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Livelihood of Local Communities and Their Dependence on Dry Forests in The Central Dry Zone, Myanmar

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Abstract

Local communities depend on forest resources for their livelihood in Myanmar. In four different rainfall zones, 185 households of residents living near the remnant forests were sampled. The majority of respondents, 87% of the total surveyed, were farmers. The average annual income was 1263 USD (1USD = 1,000 MMK) However, the lowest annual income was found among landless households (664 $USDyr^{-1}$). Like farmers, even the landless householders' main source of income was dependent upon agriculture. Those living in landless households were primarily agricultural wage labourers. Overall income was significantly different among the four areas, increasing with better accessibility to income options. Local communities depended upon nearby forests for firewood with an average annual consumption of about 4.9 cubic metres of stack fuelwood per household, per year. The wood was collected mainly from natural forests in wetter areas, while in the drier areas, over 50% of wood for fuel was gathered from their farm-boundary trees. The poorer farmers, landless wage labourers, with less than 2 ha of land, were likely to be dependent upon forest resources for their income. When considering rural planning options for various local communities in each of the four zones of Myanmar, realistic diversifying income sources must be factored into the forest conservation equation.

Keywords: *central Myanmar; remnant dry forest; conservation*

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Abbreviations:

CDZ	:	Central Dry Zone
SS	:	Study sites

1. Introduction

Natural forests provide many tangible products for the rural population in developing countries [1]. Tropical dry forests and woodlands are considered to be the most important resources for the rural poor, providing a wide range of products [2]. Important diverse, dry-forest goods range from wood and thatch for homes, include foods such as fruits, nuts, mushrooms, wild vegetables, animals, and even provide access to medicinal plants. Dry forests also supply other household products such as tools and fuels, while supporting approximately 2 billion people living in and nearby them. [3]. On the other hand, humans have depleted the dry forests. Felling for firewood and agricultural expansion are some well-known, major reasons for forest depletion [4–7]. It was revealed that the tropical dry forests were the most threatened among other tropical forests [8].

Dry forests usually grow in and around the central dry zone (CDZ), the driest area in the country [9]. This region has a range of annual rainfall between 600 and 1800 mm, with a dry season of 2 to 7 months [3]. In Myanmar (formerly known as Burma), dry forests refer to dry, deciduous forests and semi-desert, scrubs that are normally growing in regions of relatively light rainfall [10–14]. An estimated 3.4 million hectares of dry forests still remain in Myanmar, covering 9.7% of the total forest area of the country, [11,15]. Like other tropical dry regions, the CDZ is one of the most densely populated areas, following the more fertile delta region, in Myanmar [16]. It is home to more than 10 million people, according to the national population census in 2014[17]. The cropland in the CDZ is mostly rain-fed and primarily dependent upon monsoon rains[18,19]. Irrigation is only available for 10% of the area, although the main river of Myanmar, the Ayeyarwady (Irrawaddy), flows through the CDZ. As previously mentioned, the dry zone farmers are among the poorest, due to the nature of highly variable and uneven distribution of rainfall. [20]. Hence, the local farmers often seek other seasonal sources of income. [7]. The dry forest is also used to feed their livestock of cattle and goats[7]. It is easy to burn land from the dry forest to convert it for agricultural usage [7]. For these reasons, the central dry zone was recognized as one of the deforestation hotspots with an annual deforestation rate of 0.7% [4].

This study, therefore aimed to explore the overall income and livelihood strategies of local communities living around remnant dry forests in central Myanmar, by means of a household questionnaire survey. Their resource usage and dependences on forests were also studied. We

hypothesized that the livelihood of local communities and their dependences on forests differ among availability of forest resources in different rainfall zones. These data may provide insight of the livelihood activities and dependency impact on forest loss. This information may also help develop programs for long-term conservation of the remnant forests with strategies to improve the livelihoods of local communities.

2. Methodology

2.1. Characteristics of the CDZ

The dry zone of Myanmar is situated approximately between 94° 20" to 96° 50" in longitude and 19° 50" to 22° 55" in latitude (Figure 1). It is referred to as the central dry zone (CDZ) representing the dry, central part of the country, including an estimated 54,390 km^2 Most of the area is under rainfall isohyets of 40 inches (1025 mm). The mean annual rainfall of the CDZ is 680 mm, [19], that is only about 3.2% of the country's total rainfall [21]. Rainfall is most plentiful during monsoon months; from late June through September [18,19]. The remaining months have very little rainfall. The temperature in the CDZ is remarkably high. The highest temperature was recorded in April and May, with temperatures as high as 45°C in certain places of the CDZ[21]. The lowest temperatures are usually in January, with records of temperatures as low as 10°C [21]. The area is sandwiched between rugged hill terrains and mountain belts; however the elevation of the CDZ is comparatively flat.

