Journal of Applied Agricultural Economics and Policy Analysis, 2021, Vol. 4, No. 1, 40-46
Available online at http://pubs.sciepub.com/jaaepa/4/1/5
Published by Science and Education Publishing
DOI:10.12691/jaaepa-4-1-5

Productivity and Profitability of Strip Cropping and Shifting Cultivation in Bandarban, Bangladesh

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Received July 10, 2021; Revised August 14, 2021; Accepted August 23, 2021

Abstract Agricultural production in the Chattogram Hill Tracts (CHT), located in southeast corner of Bangladesh, is constrained by farmers' socio-economic conditions and land topography. Farmers practice low input based, labor intensive shifting cultivation in the uplands as livelihood strategy. Productivity is low and most farm households suffer from food insecurity. Despite efforts of controlling shifting cultivation, no better options for farmers are available. In this paper we provide an analysis of the performance of strip cropping system in comparison with traditional shifting cultivation. Data were collected conducting participatory on-farm experiments involving farmers representing three tribes in three villages covering two upazilas of Bandarban district during 2020-2021. Upland rice, maize and cotton were grown in strips following standard planting configuration for each crop and simultaneously growing crops in shifting cultivation at farmers' choice. Results indicated that strip cropping of maize, rice and cotton in combination produced higher economic return than the crops grown in shifting cultivation. Switching to new cropping practice will require training and policy support.

Keywords: *shifting cultivation, tribal farmers, strip cropping, participatory on-farm trial*

Cite This Article: Abdul Hamid, Abdul Gafur, Ashrafun Nahar, G.M. Monirul Alam, Sonia Rashid, Md. Farid Uddin, Md. Kamrul Islam, M.A. Mannan Mollah, and Mong Sanue Marma, "Productivity and Profitability of Strip Cropping and Shifting Cultivation in Bandarban, Bangladesh." *Journal of Applied Agricultural Economics and Policy Analysis*, vol. 4, no. 1 (2021): 40-46. doi: 10.12691/jaaepa-4-1-5.

1. Introduction

The Chattogram Hill Tracts (CHT) comprising three hill districts of Bangladesh located in the country's southeastern corner, bordering with Tripura (India) in the north, Mizoram (India) and Myanmar in the east and south, covers an area of 13,295 km^2, approximately one-tenth of the country. The population of the CHT is about 1.5 million. Compared with landmass, population in the CHT is much low. The region is home to 12 tribes and Bengali population. Overwhelming majority is the tribal population. Most tribal people live in the hills and mountains in rural settings and agriculture is their major livelihood strategy. The land area of the CHT is covered by undulating hills and mountains. The proportion of land suitable for growing crops is about 7% of total area. Depending on land topography two types of crop agriculture are followed. The valley lands with source of perennial water supply allow intensive crop production throughout the year. Rice, vegetables, cotton, tobacco and quick growing fruits are grown in the valley lands. In the sloping uplands farmers adopt indigenous practices of shifting cultivation relying on natural precipitation. Literatures on shifting cultivation or swidden cultivation abound [1-5].

Shifting cultivation is an old practice of crop growing in the upland in the tropical countries of Asia, Africa and South America [7,8,9]. In the CHT and adjoining southeastern states of India shifting cultivation is popularly known as *jhum*. With economic growth, market liberalization and market-led demand for high value crops, jhum system is undergoing transformation throughout Asian uplands. Shifting cultivation is blamed for being 'primitive practice' and 'low productive' and thus considered unsustainable. Land degradation and loss of forest cover in the CHT is generally attributed to shifting cultivation [10,11,12].

With improving road communication and growing market demand, some farmers and entrepreneurs are growing fruit orchards. Some of the jhum farming areas are being converted to orchards, but the total area under jhum is believed to have remained stabilized somewhere around 40,000 ha. However, reliable statistics on shifting

cultivation farming is hard to estimate and the government statistics provide no information on jhum crop production in the CHT [13,14].

