Financial and environmental benefits from fruit trees in Myanmar's central dry zone

Case Study from Htee Pu Climate Smart Village

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Abstract

The village of Htee Pu in the Township of Nyaung-U, Mandalay Region suffers from drought, water scarcity, infertile soil, and high ambient temperature being part of Myanmar's central rry zone area. One of the Climate-Smart Agriculture (CSA) technologies and practices introduced by the International Institute for Rural Reconstruction (IIRR), Climate Change, Agriculture and Food Security (CCAFS) Southeast Asia, International Development Research Center (IDRC) and the Community Development Association in the village was fruit tree-based agroforestry. This study estimated the potential financial and environmental benefits that can be derived from the CSA option.

The study revealed that the potential market value of the fruits harvested would amount to USD 1.07 Million from 2021 to 2035 or an average of USD 71,072/year. The production of fruits represents the provisioning ecosystem service of the fruit trees. Per household, the average financial benefit could amount to USD 47,398 over the 15-year period or USD 3,160 per year. In addition, the fruit trees would be able to provide a regulating ecosystem service by being able to potentially sequester 5,682 tCO2 per year with an estimated value of USD 47,725. Fruit production and carbon sequestration have a combined economic value of USD 118,797 per year.

There is an upsurge in global interest in ecosystem restoration and the rehabilitation of degraded landscapes. The findings of this study are relevant to environmental agencies working to stabilize the central Dry Zone of Myanmar as including dryland horticulture and small farm agroforestry will benefit not only the local environment but also the people living in the area by making fruits available for their nourishment and livelihood. Development and agricultural agencies, on the other hand, can include CSA as a pathway for addressing degradation on small farms and associated landscapes.

Keywords

Climate-smart agriculture; agroforestry; dry zones; ecosystem service; carbon sequestration

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Acronyms

CCAFS	Climate Change, Agriculture and Food Security
CDA	Community Development Association
CO_2	Carbon dioxide
CSA	Climate smart agriculture
CSV	Climate smart village
IDRC	International Development Research Center-Canada
IIRR	International Institute of Rural Reconstruction

Introduction

The Dry Zone in central Myanmar is an arid region where annual precipitation seldom exceeds 40 inches (1,000 mm) and temperature reaches a maximum of 43 degrees Celsius in the summer period (MOAI, 2015 and NCEA, 2010). In other parts of the country such as the Coastal Region, rainfall can reach a maximum of 179 inches per year and maximum temperature seldom exceeds 31 degrees Celsius (Thein, 2005). Drought, water scarcity, and infertile soil with low water retention capacity hinder the productivity of agriculture in the central Dry Zone (Yee and Nawata, 2014). This condition is a consequence of past human activities that led to the denudation of lush natural forests that used to exist in the area (Sein and Htun, 2013; Tun, 2000). The presence of trees in an ecosystem influences climatic factors such as air temperature, local precipitation, and relative humidity. They also improve the water retention capacity of the soil and help prevent landslides and soil erosion (Ansari, 2003). The absence of trees creates an environment that currently exists in the central Dry Zone. This state of natural resources and existing ecosystem in the central Dry Zone pose a big challenge to farmers whose livelihood rely on dryland cropping systems.

The Htee Pu Village, Nyaung-U Township of the Mandalay region is located in the central Dry Zone. The township of Nyaung-U has the lowest rainfall intensity among the townships within the central Dry Zone. A 10-year rainfall data of the area from 2007 to 2017 shows that precipitation was lowest in 2009 at 13.5 inches while the maximum was recorded in 2011 (40.3 inches). Maximum temperature ranges from 33 degrees to 35 degrees Celsius (Dept. of Meteorology and Hydrology, Nyaung-U Township). Subsistence farming is a common economic activity among the households in Htee Pu Village. Agriculture is mainly rain-fed. Farmers grow sesame, pigeon pea, horse gram, tomato, and groundnut as well as small livestock. Climate-Smart Agriculture (CSA) technologies and practices were introduced in the village of Htee Pu in 2018 by the International Institute of Rural Reconstruction (IIRR) with the support of the Climate Change, Agriculture and Food Security (CCAFS) Southeast Asia, International Development Research Center (IDRC) Canada and a local Myanmar NGO, the Community Development Association (CDA). This portfolio of interventions aimed at helping farmers adapt to the harsh climatic conditions of the central Dry Zone. The project was completed in 2020.