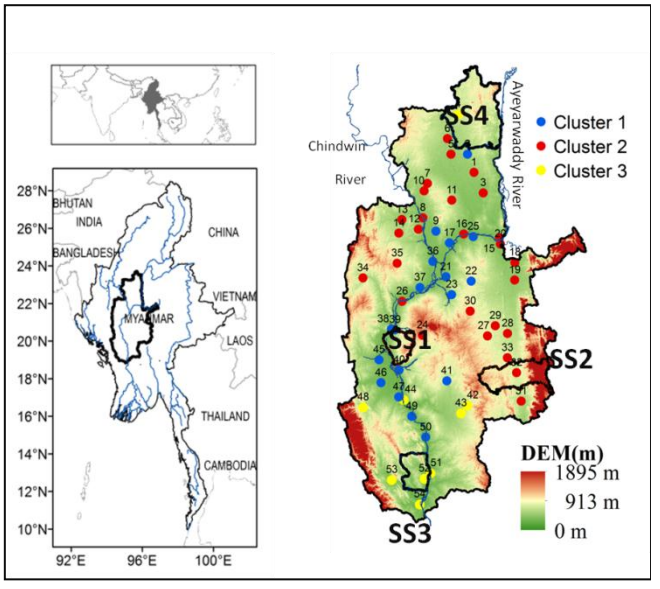

Figure 1 (a) Location of the CDZ and (b) case study sites include elevations with climate zones classified by K-means cluster analysis

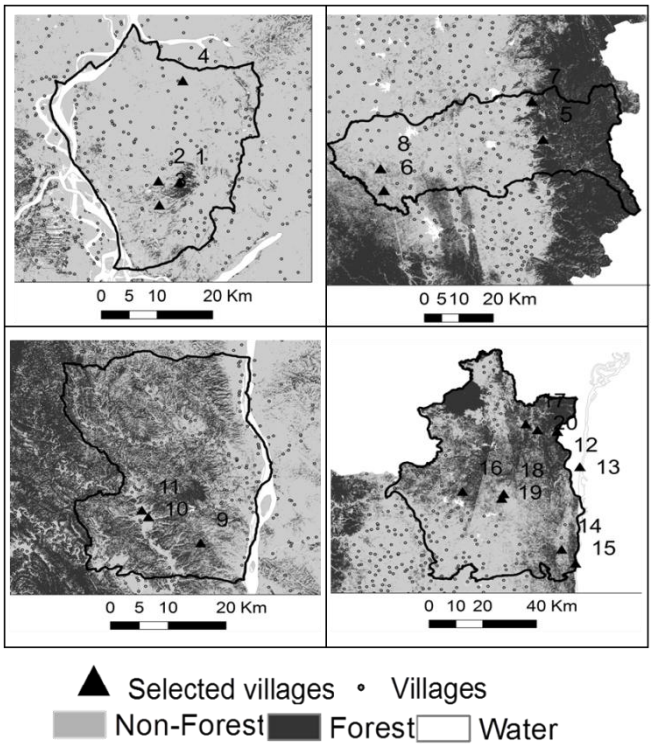

Figure 2 Forest cover maps of study areas in the Central Dry Zone

Hence, it has had the longest history of human settlement and is currently the second largest populated area in the country, after the fertile delta region, located at the south. According to the 2014 national population census, the population density of the CDZ is 122 in square kilometres; higher than the national average, with 76 persons per square kilometre. [17]

The CDZ was generally defined as a tropical dry forest[7], while vegetation such as. *Dipterocarp*, *Shorea*, and thorny trees such as *Acacia catechu* are mainly found here [10,22]. However, some evergreen forests occur in higher mountains, for example on Mount Popa (1500 m asl) and in the hilly periphery of the CDZ. Despite the natural terrain, most of the areas in the CDZ are occupied by agricultural land with dense human settlements. For several decades, it has been reported that the originally scattered natural land in the CDZ is being largely replaced by agricultural land. [15]. These agriculture lands in the CDZ are mainly dependent on monsoon rainfall. Dry, resistant crops such as various kinds of pulses (pigeon pea, chickpea and green gram, etc.) and edible oil crops such as groundnut and sesame are major crops grown in the CDZ [23]. The cultivation of paddies and winter crops are usually found in irrigated areas and in some wetter areas. However, the ability to plant annual crops without irrigation is decreasing in the areas of rice paddy fields.

2.2. Selection of study sites and study villages

Livelihoods and resource usage are largely governed by climate factors. The remaining forests cover resource availability. Four study sites later referred to as SS1 to SS4, were selected based on criteria below. Sites from different climatologic rainfall zones were classified by K-means cluster analysis using monthly rainfall during the rainy seasons from 2000-20 15 (May to October). The three clusters were identified in Figure 1b as having the lowest rainfall zone (cluster 1), the highest rainfall zone (cluster 3) and intermediate rainfall between (cluster 2). The forest cover map of 2014, and the forests loss between 1989 and 2014 were estimated by maximum likelihood classification using Landsat imageries. Forests in this study are considered to be all natural vegetation types in the CDZ. The climate and forest conditions of the four sites are shown in Table 1.

