Revitalising Agrarian Economies: The Use of Biochar on Banana-based Agroforestry System in Nepal's hills

Bishnu Hari Pandit[1], Ian Nuberg[2], Krishna Kumar Shrestha[3], Edwin Cedamon[2], Swoyambhu Man Amatya[1], Bishow Dhakal[1] and Hans Peter Schmidt[4]

[1]Nepal Agroforestry Foundation, Kathmandu, Nepal, [2] University of Adelaide, Glen Osmond, Australia, [3]University of New South Wales, Sydney, Australia and [4] Ithaka Institute for Carbon Strategies, Arbaz, Switzerland

Corresponding author: bhpandit29@gmail.com

Abstract

The use of biochar in agroforestry practices is a new concept in Nepal. The soil application of biochar is a promising alternative to increase productivity and reduce chemical fertilizers. To test this concept, an action research project was implemented in two villages of Lamjung district in the middle hills of Nepal. This study aimed at assessing the productivity and livelihood impacts of a banana-based agroforestry system with and without biochar-based fertilization. Biochar was used in one village while another village served as the control (with Nitrogen, Phosphorus, Potassium – NPK application, but no biochar). The information obtained from 111 household surveys was verified and tested through five farmers' field trials. The paper investigates the effect of different fertilizers on banana yields and its contributions on poverty reduction. The result of the study shows that the banana yield increased by 41 per cent in the plots treated with urine-biochar plus compost compared to the control with conventional NPK fertilization; and more than doubled (102%) compared to the fertilization with compost only. Findings also revealed that the poverty level of respondent households using biochar dropped by 30 per cent (from 66% to 36%) in Dhamilikuwa (biochar village) and dropped by 19 per cent (from 40% to 21%) in JitaTaxar (control village). The study implies that the use of biochar in banana-based agroforestry system has the potential for increasing soil productivity and reducing poverty, thereby revitalising agrarian economy of many Nepali villages. A wider replication of this study is therefore recommended, together with enabling public policies to support this practice.

Key words: Banana-based agro-forestry, biochar, chemical fertilizer, organic fertilizer, urine

INTRODUCTION

Agroforestry is recognised as a key contributor to income of farmers in the Nepalese mid-hills (Amatya and Newman 1993). FAO (2010) indicated that 42 districts out of 75 are food deficit in Nepal, which can be actually be addressed by growing trees on private farmlands. Despite this, there have only been a few attempts to enhancing productivity of agroforestry systems (e.g. by using biochar). There is a significant gap between the current and potential agricultural production in Nepal. The low levels of productivity are the result of several factors including a high level of subsistence farming, low level of access to and adoption of suitable improved technologies (both on farm and post-harvest), poor availability of inputs (planting material, improved breeds, fertilizer, feed, plant and animal health protection, irrigation, electricity, finance), and limited investment in the agricultural sector (MoAD 2015:pp104). Consequence of the limited investment is that farmers receive little direction and assistance in growing crops where they might capture a market advantage and improve their incomes.

Another major problem in Nepal is that the farmers have poor access to agricultural inputs, particularly chemical fertilizers. In 2012, on an average only 28.4 kg ha^{-1} of fertilizer was applied on arable land, which is very low as per the South Asian standards (Schmidt *et al.* 2015). Nepal imports all of its chemical fertilizers but the supply is not sufficient to meet the demand. Shortages in fertilizer supply is sometimes further aggravated by blockades and strikes (for example the five-month fuel blockade at the Nepal-India border in 2015-16). Although the country has a fertilizer subsidy policy (MoAD 2015:pp27), subsidised fertilizer forms only a tiny fraction of the total requirement. Therefore the remainder is supplied through uncontrolled informal channels, facilitated by open and porous border with India towards the south. Thus, as with other inputs, the quality of the supply is also a serious issue. Application of poor quality fertilizer results in lower than anticipated impacts on crop productivity and profitability (Biederman and Harpole 2013; Schmidt *et al.* 2015). The imported fertilizers are expensive and prices are rising, which further limits the access, especially for poor farmers. Moreover, even where the supply and quality of fertilizer is sufficient, application tends to create environmental and soil acidity problems (Cornelissen *et al.* 2016).

The problem is not only with the low productivity in relatively low-value crops and poor input supply. Both the input and output markets are poorly integrated. Farmers, especially smallholders, not only lack access to quality inputs, the link to the markets for their products is also weak due to lack of infrastructure such as farm-to-market roads, collection centers and storage facilities, and poor access to information about markets and prices. The problems of market access and farmers being able to achieve a fair return from their produce can be addressed using a value chain approach to identify the most suitable crops for a specific situation and the leverage points for increasing return to the producers (Hoermann *et al.* 2010; Joshi *et al.* 2016). This paper reports an effort that adopts action research principles to enhance farmer livelihoods by; i) identifying a best-bet high value crop that can be readily integrated into existing agroforestry systems; and ii) improving the productivity of that crop by using a biochar fertilizer that releases farmers from their dependence on chemical fertilizer supply chain.

