



Assessing land use changes and livelihood outcomes of rural people in Chittagong Hill Tracts region, Bangladesh

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Title
Assessing land use changes and livelihood outcomes of rural people in Chittagong Hill Tracts region, Bangladesh

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Abstract

Land use change is a pressing concern for the livelihoods of people in tropical developing countries. Changes in land use from swidden agriculture to smallholder tree dominated areas producing timber, fruits and cash crops can result in changing livelihood outcomes for rural communities. This paper examines land use patterns of rural households and the association with food production and income across three different zones of various forest proximity across a landscape gradient (remote, intermediate and on-road) in Chittagong Hill Tracts region of Bangladesh. We conducted in-depth semi-structured surveys of households (175-300) and farm owners (30) to collect information on people's perceptions of land use change, present land use patterns and contributions to food production and income. Our research found that more than half of the surveyed households experienced a decline in the land available for food production over the past 30 years. The land use patterns revealed decreasing crop lands (mainly swidden farms) and an increase in areas of planted trees within this landscape. However, household use of the reduced crop land has not affected food production in the on-road zone, whereas the diversity of food sources has declined. People living in more remote areas engaged in swidden farming and used larger areas of crop and fallow lands, fruit orchard and accessed natural forest lands that provide a diverse reservoir of food sources. The current land uses contribute to variations in annual household income across zones, with remote dwelling people earning less to those living closer to urban areas in the intermediate and on-road zones. In summary, this transition of land uses over three decades and changes in income and food availability cannot be generalised across the region because of zone specific differences. We recommend a broader and context-reliant landscape management approach in consideration of the diversity of forest and tree benefits for the livelihoods of people in the region.

Keywords: *Forest and trees; Swidden farming; Land use; Food; Income*

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3 29 **1. Introduction**
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7 31 For many centuries swidden farming¹ has provided subsistence foods and crops for income of
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9 32 rural communities in tropical developing countries (van Vliet et al., 2012; Fox et al., 2000).
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11 33 In recent decades, swidden farming systems have changed from subsistence farming to more
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13 34 commercially orientated land uses through the adoption of cash crops and smallholder tree
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15 35 cover in many parts of Southeast Asia, Latin America and sub-Saharan Africa. In the
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17 36 countries of South Asia, South-East Asia and Latin America (i.e. India, Laos, Peru, and
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19 37 Guatemala), land use change from swidden farming practices to commercial crops (i.e. cocoa,
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21 38 cassava) and plantation trees for rubber, palm oil, charcoal and wood products, has
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23 39 contributed to an increase in income for rural households (Behera et al., 2016; Cramb et al.,
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25 40 2009; Dressler et al., 2017). This transition from swidden to mainly cash crops by farmers has
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27 41 also been reported to have increased a household's ability to purchase a wide range of foods,
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29 42 such as meat and vegetables, and improved overall food security (Cramb et al., 2009;
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31 43 Rahman et al., 2017). This shift can also mean a corresponding decline in the diversity of
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33 44 land uses (in part swidden farms and fallow lands) and reduced numbers of crops grown in
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35 45 these farming systems and food sources from natural forests (Castella et al., 2012; Cramb et
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37 46 al., 2009; McLennan & Garvin, 2012; Thaler & Anandi, 2017). The changes in land uses
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39 47 from subsistence to commercial crop production has also affected the availability and
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41 48 accessibility of lands for uses by people in Latin America and South-East Asia regions
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43 49 (Coomes et al., 2016; Cramb et al., 2009; Vongvisouk et al., 2014).
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47 51 Despite the growing global land use change in rural contexts, there is limited evidence for
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49 52 how land use transitions impact livelihood outcomes particularly in terms of food production
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51 53 and the capacity to generate income. Recent studies from across the tropics have shown that,
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53 54 due to land use transitions, the benefits accrued to rural communities from forests and other
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55 55 non-forest land uses can vary or differ across a single landscape (Rasmussen et al., 2017;
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57 56 Sunderland et al., 2017; Vongvisouk et al., 2014; Fantini et al., 2017; Broegaard et al., 2017).
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59 57 Given this context, to understand the relationships between forest and agrarian changes with
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61 58 the concomitant livelihood outcomes, it is necessary to consider a broader landscape scale