Bangladesh has attained food security and is striving for nutrition security. But food insecurity remains chronic in the CHT. Poverty is widespread with malnutrition a regular phenomenon. The extent of food insecurity is more in the district of Bandarban than other in two districts of the CHT [15]. Nahar et al [14] provide a detailed analysis of food security problem of shifting cultivators in Bandarban. Majumder et al. [16] reported seasonal variation in the severity of the food crisis. This seasonality of food crisis is related with crop growing practices and growing season. Deterioration of food insecurity occurs between May to September. Shifting cultivators plant crops at the onset of monsoon, usually in May and start harvesting crops beginning August. Main crop rice is harvested in September – October. Shifting cultivation is a practice of subsistence farming. With rising population, land holding is shrinking, length of fallow period decreasing and productivity is also decreasing. Against this backdrop, volving of high productive agriculture growing food and cash crops in the sloping uplands is imperative for improvement of life and livelihoods of hill farmers.

In Bangladesh, hill farmers have been growing cotton (*Gossypium arboreum*) over centuries. It has been an important cash crop on which hill dwellers have been dependent for long time. Cotton crop is grown in uplands as jhum and as a sole crop in the valleys. However, cotton production in the CHT is facing challenges. The challenge comes either from the unsustainability of jhum farming, or stronger crop competition in the valleys as well as in the uplands.

Bangladesh earns about US $30 billion annually through the export of readymade garment (RMG) products. However, most cotton required for sustaining RMG export is imported. The country imports nearly 8.0 million bales of cotton annually while the domestic cotton production is less than a million bales. For closing the gap between the demand and domestic production points to the bright prospect of growing cotton in Bangladesh. Thus, expanding cotton production in the hills deserves special attention.

Maize is grown in the CHT and farmers use immature, cobs as raw, parboiled or roasted. Shifting cultivators do also grow maize in association with other crops but thinly planted. Also, farmers in the hills grow late maturing, low yielding indigenous varieties of maize. Maize could be a strategic crop for meeting household food demand of the tribal population provided it matures at times when farm household face severe food insecurity. Agrarian Research Foundation (ARF) introduced hybrid maize in Bandarban hills suitable for harvesting in July-August if planted in May [17,18].

In this paper we evaluate the performance of a newly developed three-crop based strip cropping in comparison with traditional shifting cropping through participatory on-farm testing on farmers' upland plots covering an extensive area in Bandarban hills. The major objective of the study is to demonstrate the superiority of strip cropping over the traditional shifting cultivation system that the hill farmers have been practicing over centuries.

2. Materials and Methods

2.1. Study Area

Bandarban district is located in the south-eastern corner of Bangladesh. The study area covers low (125 ft msl) to high range (1000 ft msl) hills spread over 22.15 to 22.21 N latitude and 92.20 to 92.27 E longitude. Shifting cultivation plots of 28 farmers of 3 villages (Tigerpara and Senior para of Bandarban sadar upazila, and Rajakhamar of Rowangchari upazila) were selected. In the present study participating farmers belonged to three major tribes-Marma, Tanchangya and Tripura in Bandarban.

The selected farmers were trained on an improved strip cropping system potentially suitable for sloping upland selected for a large-scale trial. Three variables or treatments tested were set: (i) strip cropping maize planted in rows 70 cm apart with 20 cm inter-row distance, (ii) strip cropping of cotton planted in rows 90 cm apart with 30 cm inter-row distance, and (iii) traditional shifting cultivation. Strip cropping sub-plots received appropriate rates of fertilizers. In shifting cultivation sub-plots, farmers planted crops of their choice and management following traditional practices.

Each farmer dedicated a plot measuring of 52 m x 30 m (or 0.156 ha). Forest regrowth and bushes in the plots were slashed, dried on the ground and cleared before planting. The main plot was split into five sub-plots vertically downward from upper part of the plot keeping a pathway between two adjoining sub-plots. Width of each sub-plot was 10 m accommodating strip crops. In view of household food security, rice was planted in two plots. Number of rows in strip cropping varied depending on crops. Farmers planted the trials at the onset of monsoon. The study was carried out February 2020 through January 2021.