Table 1 General characteristics of four sites selected for the study

	SS1	SS2	SS3	SS4
Area (km2)	980	2067	1189	4167
Altitude (m) [a]	0-431	153-1416	0-490	0-633
Population Density per km² [b]	205	112	84	71
Rainfall (mmyr-1)	549	794	939	985
Forest Area (% of total area)	5.5	33.3	43.7	40.3
Forest Loss 1989-2014(%)*	No	28.8	29.3	34.4
No. of villages per site [c]	230	234	158	268
No. of villages sampled (N=18)	4	4	3	7
No. of households sampled (N=185)	49	55	51	30

[a] Extracted elevation from ASTER GDEM http://gdem.ersdac.jspacesystems.or.jp/
[b] Population census 2014
[c] Townships General Administration Department (GAD)

SS1 belongs to cluster 1, representing the driest area while SS3 and SS4 belong to cluster 3, the wettest zone. SS2 is located in an intermediate rainfall zone between other rainfall clusters. The topography is relatively flat throughout almost all of the zones except that SS2 has higher altitudes on its eastern part, with peaks ranging as high as 1895 m. The forest coverage in SS1 is the least among the study areas, with 5.5% of its total land mass covered with forests, while SS3 and SS4 still remain within the largest coverage area of forests, 43.7 % and 44.3 % of their total land area, respectively. Conversely, SS1 has the highest population density. It was once a well-known area for oil fields since the British colonial period, during the 1880s [14]. It has been the only field leading oil production in Myanmar [24]. Although the area is located nearby the Ayeyarwady River, it cannot be used for irrigation to all the agricultural areas. The major forest types found in these areas are deciduous shrubs and thorny scrubs. The SS3 and SS4 have lower population densities due to limited accessibility to forest resources. For instance, SS3, located on the western bank of the Ayeyarwady River has not yet constructed a-bridge to access the eastern bank that is normally more developed. SS4 is more developed than SS3, with a higher population density, compared to the other two areas. SS2 was located at a rainfall zone between the two locations listed above. Of these four study sites, 18 villages were selected (Figure 2). These villages are almost all located nearby the remaining forest area.

2.3. Data collection and Analysis

Data were collected during November and December 2013 and from December 2014 to January 2015. Village heads and aged people with historical knowledge provided the general background history of the 18 villages involved in the study. The surveyed villages represented less than 5% of total villages on each site (Table 1). For intensive data collection, 185 households were randomly sampled from among those 18 villages. Households were screened for selection from general information of villages, paying particular attention to the approximate proportion of different occupations and the location of farmland holdings. The interviews were conducted, including either an adult male head of the household or another adult from the household; for example, the household wife or the parents, if no household head was available at the time of surveying. A household in this study was defined as people living together and sharing their incomes.

The number of respondents per study site ranged from 49 to 55 (Table 1). The average intensity of sampled household (sampling intensity) was less than 5% of total households of all sampled villages. The respondents were questioned about their age, education, household size, annual income and expenses, land holdings, and farming practices. Annual income and outcome of each household was calculated by the respondents recalling the income during previous growing seasons by including information from all sources. The information of their dependency on nearby forests including fuelwood extraction, annual use of fuelwood and other forest resources were also collected. Then, those collected data were shown using descriptive statistics, such as non-parametric, one-way analysis of variance to investigate the variations among the study sites (Kruskal-Wallis tests). The analysis was conducted using the Statistical Package for Social Scientists (SPSS ver 16.0) software.

3. Results

3.1. Profile of research villages

The background of sampled villages is shown in Table 2. Half of selected villages were established after 1990; the year of political and government system transition in Myanmar. The history of the villages began in the colonial period. Large-sized villages were common in SS1 where forest cover remained the least. In contrast, the small-sized villages were mostly located in SS4. The number of households per village ranged from 20 to 694. The history of the villages was likely

to be linked with the size of village, the current available land for agriculture, and the remaining forest cover.

Table 2 A brief profile of sample villages

Characteristics	SS1 (n=4)	SS2 (n=4)	SS3 (n=3)	SS4 (n=9)	Total (N=18)
No. of villages by established year					
Before 1990	3	1	2	4	10
After 1990	1	3	1	5	10
No. of villages by household size					
>200 households	3	2	1	3	11
<200 households	1	2	2	6	9

SS1 to SS4 denotes for study site1 to 4 shown in Figure 1.

Agriculture was the most common livelihood in selected villages. The major crops grown in all locations were oil-seed crops and pulses (Table 3). Agricultural practices in all regions were mostly intercropping, the practice of growing two or more crops simultaneously in the same field, in order to secure at least one crop. The crops with short harvest periods, such as green grams are mostly intercropped with the ones that need longer harvest periods such as pigeon peas and long staple cotton (*Gosspium arboretum*). The lowest number of crops grown and intercropped was typically found in SS1. In wetter areas, including a part of SS2, it was highly possible to practice double cropping, planting a second crop immediately following the harvest of a first crop. The first crops were grown in the first rain period from the end of May to August and the second crops were cultivated in the beginning of the second rain period from September to the following February. Rice cultivation was rare in all four sites and it was mostly grown only for self-consumption. No households sampled cultivated rice for commercial sales.