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¹ Swidden farming involves the clearing of woody vegetation for the temporary production of staple food crops mixed with other annuals and/or perennials.

approach that encompasses a more systematic socio-ecological approach (Sunderland et al., 2017). Although broad definitions are largely lacking, landscapes represent a complex mosaic of natural resources (forest and non-forest land uses) which is managed for achieving multiple objectives (Reed et al., 2020). Landscape approaches as they relate to conservation, agriculture and other land uses seek to address the increasingly complex and widespread environmental, social and political challenges that transcend traditional management boundaries. As such, they are not prescriptive, deterministic or siloed in disciplines; they require multi-and inter-disciplinarity, defying definition and characterization (Pfund, 2010; Reed et al., 2020).

Bangladesh, one of the most densely populated countries in the world, is experiencing increasing pressure on its remaining natural resources, including its forests (BFD, 2020). The decline in natural forests has continued and the net forest conversion increased from 5800 ha in 2000 to 8200 ha in 2010 and 10,000 ha in 2017 (FAO, 2020). The natural forests alone in the Chittagong Hill Tracts region have declined from 172,000 ha in 1963 to 84,000 ha in 1990 and to 70,000 ha in 2005 (FAO, 2015). The gradual loss of trees either for revenue generation or through illegal felling and clearing/burning practices in swidden farming has increased the area of non-forestland in this region (Ahammad & Stacey, 2016). Swidden farming has been a traditional form of agriculture primarily practiced by ethnic groups in the region (UNDP, 2009), although its long-term contribution to local livelihoods and forest conservation has been questioned due to the loss of forest area, population growth and ineffective land management (Gafur et al., 2003; Rahman et al., 2011; Thapa & Rasul, 2006). In the last few decades, government extension programmes (mainly under forest and agriculture) have considered the improvement of swidden farming land uses and the promoted timber/fruit tree-based land uses within the communities as being beneficial to the conservation for soils, the restoration of forests and the enhancement of food security (Ahammad & Stacey, 2016; Rahman et al., 2016). However, the trends and impacts of these land use changes on food security and household income are rarely documented.

This paper examines the current land use patterns and their associations with the livelihood outcomes of rural people in three forest-agriculture contexts (i.e. remote, intermediate and on-road zones) in the CHT region of Bangladesh. To understand the current land use patterns and the associations with the livelihood outcomes of rural households, this study addresses three questions: 1) what have people experienced in terms of land-use change for food

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production over the past 30 years?; 2) what are the relative uses of planted tree covered lands to crop lands, fruit orchard, fallow land by households across the three zones? and 3) how do forest and non-forest contributions to food production and income differ across the three zones across this particular landscape? In this paper, ‘forest’ refers to natural forests and planted forest land is used to represent monoculture tree cover established by the households. Non-forest land includes agricultural lands used for annual crops (e.g. cereals, vegetables) in swidden farming (upland) and low-land agriculture, fruit tree orchard with fruit trees and crops (i.e. orange, banana, pineapple) and fallow lands (e.g. mixed vegetables and banana).

2. Methods and materials

2.1. Study area setting

The CHT region is located in South-Eastern part of Bangladesh and comprised of three administrative districts (Rangamati, Bandarban and Khagrachari). The CHT region comprises predominantly of agrarian communities whose livelihoods largely rely on diverse agriculture farming and the uses of forest resources. On average half of the annual income of all CHT households is generated from different agriculture related sources (UNDP, 2009). Local ethnic people are involved in the use of a wide range of forest and tree products including non-timber forest products (NTFs) for both subsistence and income-generated purposes (Ahammad, Stacey, & Sunderland, 2019). People use more than 60% forest products, including the NTFs they collect for their own usage, while selling the remaining 40% at local markets to generate cash income (Kar & Jacobson, 2012; Misbahuzzaman & Smith-Hall, 2015). The dependence on forest resources is relatively higher in more remote locations from town/urban centres, but, in general, 50% of the raw materials used in building permanent or temporary shelters are timber or NTFs (Ahammad et al., 2019).