As it will be shown, one of the most suitable crops that could be integrated into agroforestry system for the study region was banana. Low productivity of banana crops has been shown elsewhere to be very responsive to innovative approaches to inputs (Alves *et al.* 2013). Gathorne-Hardy *et al.* (2009) have suggested a number of problems associated with fertilizer access and use that can be overcome through use of biochar – a type of fine-grained charcoal created by burning wood and agricultural byproducts slowly, at low temperatures, with a reduced oxygen supply – in combination with locally available fertilizer products. Treatment with biochar combined with compost or manure has been shown to be effective in restoring severely depleted soils (Steiner *et al.* 2007; Schmidt *et al.* 2014). A combined fertilizer and soil improvement product can be prepared from cow urine and biochar and used in combination with legume crop farming, can be an important tool for increasing food security and cropland diversity in areas with severely depleted soils, scarce organic resources, inadequate water for irrigation, and limited supplies of chemical fertilizer. This type of sustainable technology using locally available products is highly relevant for smallholder farmers in a country like Nepal (Schmidt *et al.* 2015).

The action research reported here was undertaken by the Nepal Agroforestry Foundation (NAF) under a collaborative funding arrangement between two independent research projects: the EnLiFT project and the ADB project (see acknowledgements). The EnLiFT project's interest was to identify and analyze the most feasible agroforestry value chain option in these two Village Development Committees (VDCs; now municipalities or rural municipalities) areas in Lamjung district during the year 2014. At the end of the year 2014, the biochar project was implemented in Dhamilikuwa village as a collaborative activity. The paper describes the value chain selection process and comparison of the effects of biochar-based organic fertilizer and chemical fertilizer on banana planted in between high yielding legume fodder trees hedge rows. Finally, suggestions are made for the future actions both locally and country-wide.

METHODS

The research was undertaken between November 2014 and October 2016. The first phase, value-chain analysis worked with 111 families in two VDCs of Lamjung District (Figure 1). The communities are poor and their economic development is a priority for the government in both locations. Their biophysical and socioeconomic characteristics are similar in Table 1.

Table 1: Characteristics of Value-chain Research Sites in Two Sites

Research site	Dhamilikuwa	Jita	Total
Household	1154	619	1773
Population	4425	2424	6849
Male	1909	1078	2987
Female	2516	1346	3862
Elevation Range	600 to 1200 masl	500-1600 masl	500 – 1600 masl
Land Area (km^2)	16.1	8.8	24.9
Total CFUG User HHs	808	534	1342
HHs sampled for AF work	53	58	111