Table 3 List of crops grown in research villages

	Common name of Crops	SS 1	SS 2	SS 3	SS 4
Oil-seed crops	Peanuts (*Arachis hypogaea*) (Rainy season)	○	Δ	○	○
	Peanuts (*Arachis hypogaea*) (Winter)		Δ	○	○
	Sesame (*Sesamum indicum*) (Rainy season)		Δ	Δ	○
	Sesame (*Sesamum indicum*) (Winter)				Δ
	Sunflower (*Helianthus annuus*) (Winter)	Δ	Δ		
	Niger Seeds (*Guizotia abyssinica*)				Δ
Pulses	Pigeon Pea (*Cajanus cajan*)	○	○	○	○
	Green Gram (*Vigna radiata*)	○	○	○	○
	Other pulses	■	Δ	Δ	○
Cereals	Soghan (*Sorghum bicolor*)	Δ			
	Maize (*Zea mays*)	Δ	Δ	Δ	○
	Paddy (*Oryza sativa*)(Rainfed)		■	■	■
Industrial crops	Cotton (*Gosspium arboretum*)	○			
	Cotton (*G.hirsutum*)		○	○	○
	Sugarcane (*Saccharum officinarum*)				○
Vegetables	Onion (*Allium* spp.)	■			Δ
	Chillies (*Capsicum annuum*)		○	■	■
Other crops	Castor-oil plant (*Ricinus communis*)				Δ
	Bananas		Δ		

○ Major crops
Δ Minor crops
■ Minor crops only for self-consumption

3.2. General characteristics of respondents

The social characteristics of the respondents are shown in Table 4. The majority of participants continued to be from traditional households, mostly headed by men. The age of those surveyed ranged from 18 to 80 years old, however the average age was between 40 and 60. The educational system has declined in Myanmar over the past decades. It was found that 79% of the respondents mostly only finished their education up through elementary school levels (<4 years). The respondents were mostly farmers. The farmers of the CDZ rarely depended only upon farming. The productivity risks involved with uncertain rainfall and poor soil quality had driven most of the famers to seek external and/or seasonal sources of income. Therefore, 58% of the total respondents were farmers, but with multiple income sources. Farmers owned 2.83 ha of farmland on average and the majority of respondents owned less than 2.02 ha. However, there were some households with up to 20 ha of land holdings among the respondents. Fourteen percent of the respondents were engaged as seasonal wage labourers and the other three percent represented non-farmers. Non-farmers were employed as one or more of the following: salaried staff, middle-men, local shop owners, or they were engaged in farm tractor rentals or as gold-mining contractors.

Table 4 Characteristics of respondents in selected study sites percentages (%). No significant differences at p<0.001 among four sites.

Characteristics	SS1 (n=49)	SS2 (n=55)	SS3 (n=51)	SS4 (n=30)	Total	x^2	df	p
Gender								
Male	90	91	88	87	89	0.43	3	0.93
Female	10	9	12	13	11			
Occupation								
Farmers (+multiple-jobs)	61	55	51	70	58	6.10	3	0.107
Farmers	22	33	35	17	28			
Wage labourers	10	11	12	7	10			
Others	6	2	2	7	4			
Age (Average age of total respondents=49years)								
<40	16	25	35	27	26	2.9	3	0.41

40-60	57	64	55	50	57	0		
>60	27	11	10	23	17			
Education								
0	4	9	2	0	4	4.8	3	0.18
1-4 years	69	78	82	87	78	8		
5-8 years	16	11	12	7	12			
≥9years	10	2	4	7	5			
Family size (Mean family size of respondents=5 persons)								
≤6 persons	71	82	86	77	79	3.7	3	0.3
≥6 persons	29	18	14	23	21	0		0
Land holdings (Average land holding per households=2.8 ha)								
0 acres	14	13	14	13	14	12.	3	0.01
1-5 acres (0-2 ha)	51	18	61	43	43	81		
5 -10 acres (2-4 ha)	22	24	25	30	25			
>10 acres (>4ha)	12	45	0	13	19			

3.3. Overall livelihood of local communities

Overall mean household income was 1263 USDyr^{-1}. A range of 500-1500 USD represented the largest frequency (Figure 3). Gini Index of Income Inequality (G) was 0.27 in SS3 to 0.4 in SS1.

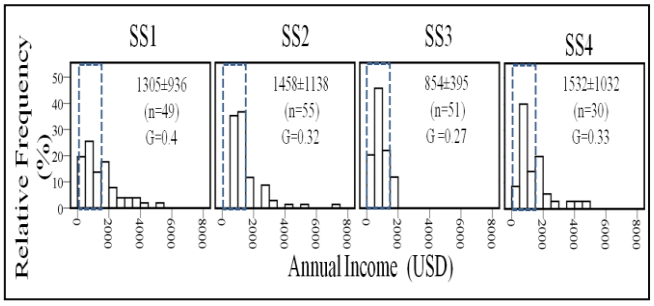

Figure 3 Income distribution among the study sites, G denotes Gini coefficient. (1USD is approximately equal to 1000 MMK)

Figure 4 showed the aggregated results of major sources of income and expenses of all respondents in study sites. The five major source of incomes were: crop sales, labour wages, local shops (both vendors and food stalls), livestock sales and transfers (remittances from family members working elsewhere inside and outside of the country as seasonal to permanent workers on sugarcane or rubber plantations, in urban restaurants and teashops, in mining, or as housemaids, etc. Forest products, mainly fuelwood and bamboo from nearby forests, accounted for 2 % of overall income of households.