Swidden farming is a traditional agricultural practice used predominantly by ethnic indigenous populations, which accounts for almost 16% of all land use in the CHT each year (Bala et al., 2013). In remote parts of the region, people mostly rely on swidden farming for cultivating a wide range of annual crops followed by fallow land for growing bananas and trees (Ahammad & Stacey, 2019)(Table 1). Key features of economic and environmental resources including forest and land uses across the landscape transition and study area are shown in Table 1. The proportion of the swidden farming practices is relatively higher in and

around government owned forests, where people rely on this land use type having limited land ownership or access to roads and thus markets in the region. Current swidden farming activities are managed alongside planted fruit-tree species (e.g. pineapple, banana, jackfruit, mango) in areas of relatively more secured and private land ownership of the households and better access to markets. Intensive forms of agricultural land use (i.e. a mixture of fruit trees and teak plantations, often termed agroforest systems), are now observed in almost one-third of the areas closest to the markets and roads (Bala et al., 2013). Aside from swidden farming, small area in the valleys and low-lying lands are used for cultivating irrigated agricultural crops.

The CHT contains natural and planted forests over almost two-third of the lands in the region (BFD, 2020). The natural forest is broadly characterised by evergreen and deciduous tree species accounting for approximately 15–20% of the total forest types. Planted forests are mainly comprised of mixed natural and planted trees, or plantations of teak (*Tectona grandis*). These occur both in government reserve areas, as well as on private lands. There is no record of the amount of privately-owned land that has been converted to planted forest, but in many villages of CHT region, agricultural lands have been gradually converted to planted forest, mainly with teak or gamar (*Shorea robusta*) (Table 1). Although timber harvesting in government-owned natural forests is currently prohibited in Bangladesh, the region still supplies a significant amount of valuable timber from private planted forests to meet the large regional and national demand (Ahammad & Stacey, 2016).

2.2. Methods of data collection

This study is based on data collected through surveys of rural households across the three study zones (remote, intermediate, on-road) in CHT region (Figure 1). These three zones represent a gradient/continuum of land-use modification from natural forests to planted tree based land uses and agriculture characteristics with swidden farming to planted or fruit orchard land uses. They also possess variations in terms of economic activities as well as different degree of proximity to roads and market in CHT region to form a landscape gradient of change (Deakin et al., 2016) (see also Table 1). By conducting a scoping survey in 2016, three distinct zones were selected for the identification of villages along them for data collection (Ahammad & Stacey, 2016). Each zone was comprised of four sample villages, with a total of 12 villages being selected for the main (i.e. household and farm) surveys

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undertaken in 2015-2016 (Figure 1). The household and farm surveys were conducted on the households in four villages from each zone (Table 2).

2.2.1 Household surveys

Household surveys were undertaken within 304 households, selected randomly from 12 villages within the three zones in CHT region. In the 12 villages, 60% of a total of 475 households were surveyed over one year, from May 2015 to September 2016 (Table 2). Households were surveyed using structured questionnaire interviews conducted by trained enumerators who were familiar with the local languages and each zone of the region. Each household survey was completed in one sitting, although any particular residual issues were investigated further, more informally, where necessary. Usually the head of the household was the respondent for the structured questionnaires. In the absence of the head of the household, another family member, aged 18 years or older was interviewed.