Data on crop yields and/or revenues were recorded at harvest. In the case of rice and maize we deliberately used data on yields and revenues on 0.156 ha plot basis in addition to converting into ha for better interpreting and translating into the practice at household level. Each of our designated plots is representative of shifting cultivator's patch of land that she/he operates [19]. Data were subjected to statistical analysis wherever applicable.

3. Results

Maize, locally known as *mokka*, is a secondary staple crop in the CHT. Tribal farmers usually grow indigenous varieties/landraces of maize which are of long duration. Hill farmers harvest maize cobs prior to maturity when the crop attains R4 stage [20] without waiting for maturity. It is consumed either raw or parboiled in salt water. Harvested maize cobs are used mainly for home consumption and/or sale. Customarily, a portion of harvest is also used as deity offering to nearby temple and priest of the temple. Regardless of variation in faith, all the tribal farmers offer prayers prior to beginning of crop growing and again at the time of harvesting of major crop rice. Offering a portion of produce to Khyang (Buddhist temple) and Bhante (priest of a Khyang) is a common practice.

The first crop harvested from the three strip cropping treatments was maize. Farmers started harvesting maize cobs beginning mid-July and continued till mid-August. Since Bandarban farmers do not retain maize in the field till grain maturity, data was recorded by counting the number of cobs of staggering harvests. Table 1 gives the number of cobs harvested and mode of utilization.

Table 1. Variation in production and utilization of maize cobs (number) in a plot (0.156 ha) across locations

Location	Home consumption	Sale		Total
		Fresh cobs	Boiled cobs	
Rajakhamar	124	552	500	1176
Tigerpara	146	601		747
Senior para	128	400	482	1010
LSD0.05	ns	164	-	172

The number of maize cobs harvested per plot varied between 747 and 1,176 (Table 1). It was the highest in Rajakhamar and the lowest in Tigerpara. The variation in maize yield between Rajakhamar and Senior para was not statistically significant. Elevation of Tigerpara is much higher (1,034 ft) than other two villages. Maize crop in all three places encountered short spells of drought in late May through early June and it is probable that drought might have affected maize seedlings in Tigerpara resulting in such yield loss. Variation in yields may also be attributed to the spatial variation in soil characteristics [21,22].

Home consumption of cobs included the consumption by the members of farmer's family and the portion offered to temple and priest. For obvious reason the actual number of cobs offered as deity is not specifically mentioned. Number of cobs used for home consumption across the villages did not differ statistically. Nearly 14 percent of total harvested cobs was used for home consumption.

Farmers sold their maize cobs in the market either as fresh cobs or processing the cobs boiling in salt water. Value addition by roasting and boiling cobs is a popular practice in three hill districts including Bandarban. The proportion of fresh cob sale was 53% while 33% cobs were sold in the market parboiled.

Table 2. Revenue earned from maize sale (BDT) per plot (0.156 ha)

Location	Revenue (BDT.) earning from maize sale		Total revenue (BDT)
	Fresh cobs	Boiled cobs	
Rajakhamar	2622	4108	6730
Tigerpara	3007	-	3007
Senior para	2111	3484	5595

All the participating farmers sold the harvested maize cobs in the market. Farmers' revenue earnings varied widely across locations (Table 2). Total revenue varied between BDT 3,007 and BDT 6,730 giving an average of BDT 5,110 per plot. As expected, the lowest earning was recorded for the farmers of Tigerpara. It was less than 45% compared with that of Rajakhamar farmers. Reviewing Table 1 and Table 2 in conjunction will reveal that processed maize fetches more income than fresh cobs. Farmers of Tigerpara sold fresh cobs which could be the reason for disproportionate earnings. Distance from the market might be another reason. Maize was harvested at a time when most hill dwellers suffer from food shortage. Maize thus serves as an important commodity for household food security as well as for earning cash income.