Image 1. A local from Htee Pu village. Source: IIRR-Myanmar

Fruit tee-based agroforestry was one of the CSA options that was proposed by IIRR as an option to help in rehabilitating the ecological landscape and provide an additional source of livelihood for the village. Agroforestry is a practical and low-cost means of diversifying agricultural production especially for small-scale producers for income generation and reducing food insecurity (Thangata, 2002). Upon consultation with the local community, mango was proposed as a primary tree crop because it was known to tolerate rainfall variability while fetching assured incomes. Farmers suggested a range of tree species that tolerated poor soils and erratic weather including lime, guava, jack fruit, custard apple, dragon fruit, and pomegranate as intercrops – small canopy crops- that permitted the continued planting of sesame, ground nuts and pigeon pea on existing farm areas in Htee Pu. A few tamarind trees were also planted around homes as shade trees to mitigate the effects of high temperature at summertime. Intra species diversification of fruit trees were deliberate to help in reducing risks to price/market and climate failure while providing ecosystem services. Fruit trees provide ecosystem services through sequestration of carbon dioxide (CO2) from the atmosphere, absorption, and storage of water to decrease water run-off, anchor soil particles to minimize soil erosion, and contribute nutrients to the soil from decomposed leaves and branches (Marais, et al., 2019). In addition, the fruit trees provide food to supplement the villagers' dietary requirements for vitamins and other nutrients needed by the body. Fruits can also be sold and, therefore, are good sources of family livelihood and better nutrition (Marais, et al.). The planting of fruit trees was a logical CSA option for the village of Htee Puu, which otherwise has already successfully relied on raising small and large livestock as a risk minimizing strategy. All fruit tree planting materials were secured from local nurseries, thus providing some assurance that these were locally adapted cultivars. Aside from planting fruit trees, vegetable gardening as well as raising pigs and poultry were also introduced in the village under the Climate-Smart Village (CSV) Project as part of the CSA portfolio of technologies. These interventions were identified through participatory consultations with the residents of the villages.

The Myanmar report was originally aimed at conducting a Cost-Benefit Analysis of all the CSA interventions that were implemented in the village of Htee Pu. A survey was being organized in January 2021 to gather the necessary financial data for the study. However, the sudden political unrest in the country put a halt on the original plan. Instead of a financial analysis on all the CSA interventions, the focus was shifted to estimating the potential financial and environmental gains that the village could receive from planting fruit trees. Using previously generated data, the study estimated the potential Gross Revenue that would be generated by valuing the annual fruit harvests once the trees reach their fruit-bearing stage. In addition, this study attempted to estimate the quantity and value of the provisioning and regulating ecosystem services of the fruit trees in Htee Pu, particularly the production of fruits for food and the sequestration of carbon dioxide from the atmosphere. The Benefit Transfer Method was used in quantifying carbon sequestration potential (Plummer, 2009; Boutwell and Westra, 2013) The study utilized data from past researches to conduct the analysis. As such the results may be considered as preliminary in nature. A study using data directly obtained from the village would provide more robust results. Meanwhile, the current study becomes relevant in terms of underlining the multiple benefits of a fruit tree-based agroforestry. In addition to the production of fruits for income generation and family consumption, the fruit trees can provide ecosystem services for the village community as well as for society in general.

Fruit tree-based agroforestry intervention in Htee Pu

Image 2. Distributing fruit tree seedlings to farmers in Htee Pu Village. Source: IIRR-Myanmar

The primary CSA approach promoted in the CSV Project by IIRR and its local NGO partner the CDA was rainfed, dryland horticulture in land previously featuring only annual crops. A total of 4,665 fruit tree seedlings composed of eight different types of fruit trees were distributed by the CSV Project and planted in the village of Htee Pu, from 2018 to 2020 (Table 1). Majority (56%) of the seedlings that were distributed were mangoes (2,610 seedlings). This was followed by custard apple (520 seedlings) and pomegranate (430 seedlings) both of which have small body mass and canopies which are suited for intercrops, between mango trees proposed by the CSV Project. The other fruit trees that were planted (in descending order of the number of seedlings that were distributed) were lime, guava, jack fruit, dragon fruit, and tamarind. The fruit tree distribution was accompanied by a CSA education effort which advocated the digging of 30 to 50 cm pits, for purposes of enhancing rainwater harvesting, the use of organic and farmyard manure and residues as mulch. The seedlings were covered with palm leaves during the harsh and long summers. Early tillage –at the onset of rains-was practiced as a rainwater harvesting method (https://hdl.handle.net/10568/108683). The planting of fruit trees was considered a low carbon means of helping local people build natural assets. The provision of fruit trees on the scale it was done, i.e. nearly community wide, was undertaken at a relatively nominal cost. The grants were viewed as a local financing mechanism, to help farmers access tree assets. After incubating the fruit tree-based agroforestry at the village level, it was assumed that subsequent outscaling through farmer-to-farmer and institution-to-village would be the result.