We interviewed the respondents in relation to their perceived land use changes over the past 30 years, the present land use, the size of planted tree holding area, the types of food crops cultivated and the relative contributions of forestland and tree covered land to the household's annual income for 2015-2016 (Table 2). The respondents were asked, "How has land use changed in your households in the past 30 years?". The answers to the perceived land use changes were collected as the responses "increased", "decreased" and "stayed the same". Then we asked, "What is the size of total land holding of this household and the specific land uses?". The survey also covered information on household economic activities and their relative contributions to the annual income for 2015-2016. Due to a lack of willingness on behalf of the participants, and the time-consuming nature of finding out income-related information, only 176 households offered any information on their annual income. We asked the respondents, "What are the main income sources for the household, and what are their relative contributions". By asking this question, we quantified the roles of forestland, including natural forests and planted trees, non-forestland and other sources in the household income in monetary terms.

2.2.2 Farm survey

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196 Following the household survey, 30 household farms were surveyed to gather information on
197 the food produced from their land (i.e. crop lands, fruit orchards, fallow land) including food
198 gathered in forests (i.e. wild foods such as vegetables, bamboo shoots) and planted tree lands
199 (Table 2). The patterns of land use and associated food production capacity were the focus of
200 the farm survey. From a total 30 sub-samples, we selected 10 from each zone (2-3 in each
201 village). The respondents were selected based on their engagement in farming activities and a
202 categorisation of the dominant land use types (agricultural, planted trees and fruit orchard
203 land uses) in each village of the zone. A farm typology was developed for the dominant land
204 uses (i.e. seasonal or annual crops, fruits and trees) and categorisation of households for farm
205 surveys by undertaking a group discussion at village level. The farm-level information
206 collected included: the patterns of land use (crops and tree-based land for timber and fruit
207 orchards and fallow land) for each household (seasonal or annual); the most important land
208 uses and crops; and the total food production (produced and gathered from the forest). All
209 information was based on the previous 12-months memories of the respondents. Each farm
210 represented the combined area that the respondent cultivated for agricultural purposes,
211 including seasonal crops, fallow land, fruit orchards and planted tree areas (Sunderland et al.,
212 2017). For the sake of consistent terminology in this study, the terms “ ‘farm’ and ‘land’ ”
213 were used interchangeably in the surveys, analysis and discussions.

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2.4. Data analysis

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217 Both qualitative and quantitative information was collected from the household and farm
218 surveys. The qualitative data relates to the responses of the household respondents on
219 perceived land use changes, while the quantitative data includes the size of the land uses,
220 including planted tree holding area, and the amount of food and income contributions from
221 forestland and tree cover lands. Following the sustainable livelihood framework of DFID
222 (1999), data related to the livelihood capital/assets (i.e. natural such as forest or tree lands,
223 agricultural crop lands etc.) and strategies (i.e. agriculture cultivation, waged activities, forest
224 or tree product harvesting) were collected to determine the livelihood outcomes (i.e. income,
225 food production). The livelihood outcomes investigated mainly focused on the data relating

to food production and income, and the livelihood strategies relating to forests, planted trees and other land uses including waged activities, employment etc.

In the first stage of the data analysis, the household responses relating to land use change (i.e. increase, decrease or stayed the same) for the 30-years period from 1990 to 2015 were quantified. The proportions of the qualitative responses “increased”, “decreased” or “stayed the same” were calculated from the total household responses, and a further categorisation was made at the zone level. Second, the average size of the land used for crops, fruit, planted tree areas for timber and fallow land was estimated at the household level, and the subsequent variations were calculated across the three zones. Third, the annual mean amount of food produced and gathered from these different land sources was estimated at the household level, and then further categorised across the zones to determine their relative difference. For the agricultural crops and fruit production, the amount of food produced by the farmers in the last season was calculated and adjusted to represent one year. The amount of forest-source foods gathered was calculated based on the respondents’ recall of the last three months. Based on the memory of the respondents, we calculated the approximate amount of foods gathered from natural forest or planted tree areas for each household annually. Finally, information collected on the cash income from forest (e.g. natural, planted trees) and non-forest (i.e. agriculture, fruit, wages, employment, business, others) sources were calculated to give the total annual income of each household and provide relative comparisons across the zones. The amount of food gathered from natural forests and consumed by households was reported by the households. The income from agricultural crops, fruit and forest products was calculated based on their relative prices at the market.