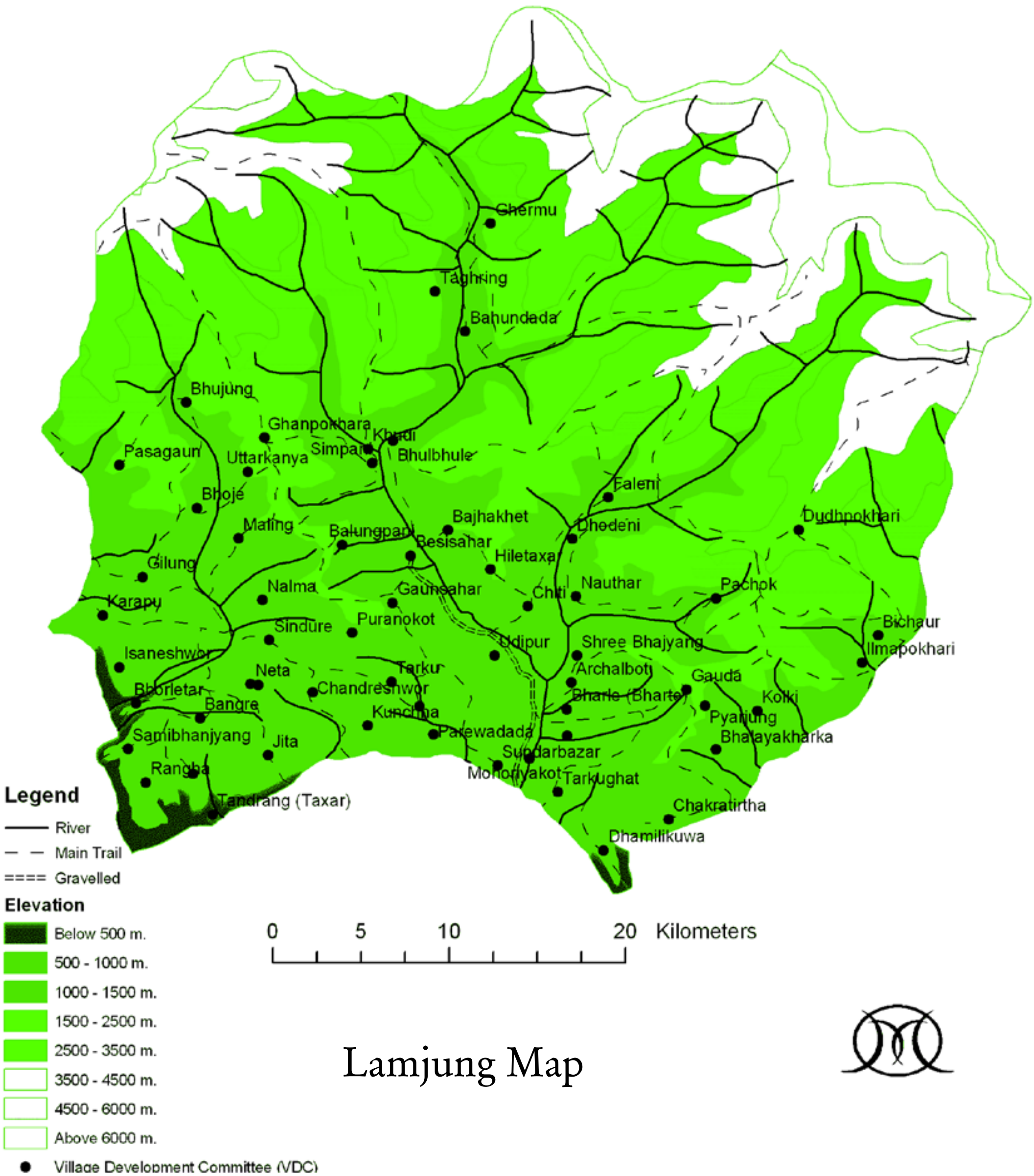

Figure 1: Map of Lamjung District with the Study Locations

This research followed two distinct methods for data collection. The first method followed a socio-economic survey, and second method used data obtained from banana and biochar action research field trial.

Socio-economic Survey

An action research methodology was chosen as it is designed to integrate economic, environmental, and social factors in the whole agroforestry system, while emphasising the strategic and political approaches to ensuring sustained improvements for disadvantaged groups (Rasul *et al.* 2012). Out of the total 1773 households in two sites, 111 participating households were selected for the interview (Table 1). In order to assess the impact of the intervention of this research, 'before' and 'after' data was collected from these participating households. Banana-based agroforestry option was selected as a priority system in both sites.

Banana and Biochar Action Research Trials

One of the important leverage points in the value chain was to increase crop productivity so that farmers would have a greater volume to sell from the small plots available. Biochar with organic fertilizer was investigated as an appropriate, low cost, and locally sustainable method of soil improvement and increasing productivity.

Biochar Production

Project staff (the principal investigator and Local Resource Person) carried out hands-on training events on producing biochar in a Kon-Tikisoil pit kiln at Dhamilikuwa with participants from all selected 35 families of Aanpchaur community forest user group (CFUG). The Kon-Tiki soil pit kiln method, also known as flame curtain pyrolysis, was introduced in 2014 as a simple and inexpensive way for small farmers to produce high quality biochar in bulk, avoiding both the emissions associated with other methods and the high costs of modern technological approaches (Schmidt and Taylor 2014). Biochar has good effects on various crops and agroforestry species and environmentally feasible to use (Jeffery *et al.* 2015). The cooled biochar was mixed with urine collected from stall-fed cattle in the ratio of 6.5 liters urine to 1 kg biochar (equivalent of 6.5 litre volumes).

Site Selection for the Field Trials

The potential for introducing banana cultivation as an important livelihood option was assessed in both sites based on the present status of banana cultivation and farmers' interest. Prior to the project intervention, almost half of farmers were growing banana for both home consumption and sale to local market, but only a few were growing banana with trees and biochar as an improved agroforestry system. Some non-governmental organisations (e.g. Jana Chetana and Choice Nepal) had promoted growing of banana and fodder trees in Dhamilikuwa among very poor farmers who have access to suitable land but cannot afford the inputs needed to grow other crops (cabbage, cauliflower and banana). As a part of their traditional farming system, both sites were growing banana in their farm lands. Farmers in Dhamilikuwa were asked about their interest in taking part in the field trials and the amount of land they could commit. More than two-thirds (35 of 53) expressed their interest in growing banana in the 2014/15using biochar. Farmers of JitaTaxar were also interested in banana growing and biochar, but the biochar promotion started only in 2016/17 after seeing the benefits of the former village (Dhamilikuwa). Therefore, Dhamilikuwa was selected as the 'biochar' village and Jita-Taxar as 'non-biochar' village. Field trial was also conducted at the former site.

Field Trials

Banana saplings were provided to the local research group (LRG) members committed to adopt biochar. The participating farmers have built their own soil type Kon-Tiki and produced biochar from feed leftover twigs and from Eupatorium, an invasive shrub omnipresent in the region. The biochar was mixed either with cattle urine (1:6.5) or with compost (1:6.5). The resulting substrate was applied in planting pits at a depth of 35 cm before planting the banana saplings as described in more detail in Schmidt *et al.* (2015). The application amount of biochar, cattle urine and compost was 1.6 t ha^{-1}, 10.4 m3 ha^{-1}, 10.4 t ha^{-1}, which corresponds to 1 kg, 6.5 l and 6.5 kg per plantation pit, respectively. The NPK fertilizer was broadcasted after plantation in the form of urea, Diammonium Phosphate (DAP), and muriate of Potash at per ha ratio of NPK 87:46:30 which corresponds to 150g urea, 100g DAP and 50 g muriate of potash per plant, respectively. No other fertilizer was applied between planting and the first banana harvest.