On the other hand, over 69% of total incomes were spent on buying staple food, mainly, rice. Educational expenses accounted for 16%. Social activities in the village are traditionally culturally compulsory at the village levels, therefore, it accounts for an average of 11% of total expenditure. Almost all villages in this study have only elementary schools; hence the students above elementary grades were staying outside of the villages where higher education was available. Households spent an average of 16% on education. However, the respondent households were able to use 2 % of their total income for farming investments.

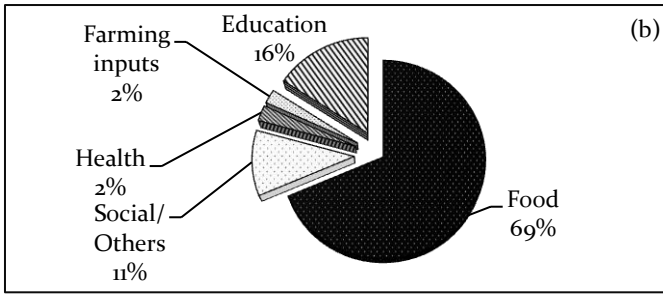

Figure 4 Overall average (a) income and (b) expenditures structures of respondents (N=185)

3.4. Comparison of livelihood by selected sites

Different occupations represent different levels of gross income of the households in all areas (Figure 5). The average annual household income of all respondents was 1263 USD. The annual income of pure farmers (1177USD) is similar to the overall average of total respondents. While farmers with multiple income sources, earned average incomes just above the average in all areas. The annual income of landless people is the lowest, about $664 on average. The average annual incomes of others such as businessmen, salary staff are recognized the highest (1833USD).

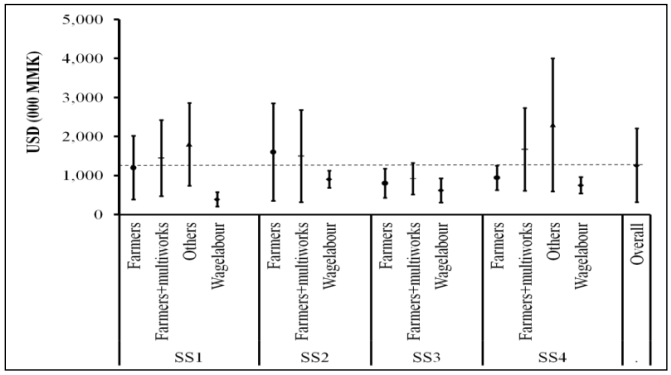

Figure 5 Relative frequencies of annual incomes of four study sties (N=185). The dotted line is drawn at the average overall income of total respondents (1263 USD) for comparison of average income of different occupations by study sites. Bars indicate the range of minimum and maximum values.

The average income with major sources of income was shown in Figure 6. The average income appeared to demonstrate a direct relationship between higher income levels found in areas with increasing rainfall and forest coverage, except in SS3, where the average income was the lowest among them. Agriculture was the main source of income over all areas. Households reported income from a total of multi crops. Various pulses such as beans were the crops that provided the greatest income in all sites. Bananas, cotton and chillies were additional cash crops found in SS2. While sesame and Niger seed crops were also important cash crops in SS4. Income from agriculture covered 75 to 100% of the expenditure of farmers.

Livestock breeding was also a noteworthy source of income for these households. Cattle represented the greatest income provision from livestock; followed by pig husbandry Chicken and other poultry were raised by the largest number of households (near 90%). Cattle and pigs were mainly sold in the market according the monetary needs of a household, whereas poultry was mostly consumed at home. Goat and sheep husbandry were primarily found in some SS1 and SS2 villages, in relatively dry areas.

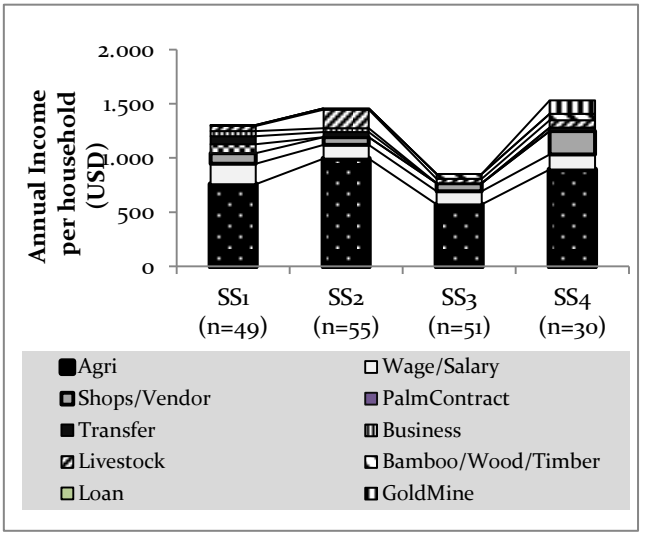

Figure 6 average overall annual incomes of respondents in four study areas (x^2=20.2, df=3, p<0.01).