The main statistical analysis used involved frequency analysis and descriptive statistics (i.e. mean, standard deviation and error, Pearson’s chi-square and correlation). Statistical Package for the Social Sciences (SPSS) v.23 software was used for all the calculations and statistical analyses. Pearson’s chi-square test of independence was conducted to find relative differences in the perceived changes in land uses for food production in the households in the three zones. To elucidate the significant association of land use and zone level, the Pearson’s chi-square test of independence was used again. This test was followed by the changes in different land uses and planted tree covers. A Kruskal-Wallis test was conducted in order to illustrate draw the difference between food production and annual income in terms of their sources and zone contexts.

3. Results

3.1. Household land use by zone

The surveyed households reported changes (increase, decrease, same) in the amount of their land under food production over the past 30 years (1985-2015). Figure 2A shows significant differences in the perceptions of the respondents who reported change in their land use for food productions ($\chi^2 = 76.19$, $df = 2$, $p < 0.001$). Over half of the households (56%) experienced a decrease in the size of their lands used for food production, while just over a quarter (28%) reported no change. Only 16% reported an increase. The changes in land use reported by the households differed across the three landscape zones ($\chi^2 = 31.91$, $df = 4$, $p < 0.001$). A high proportion (70%) of households in the on-road zone experienced a reduction in their lands used for food production. In the intermediate zone, relatively more households (40%) used crop lands for food production stayed the same. Only in the remote villages in close proximity to forests, households (27%) reported an increase in land used for food production over the 30-year period.

The reported current land use patterns included agricultural lands for annual crop cultivation, fallow land, fruit orchards, and planted tree cover for timber (Figure 2B). Overall, crop cultivation was the main land use in 50% of the households in all zones, followed by 23% of the households with planted tree cover, 15% with fallow land, and 10 % with fruit orchard (Figure 2B). Crop land was also the main use of approximately 60% of the households in both the remote and on-road zones, but contributed only 30% in the intermediate zone. There was more fallow lands in the households of remote zones (35%) than in the intermediate (8%) and on-road (5%) zones. In contrast, 50% of the households in the intermediate zone reported having managed tree cover lands compared to only 25% in the on-road and 8% in the remote zones. Fruit orchards were maintained by 12% of the households across the intermediate and on-road zones, but by only 5% in the remote zone.

The size of land used for crop agriculture, planted tree cover, fruit and fallow (left uncultivated) varied among the households in the three zones (Figure 3). Among the types of land use, planted tree cover occupied the greatest area (mean: 1.07 ± 0.10 ha), followed by crop land (mean: 0.57 ± 0.53 ha), fruit (mean: 0.25 ± 0.05 ha) and fallow land (mean: 0.21 ± 0.01 ha).