At four farmers' sites, three treatments (i) the traditional organic farmer practice with compost only; (ii) with mineral NPK only; and (iii) the organic-mineral biochar method with urine-biochar, NPK and compost, were compared in a completely randomised set-up with five replicates where each banana tree was considered as one plot. The banana trees were planted at 1600 trees per ha with plant to plant of 2.5 m. Besides, a primary trial with five treatments were compared in a completely randomised set-up (N=5) at Radha farm. To investigate the decisive factor the treatments compost + biochar (10.4 tha^{-1}+ 1.6 t ha^{-1}) and urine-biochar + compost (10.4 m3 ha^{-1} – 1.6 t ha^{-1} + 10.4 t ha^{-1}) were added to the three treatments described above. All banana trials were planted and harvested within the same week. The soils at the four sites were classified as silt loam with a pH of 4 .2 ±0.3 and soil organic matter (SOM) content of 3.2% ± 0.5%.

Statistical Analysis

Socio-economic data was analysed using a SPSS package. For the statistical analyses, normality was tested with the Shapiro-Wilk test and homogeneity of variances with Levene's test. The difference in income and poverty level between two time periods was analysed. All data were presented as means ± standard error of the mean (SE). A p-value of <0.05 was considered significant.

Treatment effects of the Radha banana trial were analysed using one-way analysis of variance (ANOVA). Results of the 4-farmer banana trial were analysed with a two-way analysis of variance (two-way ANOVA) including site location as second independent variable. Both, the one-way and the two-way ANOVAs were followed by post-hoc Tukey tests to detect differences between treatment means.

RESULTS

Agroforestry System Selection Process

There are many agroforestry-based products that are being sold in the markets from the research site. Many of them are marketed with low rates, some others have small margins, and very few of them are potentially highly profitable and socially acceptable by rural people. A total of 16 commodities were listed in the beginning from these sites (NAF 2013) and priority ranking was done to select the best options. A commodity matrix ranking framework was used to identify the most promising option (ICRAF 2014; Joshi *et al.* 2016). This framework followed four procedural steps.

Step 1, Selection criteria: The value chains were evaluated during the focus group discussions using seven criteria: market and market demand, economy of scale and outreach, high value, stakeholders' interest and commitment (women and poorest households), coordination, short turnover, and leverage.

Step 2, Weighing per cent: The first criteria 'market and market demand' was given 20 per cent weightage, the second to fifth criteria were given 15 per cent and rest two were given 10 per cent weightage each.

Step 3, Assessing commodity fit against each criterion: Each criterion was given a score from 1 to 5, with 5 representing maximum compliance and 1 minimum compliance, 2 for compliance and 3 for good compliance. Overall ranking was determined using a weighted average of the seven criteria.

Step 4, Results of commodity scoring exercise: Based on the assessment of step 3, the result is presented in Table 2. A total of 16 commodities were selected in the first phase those who received at least the score of good compliance (Table 2). In the second phase, the high scoring (max compliance) commodities such as buffalo milk, goat meat and banana were selected whose score is more than 4 highlighted with yellow color.

Table 2: Result of Agroforestry Commodity Selection Process (Phase 1)

	Dhamilikuwa	Jita/Taxar
1. Buffalo milk	√√√√	√√√
2. Goat meat	√√√	√√√√
3. Timber	√	√
4. Taxusbaccata	X	x
5. Brooms	√	√√√
6. Ginger	√	√
7. Lapsi	X	√
8. Cardamom	X	x
9. Banana	√√√√	√√√√
10. Honey	√	√√√
11. Bamboo	√	√√√
12. Drum stick	√√√	√
13. Round chilli	X	√
14. Tomato	X	x
15. Cinnamon	√√√	√√√
16. Asparagus	√	√
Number of products selected	5	6

Scale: x- no compliance (0 score); √ – little compliance (1-2 score);√√- compliance (2-3 score); √√√- good compliance (3-4 score); √√√√ – max compliance (4-5 score).

Agroforestry System Described

Traditionally, farmers in the study sites were managing trees by themselves on various types of private land. Tree planting and management activity on private land increased mainly after implementation of the EnLiFT (Enhancing livelihood and food security from agroforestry and community forestry in Nepal) project in 2013. In one form or another, hill farmers have long been practicing agroforestry to meet fodder and fuelwood requirements as well as to maintain land productivity. Farmers reported that in recent years, following implementation of this project, these practices have become crucial to meet the fodder requirements and replenish soil nutrients to increase food production.