Farmers in Bandarban grow indigenous varieties of upland rice since high yielding modern varieties are unavailable available [23]. Rice was harvested mid-September through early October. Rice yield data are presented in Figure 1. Yields obtained in Rajakhamar and Senior para were identical (average 415 kg) while significantly lower yield (312 kg) was recorded for Tigerpara.

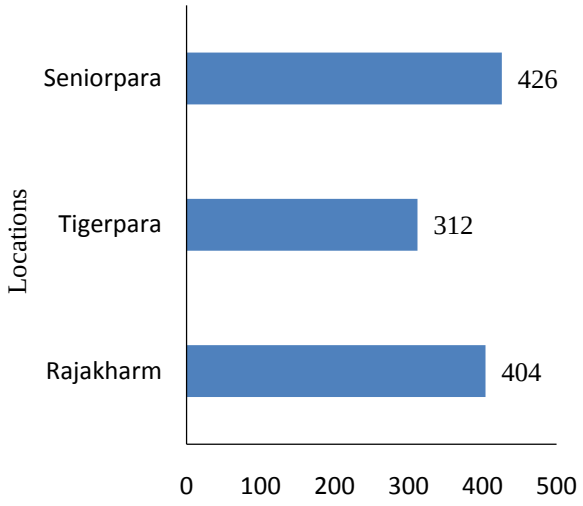

Figure 1. Variation in grain yield (kg per 0.156 ha plot) of rice grown in strip cropping across locations

Rice in shifting cultivation plots were also matured and harvested simultaneously. Farmers used the same indigenous variety of upland rice in both strip cropping and shifting cultivation plots. Variation in the grain yields of rice in shifting cultivation is shown in Figure 2. Location differed a little in rice grain yield obtained from shifting cultivation. It ranged between 341 kg (Rajakhamar) and 358 (Tigerpara) with a mean of 351.3 kg per plot. Tigerpara tended to have produced higher yield but the difference in yield across locations was not statistically significant.

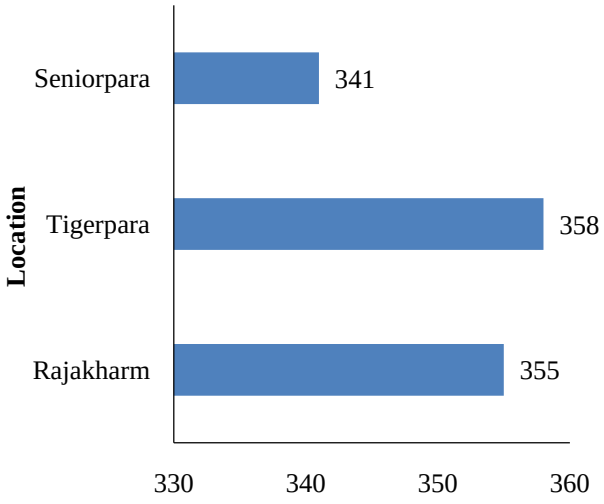

Figure 2. Variation in rice grain yield (kg per 0.156 ha plot) of rice grown in shifting cultivation across locations

Figure 3 presents a comparison of rice yields in shifting cultivation and in strip cropping by averaging yields over locations and converting plot yields into standard unit for brevity. Strip cropping tended to give higher yield but the difference between the two systems was rather minimal (8.35%). In the traditional shifting cultivation farmers usually dibble seeds disproportionately in order for allocating more areas to rice accommodating other crops in shifting cultivation. However, rice is perceived to encounter much more intra- and inter-plant competition [24] in shifting cultivation compared with rice grown in strip cropping.