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3 292 ha) (Figure 3). The land use areas also differed across the zones. Comparatively, the size of
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5 293 annual crop land (mean: 0.8 ha) and fallow land (mean: 0.5 ha) use was greater in the remote
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7 294 households than in the intermediate (mean crop land: 0.4 ha, fallow land: 0.33 ha) and on-
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9 295 road (mean crop: 0.3 ha; fallow:0.34 ha) zones (Figure 3). The area of land used to cultivate
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11 296 fruit was greater in the intermediate (0.562 ± 0.12 ha) than on-road (0.10 ± 0.10 ha) and remote
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13 297 (0.06 ± 0.04 ha) zones. Household-managed planted tree areas were greater in the on-road
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15 298 (mean:1.3 ha) and intermediate (mean: 1.2 ha) zones compared to the remote zone (mean:0.7
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17 299 ha). In total, as of the surveyed year (2015-2016), the mean land holding size for all of the
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19 300 households was 1.91 ± 1.89 ha, with size being greater in the intermediate zone (2.36 ± 2.17 ha)
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21 301 than in the remote (1.62 ± 1.16 ha) and on-road (1.72 ± 2.03 ha) zones.
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25 303 3.2. Land use for food production
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29 305 The main food crops produced by the household land holdings were agricultural and fruit
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31 306 orchards for cash and subsistence uses. Table 3 presents the amount of food produced from
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33 307 different types of land use, including gathering from forests. In 2015-2016, the average
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35 308 amount of food produced by the surveyed households was 8093 ± 814 kg (Table 3). Crop
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37 309 lands were mainly used for food production (5026 ± 736 kg yr^{-1}) compared to fallow land
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39 310 (1697 ± 368 kg yr^{-1}), fruit (962 ± 185 kg yr^{-1}) and gathering in natural forestland (430 ± 70 kg yr^{-1}).
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41 311 Rice, maize, different leafy and root vegetables, beans, tobacco and turmeric were grown on
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43 312 crop lands. The food gathered from natural forests mainly comprised vegetables, flowers and
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45 313 fruit.
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49 315 The amount of food produced and gathered from the various land uses differed significantly
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51 316 across the zones (Table 3). The amount of food produced and gathered was greater in the on-
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53 317 road zone (10096 ± 1821 kg yr^{-1}) compared to the remote (7410 ± 1331 kg yr^{-1}) and intermediate
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55 318 (6830 ± 905 kg yr^{-1}) zones. Among the food sources, the highest crop production was also in
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57 319 the on-road zone (8526 ± 1493 kg yr^{-1}), which was twice the amount in the remote (3480 ± 827
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59 320 kg yr^{-1}) and intermediate (3109 ± 583 kg yr^{-1}) zones. On the other hand, fruit production was
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321 found to be the highest in the intermediate zone (1300 ± 317 kg yr^{-1}), followed by the on-road
322 (1068 ± 378 kg yr^{-1}) and remote (962 ± 185 kg yr^{-1}) zones. The amount of food produced and
323 gathered from fallow land and forest land was greater in the remote zone.

3.3. Relative contributions of forest and non-forest sources to household income

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326 Table 4 shows the economic activities of the households, include from forest land (forest and
327 tree product collection) and non-forest including crop agriculture, fruit orchards, waged
328 labour, employment and small businesses, which provided diversified sources of annual
329 income. The mean annual income for the households was USD 1662±99 yr⁻¹, with
330 agriculture-related activities contributing the highest economic returns (USD440±57 yr⁻¹)
331 (Table 4). Employment generated the second highest income (USD297±65yr⁻¹) to the
332 households, for those engaged in a formal job, followed by small business (USD211±37 yr⁻¹).
333 Forest income (USD175±30 yr⁻¹) came from the collection of forest and tree products
334 including bamboo, foods and timber, and was slightly higher than the waged (USD162±23yr⁻¹)
335 and fruit (USD159±18 yr⁻¹) incomes. Livestock provided USD129±30 yr⁻¹, just higher than
336 the other income activities (rent and driving: USD102±25 yr⁻¹).

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338 Table 4 illustrates that the household economic activities and associated income contributions
339 differed among the three zones. The overall mean annual household income was higher in the
340 intermediate zone (USD1989±201 yr⁻¹) than in the on-road (USD1728±179 yr⁻¹) and remote
341 (USD1239±100yr⁻¹) zones. Agriculture provided the highest source of household income in
342 the on-road and remote zones (USD567±146 yr⁻¹ and USD515±71 yr⁻¹, respectively), which
343 was almost double that of the intermediate zone (USD234±40 yr⁻¹). In contrast, in the
344 intermediate zone, employment generated the highest annual income (USD570±162 yr⁻¹)
345 which was also slightly higher than any other sources among the zones. Forest and tree
346 sourced economic activities (selling timber, bamboo and food) provided the second highest
347 income source (USD204±36 yr⁻¹) in the households of the remote zone. In the intermediate
348 zone, fruit-based income (USD274±41 yr⁻¹) was the second major source of income, followed
349 by forest and tree products (USD257±72 yr⁻¹) and small business (USD222±59 yr⁻¹).

350 Compared to the remote and intermediate zones, there was significantly less forest income
351 (USD65±30 yr⁻¹) in the on-road zone, although income from small businesses and waged
352 activities were relatively high there (USD340±84 yr⁻¹ and USD288±50 yr⁻¹ respectively).