It was observed that most of the agroforestry species were naturally grown on the edges of terraces and farm boundaries along with upland crops and on the walls of gullies and barren land called *kharbari*, where some kinds of thatch grasses grow naturally. Recently, the improved fodder trees and grasses are planted on terrace edges and risers, and on fallow land, in close spacing by maintaining 1–2 m tree height as hedgerows. Table 3 shows that number of fodder trees (*Leucaena, Flemingia, Teprosia, Artocarpus, Ficussemicordata, Bauhinia purpurea/ variegata, Chuletro, gogan, Dhudhilo, Morus alba etc*) on farm land terraces increased by five to six folds, while timber (*Bakaino, teak, khair, Masala, Paiyu, Uttis, champ*) and non-timber tree species (*Lapsi, Tejpat* and *Loath Salla*) increased by almost three folds now (2016) than before 2013. Farmers shifted to growing more understory crops such as tomato, ginger, cardamom, round chili and banana to augment their family income. Large animal number (cattle and buffalo) remain almost same while little increase of goat number was observed (Table 3).Consistent with the information shown in Table 3, the banana based agroforestry system is dominant in Dhamilikuwa and JitaTaxar. Tomato, high yielding fodder buffalo system at Dhungkharka, and ginger and cardamom at Mithinkot and Chaubas, respectively were observed.

Table 3: Change in Agroforestry System Components Over Time (2013 to 2016)

Before		Jita-Taxar		Dhamilikuwa	
		After	Before	After	
1. Trees	Fodder	16	226	14	109
	Timber/Fuel	8	31	4	27
	NTFP trees	1	30	1	24
2. Under storey crops	forage/grasses	130	333	37	147
	Banana	8	30	12	43
	Tomato	1	3	1	2
	Ginger	0.7	0.8	0.1	0.4
3. Animal	Cattle/buffalo	2	2.1	1.7	1.8
	Goat	1.6	2.9	2.3	3.3

Banana Based Agroforestry System

Banana (*Musa paradisiaca*) is a high value agricultural product, used as cash under story crop in many parts of Nepal. Its potential to contribute to the national economy and generate income for farm families in tropical and sub-tropical regions has been well recognised in recent years (Tukan *et al.* 2005). They mature in 18 months and can provide income at the end of second year in a good agronomic condition. Banana is currently grown in 68 out of Nepal's 75 districts, and the total productive area of banana plantations in 2012/2013 was 11,864 ha, with a total production of about 182,005 tonnes. Despite its potential, there are very few banana plantations and its productivity is low, where the productivity ranging from 13.2 t to 20 t/ha (ICIMOD 2013). Nepal imported 27878 tonnes from Indian in the year 2011/12 to fulfill the domestic demand (TEPC 2012).

The key challenges to realising the potential of banana production in contributing to farm income include lack of storage for longer periods and need for immediate sale for cash to meet regular needs; borer and root rot infestation, poor information about markets; lack of structured markets; planting of multiple crops on a single plot; and lack of access to quality seedling. Banana cultivation is highly labor intensive and requires high application of manure and fertilizer (Tukan *et al.* 2005). The highest cost associated is for manure and fertilizer (needs three times more fertilizer than cereals), followed by human labor, and pesticides and other chemicals (fungicide). Thus reducing the cost of fertilizer is a very promising approach for upgrading the banana-based agroforestry system.

Banana and Biochar Action Research Trial Results

As a part of the action research, investigation on replacing costly chemical fertilizer with locally produced organic urine-biochar fertilizer was done. In the 4-farmer trial, the application of cattle urine enhanced biochar increased the yield by 102 per cent compared to the treatment with compost only and by 41 per cent compared to the application of mineral NPK fertilizer (Figure 2). In the primary trial at Radha farm, it was further demonstrated that the addition of biochar to the compost improved the fertilizer efficiency of the compost by 53 per cent. However, when biochar added to the compost was first impregnated with cattle urine, the number of harvested bananas increased by 84 per cent compared to the compost only and by 20 per cent compared to the compost and biochar treatment. Moreover, the treatment with urine-biochar and compost was not significantly lower than the same urine-biochar and compost treatment with added NPK. It could thus be demonstrated that the application of farmer made organic biochar-based fertilizer can increase the yield compared to the application of expensively purchased mineral-chemical NPK fertilizer. The combination of urine-biochar and compost with mineral NPK fertilizer did not prove to be advantageous compared to the purely organic biochar fertilizer treatment. The observed yield increase compared to both, the traditional compost soil amendment and the NPK fertilization, corroborates earlier results of similar organic biochar-based fertilization methods in 13 other crops (Schmidt *et al.* 2017).