There was a total of 290 households in the Htee Pu CSV some of which planted more than one type of fruit tree seedlings. Of this total, 122 households planted mango seedlings within the three-year period. A large number (126 households) also planted custard apple, a drought tolerant crop that cattle do not browse on. A smaller number of households planted dragon fruit (21 households) and tamarind seedlings (20 households). Lime, guava, jack fruit, and pomegranate are grown in the farms of more than 21 households.

Table 1. Number and type of seedlings distributed by IIRR, Htee Pu Village, Mandalay, 2018 to 2020

Year	2018		2019		2020		Total No. of seed-lings	Percent (%)	Total no. of recepient
	No. of seedlings	No. of recepient households	No. of seedlings	No. of recepient households	No. of seedlings	No. of recepient households			
Mango	1,160	30	550	40	900	52	2,610	56	122
Lime			125	25	250	52	375	8	77
Guava	120	12	150	40	100	28	370	8	80
Jack Fruit	105	21	50	25			155	3	46
Custard Apple	105	21	125	25	290	80	520	11	126
Dragon Fruit	105	21					105	2	21
Tamarind			100	20			100	2	20
Pomegranate	180	18	150	40	100	28	430	9	86
Total	1,775	123	1,250	215	1,640	240	4,665	100	578

Image 3. Mango seedlings planted in Htee Pu village. Source: IIRR-Myanmar

Financial and environmental benefits

The assumptions that were used in the study to estimate the Gross Value of the fruit trees are presented in Table 2. Included in the assumptions were the fruit-bearing age of the trees, yield per tree, farmgate prices, and seedling survival rate. The fruit-bearing age of most of the trees varied in terms of the earliest and latest year that the trees will start producing fruits. Taking a conservative stance, this analysis used the maximum number of years for the trees to reach the productive stage as the basis to determine which year each tree will start generating a revenue. The earliest fruit-bearers are custard apple, dragon fruit, and pomegranate. These perennials will reach their fruit-bearing age in three years after planting. The tamarind trees would take the longest time (8 years) before they could be productive. A lesser amount of yield was expected during the first five years of fruiting (adolescent stage). Thereafter, the volume of harvest would increase when the perennials reach their mature age where maximum yield can be attained. This is presumably after five years of fruiting.

Table 2. Assumptions used in estimating Gross Value of the fruit trees

Fruit Tree	Years to bear fruits	Ave. yield within 1st 5 yrs of fruiting (Kg/plant)	Ave. yield after 5 yrs of fruiting (Kg/plant)	Ave Farmgate Price (MMK/Kg)	Ave Farmgate Price (USD/Kg*)
Mango	5	10	20	625	0.42
Lime	3 to 4	50 (2x/season)	100 (2x/season)	1,000	0.67
Guava	3 to 5	10 (2x/season)	10 (2x/season)	500	0.34
Jack fruit	5	750	900	600	0.40
Custard apple	2 to 3	10	10	500	0.34
Dragon fruit	1 to 3	5	7	500	0.34
Tamarind	6 to 8	50	160	600	0.40
Pomegranate	2 to 3	10	15	1,000	0.67

* 1 USD = 1,485 MMK

Source: Myanmar CSV research team

The farmgate prices of the fruits varied. Lime and pomegranate were the most expensive at USD 0.67/kg. Guava, dragon fruit, and custard apple had the lowest farmgate price (USD 0.34/kg). It is interesting to note that there are more households that planted mango trees despite the longer length of time before they start to bear fruits as well as its lower farmgate price relative to lime and pomegranate. A number of factors could influence this decision. For instance, it is a fact that mangoes are very popular in Myanmar and, hence, their preference. The marketability of the fruit particularly the Sein Ta Lone mango that grows best in the central dry zone is another reason why they chose to plant mangoes. The tolerance of mangoes to climate variability was an important reason for them to propose mango.

Seedling survival rate was assumed to be 70% reflecting mortality from the time of planting until three years. This is the period that the trees are highly sensitive to environmental and nutritional stresses. On this basis, the original tree count was reduced from 4,665 to 3,266 trees (Table 3). Mortality losses from 2018 to 2020 summed up to 1,400 seedlings.