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354 The Pearson's correlation analysis indicated the relationships between the different income
355 sources of the households and their total household income (Table 5). Total household
356 income was positively correlated with employment (0.567) followed by agriculture (0.493),

fruit (0.400), livestock (0.371), forest (0.243) and small business activities (0.236) (Table 5). Only waged income was found to be negatively correlated with total income. At the zone level, agricultural land use was correlated with total household income in the on-road (0.756) and remote (0.696) zones. On the other hand, forest sourced income was related to total household income in the on-road (0.408) and intermediate (0.294) zones. The same pattern of relationship exists for waged income and total household income in the on-road zone. However, livestock income was positively related to the household income in the remote (0.592) and intermediate (0.491) zones.

4. Discussion

The current land use patterns of the CHT show a small increase in planted tree cover due to the decline of agricultural production areas over the past 30 years. The increase in areas with planted trees and fruit orchards has been associated with the decline in farm areas used mainly for swidden farming. Our findings are similar to those of studies that have determined that swidden landscapes are being transformed by a higher proportion of planted tree cover in the Southeast Asian region (Cramb et al., 2009; Newby, Cramb & Sakanphet, 2014). The decline in swidden farming in the CHT region is also consistent with a global review by Heinimann et al. (2017), leading the authors to project a continued decline of swidden over the next 20 years, and its complete disappearance across Asia, Africa and Latin America by 2090. Heinimann et al. (2017) pointed to the disappearance of swidden farming in Bangladesh by 2030, although they did not identify the land use trends that might replace this form of land use. The findings from the CHT study revealed a replacement of swidden farm areas by a trend towards mainly planted tree cover across the three zones.

The land use extent and planted tree cover differed across the remote, intermediate and on-road zones of the region. This finding supports those of McLennan & Garvin (2012), who revealed that the abandonment of traditional subsistence agriculture, followed by new land uses with timber plantations varied among the five communities depending on their locations in Costa Rica. Coomes et al. (2011) determined that initial land size and the mode of land acquisition influenced the changing land use and acquisition of tree cover in the swidden farming system of an Amazonian peasant village. In the CHT region, households in the intermediate and on-road zones had larger land holdings and more tree-cover land, including

fruit orchards, with secure ownership being more prevalent in these zones than in the remote area. Conversely, the crop land and fallow areas were large in the remote zone, with the households having limited tree-cover land. Overall, the households that maintained swidden farming without secure ownership had smaller holdings. Thus, the geographic location differed in terms of management regime, which contributed to different current land use sizes in the region.

The contribution of land use to overall food production or gathering varied along the three zones in CHT. The food production (cereal, vegetables) is largely subsistence oriented in the remote location, although people maintain diverse food production from swidden farming, and fallow and fruit-tree land uses. The greater food production from swidden farming contrasts with the finding of Islam et al. (2007), who reported relatively low food production from land used in swidden farming. This suggests that generalisations about the declining role of swidden farming in subsistence level food provision may underestimate the importance of the land use for maintaining diverse food sources in different landscapes. Alternatively, households had relatively small crop land areas and large tree cover areas in the on-road zone, but their capacity for food production tended to increase. This finding supports research that found farm size patterns were not a barrier to high productivity in Indonesia (White, 2018). The recent increase in growing cash crops (vegetables, beverage, spices food groups), and the intensive use of lands, has contributed to the increase of food production capacity in the on-road zone. However, people's dependence on forest-sourced food has tended to decline in the intermediate and on-road zones, where the expansion of planted tree areas has resulted in monoculture timber plantations and cash crops affecting the diversity of food sources and diets. This trend implies a possible trade-off between planted tree cover and diverse food provisioning services such as wild vegetables gathered from fallow land and forests in CHT region.