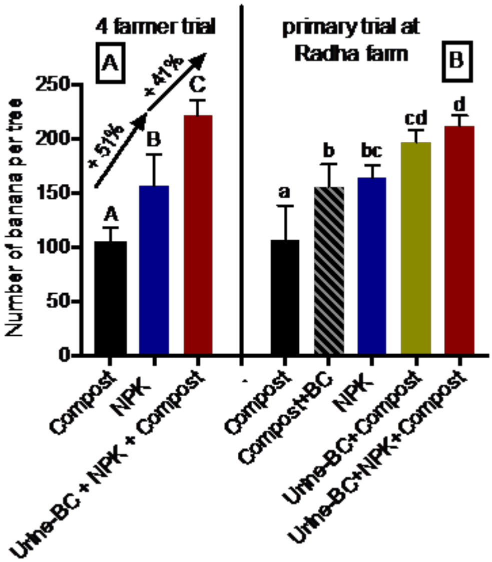

Figure 2: Number of Harvested Banana 18 Months after Planting and Fertilizer Application (A) at Four Farmer Sites and (B) at Radha Farm, all in Dhamilikuwa, Lamjung. Bars Show Means + Standard Deviation, Numbers of Replicates per Treatment were Five at Each Trial Location. Different Letters Indicate Significant Differences between Treatments.

Impact on Family Income and Reducing Poverty Level

The rural landscape that encompasses the agrarian economy, fragile ecology and complex and differentiated society is changing rapidly with the creation of new opportunities and challenges (Choudhary *et al.* 2011). Despite this rapidly changing environment, the rural economy is still based on subsistence agriculture in rural villages of Nepal. In such a context, the cash income derived from agroforestry products (fruits, nursery, animal products and understory crops) has played a significant role in sustaining rural livelihoods (Gilmour 2011). The change in income due to understory crop during the project period is more than 10 per cent (from 6 to 16%) in Dhamilikuwa, where biochar was used compared to only 5 per cent at JitaTaxar village (without biochar). The change in income received from understory crops is significant at $p < 0.001$ level between after and before situation, while the overall change is significant at $p < 0.05$ level. The study area has opened up new opportunities for the hill farmers to pursue banana-based agroforestry system (Table 4). This is an additional income for the farmers. Of all sources of income, the combined income from salary, pension and remittance had been the largest source of household incomes, contributing 53 per cent at Dhamilikuwa and 60 per cent at JitaTaxar, before the project was implemented. After the project, this reduced to 43 per cent in the former, while it remained at only 56 per cent in the latter (Table 4). The remittance based economy was a result of out-migration of rural youths, which consequently ensued fallowing or abandonment of large tracks of fragile landscape in the study area. This land is utilised effectively through expansion of agroforestry, which would contribute to both carbon sequestration and farm income in the hill slopes of Nepal, and is expected to reduce migration.

Table 4: Sources of Cash Earning Per Household

Sources of cash income	Dhamilikuwa (with biochar)*				JitaTaxar (without biochar)			
	Before	%	After	%	Before	%	After	%
Sales from farm crops & vegetables	6585	7	12469	10	2190	2	6419	4
Sale of livestock and livestock products	19645	20	24200	19	12290	11	19767	13
Sale of understorey (banana and broom)**	5668	6	19580	16	4208	4	13268	9
Sale of timber	1938	2	2891	2	1431	1	1667	1
Work labor	3273	3	1364	1	2300	2	1966	1
Business	8327	9	10218	8	21413	20	23997	16
Service and pension	43727	45	35509	28	47397	44	52586	34
Remittance	7273	8	18473	15	17241	16	33534	22
Total	96436	100	124704	100	108470	100	153204	100

Change in Poverty level

The Nepal Living Standard Survey (NLSS) uses 2,200 calorie consumption by a person per day and access to essential non-food items as the index to measure poverty in Nepal. Based on the current market prices, a person needs an income of at least Nepalese Rupees (NRs) 19,450 a year to manage food equivalent to 2,200 calorie per day and other essential non-food items (NLSS 2013). As per the report, an individual earning less than NRs 19,450 per year is below the poverty line. The average household size of the communities in the study sites is 4.41 and therefore below poverty line income per household is 97,250 (5 HH size x 19450) as indicated in Table 5. The study found that the percentage of households living below the poverty line dropped from 66 per cent in 2013 to 36 per cent in 2016 in Dhamilikuwa and 40 per cent to 21 per cent in Jita Taxar (Table 5). The reduction in poverty is attributed mainly to the promotion of banana-based agroforestry with biochar.

Table 5: Poverty Level 'Before' and 'After' Project

Period	Poverty level	Dhamilikuwa (n = 53)		JitaTaxar (n = 58)	
		Frequency	%	Frequency	%
Before (2014)	Below poverty line[a]	35	66	23	40
	Above poverty line[b]	18	34	35	60
After (2016)	Below poverty line[a]	19	36	12	21
	Above poverty line[b]	34	64	46	79
	Total	53		58	

[a]Below poverty line: ≤NPR 97250 per annum/household, [b]Above poverty line: ≥ NPR 97250 per annum/household

DISCUSSIONS

The aim of this study was to assess the impact of the use of biochar on banana-based agroforestry system on food security and livelihoods. The paper draws on the lessons from the action research project and highlights lessons for future interventions in the biochar-based agroforestry sub sector. Using recalling ('before' and 'after') method, we tried to assess the level of poverty and income change among the participant households due to project intervention. Our analysis suggests that the project helped increase income and reduce poverty among project participants, as well as improve the skills and knowledge of farmers in banana production.

