Revitalizing agrarian economies: the use of biochar on banana-based agroforestry systems in Nepal's hills

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Introduction

In view of the declining productivity and costly chemical fertilizer, the action research project on agroforestry (AF) implemented in two Village Development Committees (VDCs), namely Dhamilikuwa and Jita-Taxar of Lamjung district of Nepal (Fig 1) covering 111 sample households including five field trials at Dhamilikuwa. This study particularly focuses on assessing the productivity and livelihood impacts of a banana based Agroforestry (AF) system with biochar in two VDCs. The paper describes the selection process of agroforestry system and comparison of the effects of different fertilizers on banana yields (Fig 2) and thereby over all banana based agroforestry system.

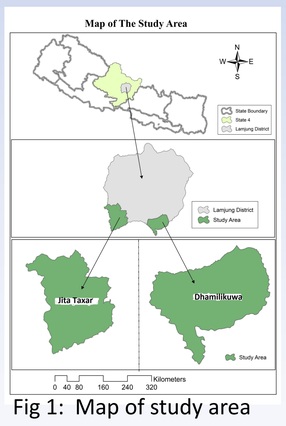

Fig 1: Map of study area

Fig 2: High banana yield

Why biochar fertilization?

The low levels of productivity in Nepal 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 (mainly fertilizer) MOAD 2015:104 page). In 2012, on average only 28.4 kg ha^{-1} of fertilisers were applied on arable land, which is very low even by South Asian standards (Schmidt et al. 2015). The imported fertilizers are expensive and prices are rising, which further limits access, especially for poor farmers. Finally, even where the supply and quality of fertilizer is sufficient, application tends to create environmental and soil acidity problems (Cornelissen et al.2016). Therefore the need for biochar fertilization was felt necessary. We used the simple Kon-Tiki kiln for biochar preparation. The process of biochar production and use are shown in Fig 3, 4 and 5 as follows:

Fig 3: Biochar feedstock pyrolysis

Fig 4: Biochar produced in Kon-Tiki Kiln

Fig 5: NPK enriched biochar applied to banana plant

Methodology

An action research methodology was chosen as it is designed to integrate economic, environmental, and social factors in the whole agroforestry system, while emphasizing strategic and political approaches to ensuring sustained improvements for disadvantaged groups. Of the total 17,73 households in two sites, 111 participating households were selected for household interview (Table 1). In order to assess the impact of the intervention of this research, the 'before' and 'after' data was collected from these participating households. Banana based agroforestry option was selected as a priority system in both sites. In order to validate the data obtained through households survey, we used the data from five farmers' field trials including primary trail (Fig 6) held at Dhamilikuwa.

Fig 6: Primary trial established at Radha farm

Banana based AF system selected

A commodity matrix ranking framework was used to identify the most promising option (ICRAF 2014; Joshi, 2016) for selection of best system using four steps:

Step 1: **Defining selection 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 % - The first criteria 'market and market demand' was given 20% weightage, the second to fifth criteria were given 15% and rest two were given 10% weightage each

Step 3:**Assessing commodity fit against each criteria**- 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 1. A total of 16 commodities were selected in the first phase those who received at least the score of good compliance (Table 1). 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 1: Result of Agroforesty commodity selection

Commodity	Dhamili Kuwa	Jita/Taxar
1. Buffalo milk	√√√	√√
2. Goat meat	√√	√√√
3. Timber	√	√
4. Taxus baccata	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

Field trials

Banana saplings were provided to the Local Research Group (LRG) members committed to work with 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 spread 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. Farmers are taking their share of biochar produced during the training to their home for trials (Fig 7).

Fig 7: Farmers dividing their share of biochar for their trial

At four farmers' sites, three treatments (1) the traditional organic farmer practice with compost only and (2) with mineral NPK only and (3) the organic-mineral biochar method with urine-biochar, NPK and compost, were compared in a completely randomized set-up with five replicates where each banana tree was considered as one plot. The banana trees were planted at 1600 trees per hectare with plant to plant of 2.5 m (Fig 8)

Fig 8: Farmers mixing NPK nutrients with biochar

Besides above, a primary trial with five treatments were compared in a completely randomized set-up (N=5) at Radha farm. To investigate the decisive factor the treatments compost + biochar (10.4 t ha^{-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. The change in growth of banana plants of primary trial is shown in Fig 9.

Fig 9: Five months growth of banana primary trial

Results

Significant increase in Banana yield

The action research investigated replacing costly chemical fertilizer with locally produced organic urine-biochar fertilizer. In the 4-farmer trial (A), the application of cattle urine enhanced biochar increased the yield by + 102% compared to the treatment with compost only and by 41% compared to the application of mineral NPK fertilizer as is the conventional farming method. In the primary trial at Radha farm (B), it was further demonstrated that the addition of biochar to the compost improved the fertilizer efficiency of the compost by 53% but when the biochar added to the compost was first impregnated with cattle urine, the number of harvested bananas increased by 84% compared to the compost only and by 20% compared to the compost + biochar treatment (Fig 10).

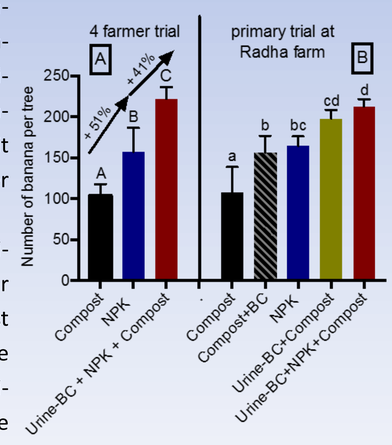

Fig 10: Farmers trial results

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 current market prices, a person needs an income of at least Rs 19450 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 Rs 19450 per year is below the poverty line. The household size of the study communities is 4.41 and therefore below poverty line income per household is 97,250 (5 HH size x 19450) as indicated at the bottom of the Table 2. The study found that the percentage of households below the poverty line dropped from 66 % in 2013 before project implementation to 36 % after the project in 2016 in Dhamilikuwa and 40% to 21 % in Jita Taxar (Table 2). The reduction in poverty is attributed mainly due to promotion of banana based agroforestry with biochar.

Table 2: Poverty level 'before' and 'after' project

		Dhamilikuwa (n = 53)		Jita Taxar (n = 58)	
Period	Poverty level	Frequency	%	Frequency	%
Before (2013)	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

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% over the next 20 years.
- The introduction of high yielding legume fodder trees such as *Laucaena, Flemingia* and *Tephrosia* 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.

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