Looking at the incomes from various livelihood strategies, agricultural land use is a major contributor to the household economy, with employment and small businesses also being significant. Cash-crop agriculture, planted tree land and off-farm activities including employment, have contributed to an increased income for the households in the intermediate and on-road zones. The highest annual household income in the intermediate zone indicates an increased contribution from the employment sector. Waged-income activities increased in the on-road zone as a result of changes in land uses towards intensive agriculture, involving

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3 424 crops, fruit orchards, and the timber-harvesting sector (i.e. planted tree cover), which have
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5 425 required more labour. As a result, a direct reliance for income on the forest sectors remains
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7 426 higher in the remote and intermediate locations than in the on-road area, where waged
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9 427 activities associated with timber harvesting are viable alternative economic activities.
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11 428 Nevertheless, neither forest income nor waged activities will sustain the economies of
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13 429 households that do not have access to, or the economic capital to adopt tree areas. This is of
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15 430 concern to the people in the remote zone, where swidden farming and natural forest use is not
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17 431 a sustainable way to maintain their incomes in the long-term .
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19 433 **5. Conclusions**

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24 435 This study explores land use patterns and their association with livelihood outcomes (food
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26 436 production, income) in rural households along three zones in different forest/agriculture
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28 437 landscapes of CHT of Bangladesh. Our study revealed a diverse range of land use, from
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30 438 crop-lands under swidden farming practices to fruit orchard, fallow land and planted tree
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32 439 covers. The transition from swidden farming to tree cover land uses cannot be generalised
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34 440 across the CHT region (Sunderland et al., 2017). For instance, there was more crop land used
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36 441 under swidden farming practice in the remote location, while this decreased in the on-road
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38 442 and intermediate zones, being replaced by fruit orchards and planted tree areas. In examining
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40 443 livelihoods, it was revealed that the largest area of tree-based land use had a positive
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42 444 association with household income, which included waged activities related to timber
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44 445 harvesting. Notably, the use of smaller crop lands has not affected the level of food
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46 446 production in the on-road zone, where people without access to crop land or household
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48 447 owned tree cover lands are likely to depend on waged activities to secure their income. Only
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50 448 in the remote locations do higher proportions of households uses cropland, forestland and
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52 449 fallow lands for diverse food sources, with and options for food security.
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55 451 Our findings offer a critical insight into land use transition patterns/trends, and the need for
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57 452 specific interventions for maximising the benefits of forest and tree-based land across the
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59 453 broader landscape. The economic value of planted land influences household land-use
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454 decisions, promoting a transition from swidden agricultural land uses to tree plantations in
455 specific locations of the region. However, swidden farming remains important land use
456 practice in their livelihoods despite it viewed as a low-level contributor in food production.

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3 457 Remotely-located people use swidden farming and natural forests (i.e. state owned) to secure
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5 458 a diverse range of dietary and income options. Nevertheless, the decreasing trend of swidden
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7 459 farming has raised concerns over its future replacement with planted land uses can generate
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9 460 diverse food and income sources in the remote area. The current national forest policy of
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11 461 Bangladesh has advocated for the development of plantations alone for the region rather than
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13 462 specifying a more integrated approach for forest, agriculture and plantation management at
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15 463 the landscape scale (GoB, 2019). Since the current planted land use has considered only
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17 464 economic gain over a wide range of livelihood benefits including food and environmental
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19 465 services, a more inclusive land management strategy can contribute to supporting forest and
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21 466 tree based land uses which meet the long-term diverse livelihood needs of the region.
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For Peer Review

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Figure Legends

Figure 1: Study villages indicated by dot point on the map across three zones: 1: remote; 2: intermediate and 3: on-road in CHT region of Bangladesh

Figure 2: (A) Percentage of households (n=304) that experienced changes in the amount of their land used for food production in the period 1985-2015; (B) Percentage of households using lands for four main purposes (crops, planted tree cover, fallow, fruit orchard); (C) Percentage distributions of household land use at the zone level. hhs=households.

Figure 3: Relative (mean) size of land uses for crops, fruit, planted trees for timber and fallow land of households across three zones in CHT region (source: household survey 2015-2016).