This paper also assesses the economic benefits from the use of biochar that help to scale-up the utilisation of biochar as a strategy for addressing climate change adaptation and improvement of soil health, fertility and plant productivity. Moreover, it also looks at impact in the farm income, while reducing the import of carbon-intensive agri-inputs. Evidence from the field trials conducted in Dhamilikuwa and other project sites showed that urine-enriched biochar can indeed improve crop yields and farm incomes in this region in a sustainable manner. Such sustainable farming technologies are becoming increasingly relevant for farmers experiencing low soil quality, especially smallholder farmers, given the poorly integrated input markets and lack of access to affordable quality fertilizer and other inputs. The imported chemical fertilizers are expensive and prices are rising; urine biochar offers a cheap, effective, and locally available alternative, acting both as a fertilizer and a soil improvement treatment. Urine biochar in combination with legume crop farming can be an important tool to increase food security and crop land diversity in areas with degraded soils, scarce organic resources, and inadequate water and chemical fertilizer supplies. Many of the families in the study area, particularly (Dhamilikuwa) already have considerable savings available for marketing and are thus in a good position to develop the banana-based agroforestry system that maximize the returns from their small plots of land and reduce their vulnerability to food insecurity.

The benefits of biochar have been recognised by many groups worldwide and were also illustrated by the results of the farmers' trials. The Government of Nepal (GoN) has been emphasising the promotion of organic farming. The National Agriculture Policy 2004 emphasises promotion of organic farming with the support of organic certification. The Agriculture Development Strategy (ADS) document includes complementary measures to improve productivity and fertilizer use efficiency. Biochar-based organic fertilizer can play an important role in sustainable organic production and, at a supplementary or complementary level, can help sustain soil fertility and minimise the use of inorganic fertilizers while maintaining the productivity.

Overall, it can be concluded that the project activities had no harmful environmental impacts and at the same time, the project had been successful in reducing poverty to a significant level. It happened because of adequate and balanced application of inputs (especially biochar-based organic manure, which kept the soil fertile and prevented from soil degradation).

This study provides important insights for people of this region, particularly policy-makers in relation to livelihood improvement and poverty reduction in rural mountain communities that depend on available natural resources for their livelihoods. For a project to have an impact on poverty, it must be well matched to the needs and priorities of beneficiaries. However, people expectation in the initial stage of the project was relatively high, which needs to be addressed through participatory action and learning meetings and exercises. The banana farming has been affected by pseudo stem borer and root rot through *Fusarium* spp, which needs to be taken care through application of organic fermentation liquid.

The success of the project is also dependent on the extent to which it can link with other projects to bring about synergies. The success of the project in reducing poverty would have been impossible without the links with other project (such as ADB and Ministry of Agriculture Development). Based on the lessons drawn, the paper makes the following recommendations:

- Promotion of biochar-based organic fertilizer in agroforestry crops should be made a priority in Nepal to help meet the government target of increasing organic matter content in soil from 1 to 4 per cent over the next 20 years.
- The introduction of high yielding legume fodder trees such as *Laucaena*, *Flemingia* and *Teprosia*spp with biochar-based organic fertilizer is an important approach for achieving the government's goal of increasing productivity. Urine-biochar fertilizer with banana-based aroforestry farming can complement government plans and policies. The District Agriculture Development Offices are mandated to supply inputs (seeds and fertilizer) in their respective districts. This can be a leverage point for development of the urine-biochar based banana tree farming. Government interventions should focus on reducing the use of chemical fertilizers and replacing them with urine-biochar based organic fertilizer.
- Extension on best practices and demonstrations involving private sector suppliers and manufacturers of biochar is needed to further improve agricultural productivity.
- Establishment of commercial bio-fertilizer production enterprises based on the available material (invasive plants – *Eupatorium*, crop residues, municipal biomass and agro processing waste) should be facilitated.
- Farmers should be organised as producer groups or associations that can access larger markets and can also be sold locally through weekly market, which was initiated at Dhamilikuwa (Syaule Bazaar).
- Opportunities should also be explored for targeting key institutions with processed banana products (such as banana chips). Non-Governmental Organisations and others can provide key linkages for farmers to access these markets, including relevant training on markets.
- LRG groups in all six VDCs have established savings mechanisms and are in the process of developing cooperatives. The finance available should be invested in the development of any innovative agroforestry system.

ACKNOWLEDGEMENTS

This project was funded under a collaborative arrangement between two research projects: the EnLiFT project, which was funded by the Australian Centre for International Agricultural Research (ACIAR) and the ADB/NDF funded project.

REFERENCES

Amatya, S. and Newman, S. 1993. Agroforestry in Nepal: Research and Practice. *Agroforestry System*, **23**:215-222.

Alves, E.P., Silva, M.O., Sílvio, N., Barella, O. and Ricardo, T.P. 2013. Economic Analysis of a Coffee-banana System of a Family based Agriculture at the Atlantic Forest Zone, Brazil. *Ciênc. Agrotec*, **39**(3). https://doi.org/10.1590/S1413-70542015000300004

Biederman, L.A. and Harpole, W.S. 2013. Biochar and its Effects on Plant Productivity and Nutrient Cycling: A Meta-Analysis. *GCB Bioenergy*, **5**: 202–214.