The remittances transferred from family members working outside of the area were found in almost all areas except SS3. The highest proportion of such income accounted for 18% of total income in SS1, followed by SS4, where the information for migration was accessible from their local seniors and contacts. However, no respondents received that kind of income in SS3.

Other options such as palm products and gold mining were localized. The former was only available in SS1, accounting for 18% of household income, while the latter was found in SS2 of and SS4, accounting for only 2 % of income. Most of the respondents also received their income from sales of local processed products such as bean paste, fried beans, and palm sugar (shop/vendor in Figure 6). It also supports seasonal income for the majority of the household (5 to 14 %).

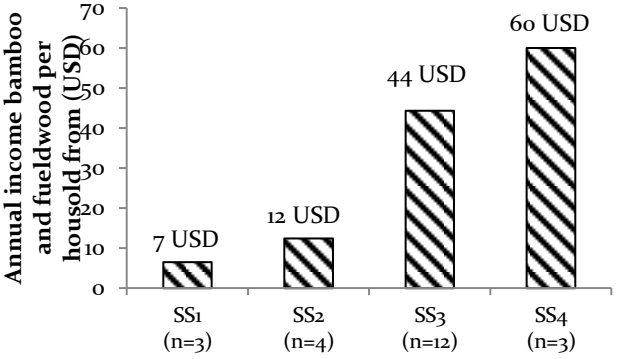

Figure 7 Average incomes from bamboo and fuelwood of respondents who engage the business.

Forest resources (Figure 7) accounted for only 2% of household annual income on average. In the driest areas, the absolute income from the forest is approximately 7 USD per year, accounting for 1% of their income. However, in the wetter areas, SS3 and SS4, collection and availability of wood fuel and bamboo gathering is more common and relatively high. Absolute income generated through wood and bamboo sales in SS3 and SS4 constitute 44 USD and 66 USD per year that accounts for 5% and 4% of their income, respectively.

3.5. Dependence on forest resources

The local communities in the study areas mainly depended on forest for fuelwood (Table 5). Other products such as bamboo, bamboo shoots, mushrooms, honey, medicinal plants, thatch and wild meat were also collected in the areas, where available (Table 6).

Table 5 Use of fuels and source of fuelwood of respondents in percentage (% of respondents per individual site)

Attributes	SS1	SS2	SS3	SS4	Total
Major fuels	**n=45**	**n=34**	**n=51**	**n=24**	**N=154**
Wood	18	97	84	92	69
Wood+Crop residue	80	3	14	8	30
Crop residue	2	0	2	0	1
Source of fuelwood	**n=37**	**n=32**	**n=51**	**n=25**	**N=145**
Forest	41	16	100	80	63
Farm	43	75		4	28
Forest+Farm	3	9		4	3
Farm+Bought	8				2
Forest+Bought	5			4	2
Bought				8	1

Traditionally, wood is a major source of fuel in the research villages (Table 5). In total, 69 % of respondents used wood for fuel while the other 30 % additionally used other fuels such as crop residue (the roots and stems of

pigeon peas, sesame and cotton), palm materials (palm stalks and leaves). They were used seasonally, after the harvesting season of each crop. The non-wood fuel was particularly used in the drier areas where the availability of wood was limited. Conversely, crop residue is usually burnt on farms as bio-fertilizer, particularly in the wet areas. Regarding fuelwood, 65% of households collected fuelwood from nearby forests, while 26% of them used trees they conserved from their own farmlands. Other households, engaging labour forces, collected fuelwood from the natural forest. Fuelwood is also available in the local market within the villages, but households purchasing fuel from the markets accounted for only 1% of the total respondents. On average, each household used 4.9 cubic meters of stack fuelwood per household, per year. The highest amount of fuelwood was used in the wet area (SS4) followed by the driest area (SS2).

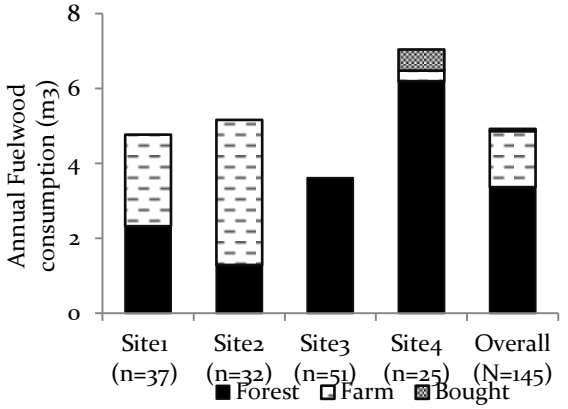

Figure 8 Fuel consumption per household per year. The fuelwood shared from forests are shown in bold. 1 cubic meter stack is approximately equal to 0.3 cubic meters solid volume. There was significant difference of sources between four sites ($x2=20.2$, $df=3$, $p<0.01$).

