrium temperature that will result from climate change is directly proportional to the concentration of greenhouse gases (GHG) such as CO_2 and methane (CH_4) in the atmosphere. Even as humanity strives to reduce CO_2 emissions over coming decades, the CO_2 concentration will continue to increase. It takes a century to decay atmospheric CO_2 to 50 per cent, while 20 per cent of it remains for millennia (Hansen *et al.* 2016). Because of this, the amount of warming due to CO_2 by each nation is closely proportional to the cumulative amount of CO_2 emitted globally.

There has been a consensus that the current CO_2 concentration in the atmosphere, along with the unavoidable future emissions, commits the planet to warming of more than 2°C over pre-industrial average temperature (Rockström *et al.* 2016). In order to keep climate change within "control", we not only have to reduce emissions quickly, but we also must actively withdraw the excess CO_2 from the atmosphere over coming decades (Boysen *et al.* 2016; Rockström *et al.* 2009, 2016, 2017; Hansen *et al.* 2016). If the excess CO_2 can be withdrawn and sequestered for at least 100 years, preferably longer, this would allow for the level in the atmosphere to decline enough to bring warming back within safer bounds.

Opportunities for Increasing Income through Value Added Products

In the southern lowlands of Nepal bordering India, where fertilisers, pesticides and machines are cheaper and where the market access is easy, the cultivated soils are highly degraded, as they are in large parts of India, and the groundwater is frequently tainted with toxins, especially with Nitrate. By contrast, in the poorly accessible hills and deep in the mountains of Nepal where no fertilisers and pesticides can be purchased, most of the soils are degraded. On the steep terraces, it is not profitable to grow grain beyond that needed for personal nutrition. The villages are situated far away from the marketplaces, the roads are bad, it is nearly impossible to mechanise production, and there are labor shortages as well. All of these impediments can be overcome if higher-value crops are planted and processed on-site. With local value addition, durability of the goods increases, the transport volume decreases, and marketing becomes economically viable. In this manner, silk from mulberry or tea from moringa leaves can be produced and sold instead of rice; essential Cinnamon oil instead of corn; nuts instead of potatoes; and dried banana or papaya chips instead of millet can be thought as alternatives.

CONCLUSION

The objective of the project was to address climate related risks and at the same time to contribute to food-security of the people living in the villages through forest gardening with the use of biochar based organic fertiliser that link to agro-tourism and homestays, biodiversity conservation, watershed conservation, carbon credit scheme and new forest product development. The project has established a Knowledge Centre in the field, where there has been a start in consulting and teaching new forest garden methods, exchange experiences with other agro-social projects, and develop scientific base for the multiplication of forest garden projects across the country.

In the context of changing government systems and working procedures, this learning has also been fruitful. The inclusion of eco-tourism as component of the project has helped to diversify the income of the village and to start bringing back youths who had previously migrated to cities and elsewhere. The use of biochar based fertilisers for tree planting boosted growth of both, the trees and the crops cultivated between and under the trees. The improved soil health and fertility explained the high survival rate of trees. It replaces expensive chemical fertiliser. The established forest gardens have created a new environmental balance by bringing back trees on degraded and barren land. Lost and locally threatened tree species (e.g. Cinnamon, *Michelia, Elaeocarpus ganitrus*, *Alnus*) have been reintroduced.

Finally, it is suggested that basic foods for the families should continue to be grown on-site, and the gardens surrounding the houses usually suffice for that. However, in order to provide families with a regular income, the uncultivated land must be utilised in a manner that creates more value than traditional farming.

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