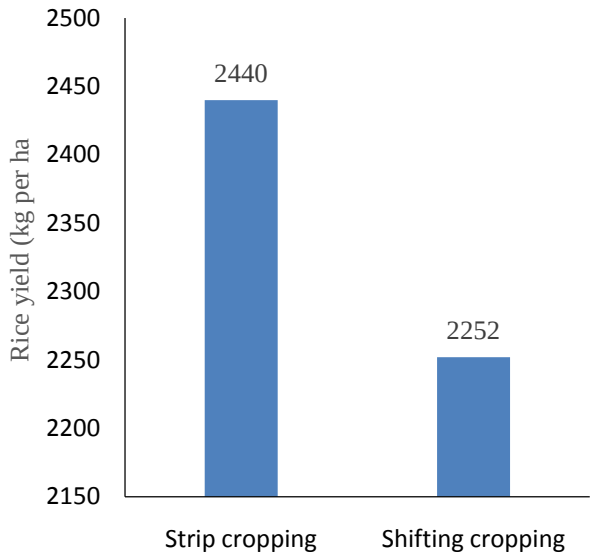

Figure 3. Variation in rice grain yields between strip cropping and shifting cultivation

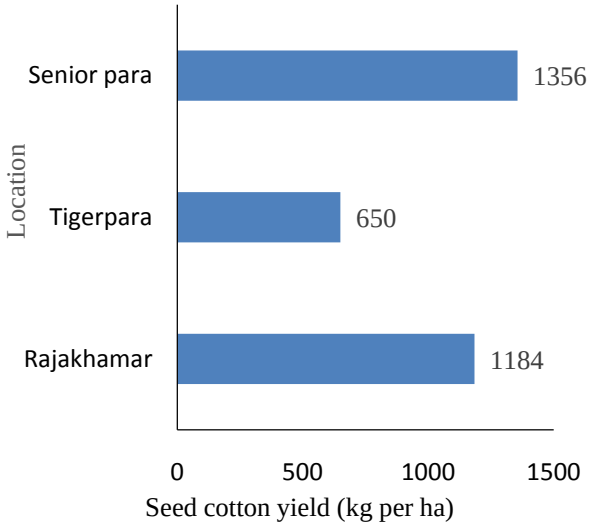

Figure 4. Variation in seed cotton yield across locations

Maize and rice were harvested in succession and in the experimental plots cotton as strip cropping and a few crops in shifting cultivation sub-plot were in the field past September. Being a long duration crop cotton remained in the field till mid-January requiring 3 pickings. Results of cotton harvests are presented in Figure 4. Seed cotton yield ranged between 650 kg and 1,356 kg per ha with an average of 1,063 kg per ha. Yield difference across locations were statistically significant. The highest yield was obtained in Senior para while the lowest yield was obtained in Tigerpara. Farmers in Tigerpara harvested 52% lesser seed cotton yield compared with Senior para and 45% lesser than that of Rajakhamar. The average yield of cotton was higher than average farmers' yield in the district but much lower than national average [25].

In the shifting cultivation plots farmers planted different crops of variable growth durations along with upland rice. Crop selection and the number of crops planted in shifting cropping plots was the choice of farmers [26]. These associated crops were harvested at different times for over 7 months July through January. In view of sparsely seed planting, variable coverage in the field, dissimilar yield parameters, we present aggregate revenue earned from the crops (Figure 5) instead of presenting yield data of individual crops. Revenue earnings from associated crops other than rice in shifting cultivation plots varied between BDT 2,040 and BDT 3,505 with an average of BDT 2,680. Revenue earnings varied markedly among locations. The highest earning was recorded for Rajakhamar followed by Senior para and Tigerpara had the least.