Cornelissen, G., Pandit, N.R., Taylor, P., Pandit, B.H., Sparrevik, M., Schmidt, H.P. 2016. Emissions and Char Quality of Flame-Curtain "KonTiki" Kilns for Farmer-Scale Charcoal/ Biochar Production. *PLoSOne* , **11**, e0154617.

Choudhary, D., Pandit, B.H., Kinhal, G. and Kollmair, M. 2011. Pro-Poor Value Chain Development for High Value Products in Mountain Regions: Indian Bay Leaf. International Center for Integrated Mountain Development, Kathmandu, Nepal.

FAO. 2010. Assessment of Food Security and Nutrition Situation in Nepal (An input for the preparation of NMTPF for FAO in Nepal). Food and Agriculture Organization of the United Nations UN Complex, Lalitpur, Nepal.

Gathorne-Hardy, A., Knight, J. and Woods, J. 2009. Biochar as a Soil Amendment Positively Interacts with Nitrogen Fertiliser to Improve Barley Yields in the UK. IOP Conference Series: Earth and Environmental Science, **6**, 372052.

Gilmour, D. 2011. Unlocking the Wealth of Forests for Community Development: Commercializing Products from Community Forests. 42 MindarieCres Wellington Point, Queensland, 4160, Australia.

Hoermann, B., Choudhary, D., Choudhury, D. and Kollmair, M. 2010. Integrated Value Chain Development as a Tool for Poverty Alleviation in Rural Mountain Areas: An Analytical and Strategic Framework. International Center for Integrated Mountain Development, Kathmandu, Nepal.

ICIMOD. 2013. Expanding Banana Production in Nepal - Using Ecological Niche Modelling to Guide Farmers and the Government of Nepal. International Center for Integrated Mountain Development, Kathmandu, Nepal.

ICRAF. 2014. Commodity Selection Matrix. World Agroforestry Center, Bogor, Indonesia.

Jeffery, S., Abalos, D., Spokas, K.A. and Verheijen, G.A. 2015. Biochar Effects on Crop Yield. In: Lehmann, J. and Joseph, S. (Eds.), *Biochar for Environmental Management* (pp. 301 –326). London: Earthscan.

Joshi, S.R., Rasul, G. and Shrestha, A.J. 2016. Pro-poor and Climate Resilient Value Chain Development: Operational Guidelines for the Hindu Kush Himalayas : ICIMOD Working Paper 2016/1. International Center for Integrated Mountain Development, Kathmandu, Nepal.

MoAD. 2015. Agriculture Development Strategy of Nepal. Ministry of Agriculture Development, Government of Nepal, Kathmandu, Nepal.

NAF. 2013. Qualitative Baseline Assessment of Agroforestry System in Kavre and Lamjung Districts of Nepal. Nepal Agroforestry Foundation, Kathmandu, Nepal.

NLSS. 2013. The National Living Standard Survey 2013. Central Bureau of Statistics, Government of Nepal, Kathmandu, Nepal.

Rasul, G., Choudhary, D., Pandit, B. and Kollmair, M. 2012. Poverty and Livelihood Impacts of a Medicinal and Aromatic Plants Project in India and Nepal: An Assessment. *Mountain Research and Development*, **32**(2):137-148.

Schmidt, H.P., Kammann, C., Niggli, C., Evangelou, M.W.H., Mackie, K. and Abiven, S. 2014. Biochar and Biochar-compost as Soil Amendments to a Vineyard Soil: Influences on Plant Growth, Nutrient Uptake, Plant Health and Grape Quality. *Agriculture, Ecosystem, and Environment*, **191**: 117 – 123.

Schmidt, H.P. and Taylor, P. 2014. Kon-Tiki Flame Cap Pyrolysis for the Democratization of Biochar Production. *The Biochar-Journal*, 2014: 14 -24.

Schmidt, H.P., Pandit, B.H., Martinsen, V., Cornelissen, G., Conte, P. and Kammann, C. 2015. Fourfold Increase in Pumpkin Yield in Response to Low-Dosage Root Zone Application of Urine-Enhanced Biochar to aFertile Tropical Soil. *Agriculture*, **5**: 723–741.

Steiner, C., Teixeira, W.G., Lehmann, J., Nehls, T., de Macêdo, J.L.V., Blum, W.E.H. and Zech, W. 2007. Long Term Effects of Manure, Charcoal and Mineral Fertilization on Crop Production and Fertility on a Highly Weathered Central Amazonian Upland Soil. *Plant Soil*, **291**: 275–290.

Tukan, C.J.M., Roshetko, J.M., Suseno, B. and Manurung, G.S. 2005. Banana Market Chain Improvement - Enhance Farmers' Market Linkages in West Java, Indonesia. *Acta horticulturae*, **699**(699).

TEPC. 2013. Banana Production and Import Data. Trade and Export Promotion Center, Kathmandu, Nepal.