Table 3. Number of trees at 70% seedling survival rate and mortality losses, 2018 to 2020

Perennials	Year	No. of trees planted by year of planting	No. of trees at 70% survival rate	Mortality loss
Mango	2018	1160	812	348
	2019	550	385	165
	2020	900	630	270
	Subtotal	2610	1827	783
Lime	2019	125	88	37.5
	2020	250	175	75
	Subtotal	375	263	112.5
Guava	2018	120	84	36
	2019	150	105	45
	2020	100	70	30
	Subtotal	370	259	111
Jack fruit	2018	105	74	31.5
	2019	50	35	15
	Subtotal	155	109	46.5
Custard apple	2018	105	74	31.5
	2019	125	88	37.5
	2020	290	203	87
	Subtotal	520	364	156
Dragon fruit	2018	105	74	31.5
	Subtotal	105	74	31.5
Tamarind	2019	100	70	30
	Subtotal	100	70	30
Pomegranate	2018	180	126	54
	2019	150	105	45
	2020	100	70	30
	Subtotal	430	301	129
TOTAL		4,665	3,266	1,400

Gross Value of Fruits

Fruits that can be harvested from the fruit trees can either be sold to buyers or consumed at home. Since not all fruits are expected to be sold, the term, Gross Value, instead of Gross Revenue was applied in referring to the economic value of the potential annual harvest from the perennials. Annual fruit production was valued by applying the average farmgate prices presented in Table 2. In computing Gross Value, Revenue, possible changes in farmgate prices due to market movements and inflation were not factored in. The increases in value revenue only reflected the increases in yield per tree and in the number of trees reaching their fruit-bearing age over time.

The early fruit-bearing trees - custard apple, dragon fruit, and pomegranate- will start producing fruits in 2021. The other trees as earlier indicated, will bear fruits by 2023. The fruits that will be harvested in 2021 will fetch a value equivalent to USD 1,217.00 (Table 4). Gross Value would increase to USD 2,216.00 in 2022 and USD 35,438.00 in 2023 as the fruit trees of the same species that were planted in 2019 and 2020 also reach their fruit bearing age. In addition, mango, lime, guava, and jack fruit will start bearing fruits by 2023, therefore, giving a significant boost in the Gross Value on that year. Further increases in value would be generated in 2024 and 2025 as the rest of the seedlings planted in 2019 and 2020 start to produce fruits. Increases in Gross Value from 2028 onwards would come from additional yields as the trees attain their maximum fruit-bearing capacity. Gross Value in 2028 would amount to USD 79,307.00 and would reach a maximum of USD 100,475.00 per year from 2031 onwards.

Computing the per household Gross Value starting from the values on the second year of fruiting until 2035 involved a step-wise approach. Taking mangoes as an example, note that there are three groups of households based on the year the seedlings were planted, i.e. 30, 40 and 52 households in 2018, 2019, and 2020, respectively. The planting of mango trees in 2018 was done by 30 households. These trees are expected to be the first to bear fruits by 2023 and the value of the harvested fruits (USD 3,410.00) for that year was divided among the 30 households, i.e. USD 114.00 per household. By 2024, the same trees will again bear fruits and the value (assuming no change in farmgate prices) were again divided among the 30 households. In addition, the trees planted in 2019 will start to bear fruits on the same year (2024). These trees were planted by 40 households. The value of the fruits harvested from these trees was estimated as USD 1,617.00 and this was divided among the 40 households, i.e., USD 40.00.00 per household for 2024. Thus, the total Gross Value per household in 2024 was computed to be USD 154.00 which is the sum of the per household Gross Value of the first group (30 households) and that of the second group (40 households), i.e., USD 114 + USD 40.00 = USD 154.00. For 2025 until 2035, the same steps were followed but with the addition of the per household Gross Value of the third group (52 households). The same procedure was followed in determining the value of fruits that can potentially be harvested from the other fruit trees. Gross Value from lime would start at USD 236.00 per household and could reach USD 923.00 per household by 2030. It was assumed that the volume of harvest and the Gross Value from all fruit trees will be constant until 2035. Jackfruit is a big earner and would allow a household to generate USD 1,057.00 in 2023. Gross Value It will be increasing to USD 2,373.00 from 2030 until 2035. Similarly, each of the 18 to 21 households that planted the early fruit-bearers (custard apple, dragon fruit, and pomegranate) in 2018 would be earning USD 12.00, 6.00, and 47.00, respectively, in 2021. There will be increases in yield starting 2022 but the revenue and value of fruits to be consumed by the family members will be shared by the other households that planted the same fruit trees in 2019 and 2020. Taking all fruit trees together, the average Gross Value per household would range between USD 65.00 in 2021 to USD 4,163.00 from 2030 to 2035.