Besides firewood, the extraction of other forest resources varied with the current condition of the remnant forest and its availability. Several types of mushrooms were picked seasonally in all areas while other resources were available in all but the driest areas. Seasonal young bamboo shoots and honey were the most commonly collected forest resources for self-consumption. Wood resin derived from particular trees such as *Dipterocarpus tuberculatus* and *Shorea* spp. and grass for thatch was gathered. , Rabbits and wild birds were hunted to eat. Wild vegetables and fruits (*Boscia variables, Terminalia chebula, Emblica officinalis, etc*), and some medicinal plants (*Croton* sp., *Morinda* sp.) were also extracted from the forest in all areas other than the driest zone. Considering overall quantities for all forest products collected by the people, only 10 to 30 % of available forest resources were for selling. Bamboo culms and wood resin were collected mainly for selling.

Table 6 Resources collection of the respondents from nearby forests in percentage (%)

Resources	SS1 (n=11)	SS2 (n=17)	SS3 (n=51)	SS4 (n=16)	Total (N=85)
Bamboo shoot [c]	-	71	98	63	76
Honey [c]	-	71	94	50	72
Mushroom [c]	82	57	82	38	72
Vegetables [c]	-	-	10	-	7
Medicinal plant [c]/Resin [s]	-	-	6	6	5
Thatch [c,b]	-	14	6	19	8
Bamboo culm [b]	-	-	4	19	6
Wildmeat [c]	-	-	4	-	2

[c] for own consumption
[s] for sale
[b] for both consumption and sale

The numbers of households earning their income from forest products were observed in only 22 households that accounted for 12 % of total households sampled. Both the farmers with land holdings of less than 4 ha (10 acres) and landless households (wage labourers) earned their income from the forest (Figure 9). Those incomes are mainly derived from sales of fuelwood followed by bamboo in areas where it is available.

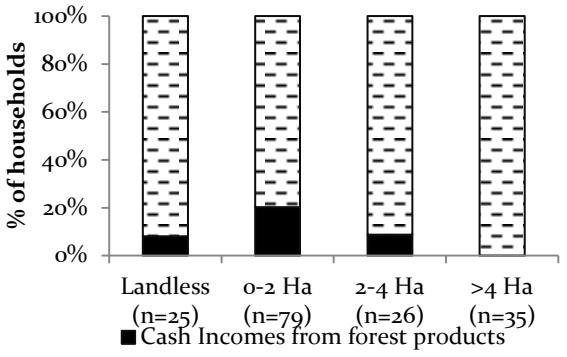

Figure 9 Percentage of households depending income source on forest products by farmland area class (N=185)

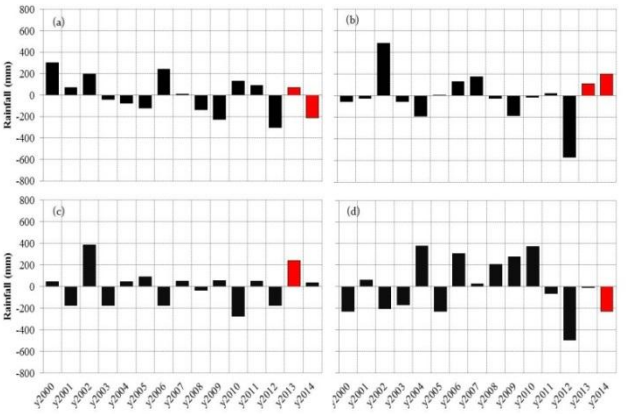

Figure 10 annual rainfall departures from mean annual rainfall of (a) SS1, (b) SS2, (c) SS3 and (d) SS4 during 15 years (200-2014).

4. Discussion

4.1. Livelihood of the local communities of the CDZ

The majority of the local communities in the CDZ were farmers Agriculture constituted the major source of income for both farmers and landless households whose major livelihood was agricultural wage labour. Forests provided significant proportions of their overall income that was significantly different among study sites. The lowest income, 664 USD was documented among agricultural labourers and in farmers with land holdings less than 2.02 ha. It is likely the reason for lower annual incomes in SS3 where two-thirds of famers have approximately less than 2 ha of land and no more than 4 ha of land.

In addition, the information collected from non-agricultural income sources was also considered to be important to augment overall income in all areas. Localized products such as palm products and gold mining are also likely to be factors yielding the difference in overall income between the four sites. Furthermore, unpredictable seasonal and temporal rainfall may have decimated their annual income. For instance, many households in SS3 responded that their crops were lost in 2013, due to flash floods. Small rivers nearby had overflowed from heavy rainfall. Figure 10 illustrates that the annual rainfall in 2013 was 220 mm higher than the mean annual rainfall of ten years since 2002. In SS3, as their main crops were on the flood plain of river, the farmers lost most of crops in 2013. Flash floods appeared to have affected almost all of the respondents, even among the highest levels of income. Hence, income conditions in SS3 depended partly on this climate event.

Typically, the remaining forest cover and resource availability were different among the four sites. Other optional income sources were also varied among these four areas. Thus, the amount of rainfall, forest coverage and type of forest are tangible reasons for the income differences among the different areas.