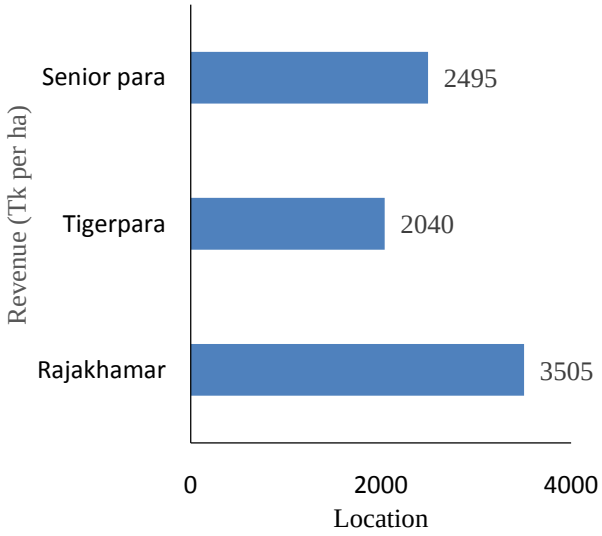

Figure 5. Variation in revenue earnings (Tk. per h from associated crops other than rice in shifting cultivation

In view of diversity of crops and disproportionate land area allocated to crops, two different production systems can be amenable to evaluate the crop performance provided a common denominator is selected. Revenues earned from each of three strip cropping, rice in shifting cultivation, and the aggregate earning from heterogenous crops in shifting cultivation other than rice was a choice for the analysis.

Paddy is not traded in Bandarban [14] and none of the participating farmers sold their paddy rice in the market. However, assuming a blanket rate of BDT 22 per kg paddy, we estimated revenue earnings from rice (both stripped cropping and in shifting cultivation). Cotton price is annually fixed by the government. Cotton was traded at BDT 60 per kg in 2020-21. For comparing system differences in revenue earnings from cotton and rice, we used average yield data of three locations and multiplied

by unit price of each commodity. Table 3 shows average revenue earnings from cotton, maize, rice (both shifting cultivation and strip cropping) and associated crops in shifting cultivation.

Table 3. Revenue earning from strip cropping of cotton, maize, rice and shifting cultivation crops (BDT per ha)

Production system	Crops	Revenue (BDT per ha)
Strip cropping	Cotton	63,780
	Maize	72,708
	Rice	53,680
Shifting cultivation	Rice	49,544
	Associated crops	2,680
	Rice+Assoc crops	52,224

Derived data calculated by multiplying yield with price (Table 3) were not subjected to statistical analysis. However, crops and production system showed appreciable differences in revenue earnings. Revenue from maize was the highest followed by cotton. Strip cropping of rice ranked third next to cotton. Mixed crops together with rice in shifting cultivation gave the lowest earning.

4. Discussion

Shifting cultivation is in transition throughout South and South Asian countries [6] and sustainability of shifting cultivation in Bangladesh is also being challenged [10,13]. Loss of forest cover, land degradation, loss of soil productivity due to narrowing of fallow length all contribute to challenges for the sustainability of shifting cultivation in the highlands of southeastern Bangladesh. However, better performing crop production system that thrives in the mountainous terrain depending on natural precipitation has not yet been evolved. In the present study superiority of strip cropping of cotton, maize and rice over the traditional shifting cultivation has been demonstrated. Although the differences in revenue earnings from three different crops in strip cropping are not spectacular, identification and selection of three crops in strip cropping system is of significance. Rice and maize offer option of coping with seasonal household food insecurity [2]. Maize is harvested at a time when most farm households face severe food deficits. Maize is a secondary food staple for the tribal peoples on the CHT. Surplus production of maize is a source of earning income. Results indicated that 14% of maize cobs harvested were consumed in the households, and the surplus (86%) amount of production was marketed indicating both popularity and market demand of the commodity.