4.2. Forest dependency

Removal of firewood for fuel, is the most prevalent form of extraction from the forest in this study and is also a prominent pattern that has been reported in many dry forests [5,6,25]. Fuelwood is the only forest product that is required on a daily basis for cooking and heating. The sale of fuelwood was an asset, particularly for the low-income farmers who hold less land. In addition, the farmers within the study areas generally raise cattle for labour purposes and for local transportation. Most of the famers have at least a couple of cows. The grazing areas for farmers are mostly in nearby forests. Some farmers, who have more land, keep some area for growing cattle feed. Some also have enough labourers to collect animal feed from forests. However, the farmers who lacked both wider land space for grazing and labour, depended mainly on forests for grazing. Recent research revealed that grazing by local communities in nearby forest had a higher probability of more forest product extraction at the time of grazing their cattle [7]. These farmers generally used the forest more than the others did and they were likely to extract forest products such as a bundle of fuelwood per grazing time.

The sampled households in this study showed a low intensity of collection from the forests except for fuelwood and bamboo culms. The extraction of other products was the least in the driest site, SS1, where the forest cover was also the least. Hunting for wild game and collecting medicinal plants were uncommon in all areas, except by professionals with those areas of expertise. The collection of other food products from the forest such as mushrooms, bamboo shoots, and wild fruits, were more common. They were mainly used for their own consumption except

bamboo shoots, which were both sold to generate income and consumed at home.

4.3. Forest dynamics

Recent research revealed that globally, the tropical dry forests have had the highest levels of decline compared to other tropical forest types [5–7]. Degradation of forests and loss of species by over-use continues to happen in many tropical dry forests [6]. In this study, the level of forest loss was likely to be related to the availability of resources from the forest areas, in spite of the fact that the loss of forestland was found to be highest in SS4, where forest cover was still high. The fuelwood usage was the highest in high forest-loss areas. Additional fuels were used and the fuel reserves were gathered from where their farm boundaries were lacking. Another implication of depleting forest dynamics was tied to land holdings. The poor income generated from less land holdings combined with the incidence of irregular rainfall were likely associated with higher dependency on forest products. Besides, increasing population in CDZ and less land availability may force rural people to depend on forest resources in the long run.

On the other hand, no further forest loss was currently observed in the driest areas, SS1. Out-migration is increasing in the area where people are accessible to information on job opportunities. The palm sugar collectors who are big consumers of fuels are recently fleeing to outside of the villages for the better income and consequently the fuelwood needs might decrease. Current economic growth and increasing employment opportunities will absorb poor people in rural area and may reduce the pressure on the forests in those areas.

4.4. Conservation implications

This study revealed that fuelwood extraction put pressure on forest depletion in the past and is still the driving force of further deforestation. In the driest area, where the tree cover is the least, farmers adapted by collecting fuelwood from trees at the farm boundary and used additional fuels such as crop residues. Those activities should be equally practiced in areas where forests are still remaining. Simultaneously, systematic fuelwood plantations with high density of short rotation fuelwood species must be introduced to help reducing the pressure on natural forests. Community forestry and agro-forestry with fast-growing tree species are better options to fulfil the needs for fuelwood and mitigate further extraction of fuelwood from forests. Those activities in the fields should be spread among farmers through education and supply of suitable planting materials. Besides, it is essential to make them stakeholders in developing forest conservation and sustainable management strategies.

Animal husbandry programmes, is one alternative income source of local communities in the central dry zone, but it should aim to be used in a more sustainable way. In addition to these measures, new agricultural techniques are required to improve so that population needs can be met on limited cropland and by avoiding endless conversion of forest into cropland. Agricultural intensification by use of proper ecological based management strategies is a good example to sustain agricultural yields [26]. Proper water and soil management strategies in the CDZ is the most promising way to improve the crop yields and to mitigate their loss by unpredictable rainfall[27]. Overall, the efforts including both ecological and social points of view must be integrated to achieve the conservation of the remnant dry forest and the sustainable use of the remnant forests for peoples in the CDZ.

5. Conclusion

Accessibility to income options was the most important source for overall economic improvement among the areas. The income generated from forests varied depending upon the availability of forest resources in the four different climate zones. Therefore, the creation of innovative employment opportunities and the development of strategies are needed for optimal extraction of forest resources. The highest priorities are addressing the allowable limit of deforestation, while improving the livelihood of the local inhabitants. Introducing both better technology that increases agricultural productivity, and marketable species in agroforestry systems, while using proper water and soil management strategies are the most promising ways to improve their income in the CDZ. Hopefully, these strategies may protect further expansion on forestland. Normally, the, main source of livelihood of local agricultural communities, and woodfuels, their major energy source for daily use, contribute to cropland shortage via higher demands of an ever-increasing population. These factors point to a high probability of the depletion of remaining forests in the near future. Therefore, conservation strategies should also be considered before they completely lose their remaining forests. In addition, the farmers' adaptation to fuelwood shortages in the driest areas by planting fuelwood tree reserves at the farm boundaries and using additional fuel sources such as crop residue should be practised in all other areas where forests still remain. Overall, integrated considerations are needed by exploring all possibilities of developing and applying detailed but comprehensive, consistent information of the availability of forest resources; climate and income options for sustainability of both remnant natural forests as well as the local people.

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