Rice in strip cropping gave higher yield and economic return compared with rice grown in shifting cultivation although difference was small. This was not unexpected. Farmers plant enough rice seeds covering the plot allocating relatively much lesser space in mixed cropping under shifting cultivation. Rice plants stand is perceived to have encountered inter-specific competition in mixed than intra-specific competition in strip cropping [10], but the extent of difference manifested in yield is usually small. Planting of rice seeds in the upland for both strip cropping and shifting cultivation followed direct dry seeding (DDS) method. Dry direct-seeded rice is a process of crop establishment seeding in the non-puddled and unsaturated soil. Liu et al. [27] demonstrated that in China grain yield of dry direct-seeded rice, of 9.01 Mg/ha, is identical to grain yield of transplanted-flooded rice. Florence and McGuire [28] who reviewed a large number of published comparisons between crop mixtures and monocultures found that in 88% of the comparisons, the monoculture and mixture performed comparably, and in 19%, monoculture did better. Earlier, Singh and Ladha [29] reported yield reduction of direct dry seeded rice to the extent of 7.5% to 28.5% in India. Our results are in agreement with both McGuire and Singh and Ladha [28,29]. Farmers planted upland rice landraces that encountered stresses due to local ecological and environmental conditions [23] and might have acquired physiological attributes contributing to compensatory mechanisms to sustain growth and yield production.

Cotton in strip cropping had prolonged growth. In the hilly terrain, rainy season ceases in September. Even in shifting cultivation, most crops including rice are harvested by October. During the post-monsoon dry season, November through March, farmers do not grow crops in the hills. Cotton remained in the field until January when most shifting cultivation lands remain empty. Neither the farmers have job opportunity during the dry season [30]. Cessation of rainfall synchronizing with blooming of boll was favorable for cotton [31]. Seed cotton has assured market with stable price. Harvesting and marketing of seed cotton in dry season presents an opportunity of earning a substantial cash income that farmers can see a boon for them.

5. Conclusion and Recommendation

With an underlying objective of replacing traditional shifting cultivation in hilly terrain of the CHT in Bangladesh a three-crop strip cropping system has been designed and field-tested involving shifting cultivators. Productivity and economic returns of upland rice, maize, and cotton planted in rows maintaining systematic configuration were compared with crops grown in shifting cultivation on the same field. On-farm results demonstrated that maize, rice and cotton in combination produced higher economic return than the crops grown in shifting cultivation.

Shifting cultivation is a low input based, labor intensive, low productive agriculture. It is still being practiced in the CHT primarily due to non-availability of better production technologies promising higher yield and profitability. Despite the traditional shifting cultivation being deeply rooted in tradition, culture, beliefs, and myths of tribal population, it is conceivable that the CHT farmers would like to prosper adopting profitable farming practice at affordable cost. The rice-maize-cotton strip cropping has been designed keeping in view of land topography, socio-culture of tribal population and most importantly farmers' economic wellbeing and household food security. This study on participatory on-farm trials covering a large area in hilly terrain demonstrated that the system with three strategic crops being profitable and easy to adopt, strip cropping may be an important vehicle for replacing the

traditional practice of shifting cropping. But shifting away from subsistence farming for the transition to commodity cropping will be driven by a range of socio-economic and technical factors [32]. Adoption and sustainability of the three-crop strip cropping replacing the traditional shifting cultivation will require motivation, community participation, institutional support and market development. But switching to new practice will also require training and policy support. Large scale production of cotton will spur developing value chain actors like ginners and spinning mill. The demand for fresh and boiled cobs being limited and localized within communities and nearby markets, expanding maize production across districts will require farmers to produce grains and get into value chain linked to feed industry. The present study was conducted in villages and communities not far from the district town Bandarban. For large-scale production of maize in the CHT entails commercialization of agriculture that the government is striving for. Poor infrastructure and communication networks in the mountainous terrain, particularly in Bandarban district will place a challenge for developing such commercialization of agriculture in the CHT.

Acknowledgements

Krishi Gobeshona Foundation through its Competitive Grants Program provided financial assistance for conducting the study. We gratefully acknowledge the farmers who collaborated in conducting on-farm trials. Aung Swiy Singh Marma and M. Shah Newaz assisted us setting and supervising the trials amid COVID pandemic. We thank them all.

Statement of Competing Interests

Authors declare no competing interests

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