Table 4. Projected total and per household gross value by year based on number of surviving trees, 2021 to 2035

Year Planted	No. HH by year of planti	›. of survivi trees	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031 to 2035
			Gross value per year based on start of fruit-bearing age, yield per tree and farmgate price										
Mango													
2018	30	812			3,410	3,410	3,410	3,410	3,410	6,821	6,821	6,821	34,104
2019	40	385				1,617	1,617	1,617	1,617	1,617	3,234	3,234	16,170
2020	52	630					2,646	2,646	2,646	2,646	2,646	5,292	26,460
Subtotal	122	1827			3,410	5,027	7,673	7,673	7,673	11,084	12,701	15,347	76,735
Per HH					**114**	**154**	**205**	**205**	**205**	**319**	**359**	**410**	**2,050**
Lime													
2019	25	88			5,896	5,896	5,896	5,896	5,896	11,792	11,792	11,792	58,960
2020	52	175				11,725	11,725	11,725	11,725	11,725	23,450	23,450	117,250
Subtotal	77	263			5,896	17,621	17,621	17,621	17,621	23,517	35,242	35,242	176,710
Per HH					**236**	**461**	**461**	**461**	**461**	**697**	**923**	**923**	**4,615**
Guava													
2018	12	84			564	564	564	564	564	564	564	564	2,822
2019	40	105				706	706	706	706	706	706	706	3,528
2020	28	70					470	470	470	470	470	470	2,352
Subtotal	80	259			564	1,270	1,740	1,740	1,740	1,740	1,740	1,740	8,702
Per HH					**47**	**65**	**81**	**81**	**81**	**81**	**81**	**81**	**407**
Jack fruit													
2018	21	74			22,200	22,200	22,200	22,200	22,200	26,640	26,640	26,640	133,200
2019	25	35				10,500	10,500	10,500	10,500	10,500	12,600	12,600	63,000
Subtotal	46	109			22,200	32,700	32,700	32,700	32,700	37,140	39,240	39,240	196,200
Per HH					**1,057**	**1,977**	**1,977**	**1,977**	**1,977**	**2,189**	**2,373**	**2,373**	**11,863**
Custard apple													
2018	21	74	249	249	249	249	249	249	249	249	249	249	1,243
2019	25	88		296	296	296	296	296	296	296	296	296	1,478
2020	80	203			682	682	682	682	682	682	682	682	3,410
Subtotal	126	364	249	544	1,226	1,226	1,226	1,226	1,226	1,226	1,226	1,226	6,132
Per HH			**12**	**38**	**79**	**79**	**79**	**79**	**79**	**79**	**79**	**79**	**394**
Dragon fruit													
2018	21	74	124	124	124	124	124	174	174	174	174	174	870
Subtotal	21	74	124	124	124	124	124	174	174	174	174	174	870
Per HH			**6**	**6**	**6**	**6**	**6**	**8**	**8**	**8**	**8**	**8**	**41**
Tamarind													
2019	20	70						1,400	1,400	1,400	1,400	1,400	22,400
Subtotal	20	70						1,400	1,400	1,400	1,400	1,400	22,400
Per HH								**70**	**70**	**70**	**70**	**70**	**1,120**
Pomegranate													
2018	18	126	844	844	844	844	844	1,266	1,266	1,266	1,266	1,266	6,332
2019	40	105		704	704	704	704	704	1,055	1,055	1,055	1,055	5,276
2020	28	70			469	469	469	469	469	704	704	704	3,518
Subtotal	86	301	844	1,548	2,017	2,017	2,017	2,439	2,791	3,025	3,025	3,025	15,125
Per HH			**47**	**104**	**146**	**146**	**146**	**170**	**198**	**220**	**220**	**220**	**1,098**
TOTAL	578	3,266	1,217	2,216	35,438	59,986	63,102	64,974	65,326	79,307	94,749	97,395	502,874
TOTAL PER HH			**65**	**147**	**1,685**	**2,888**	**2,956**	**3,052**	**3,080**	**3,662**	**4,112**	**4,163**	**21,588**

HH = household

Costs in the establishment and maintenance of the fruit trees

The inputs in the fruit tree project include the seedlings that were distributed in the village over the duration of 2018 to 2020, labor in planting and maintenance of the seedlings, and cost of fertilizer. While flower inducers are usually sprayed on fruit trees in a commercially operated orchard, it was assumed that the farmers in Htee Pu will not use chemicals to induce flowering.

Following the convention of performing a financial analysis (versus an economic analysis), the noncash costs in the establishment and maintenance of the fruit trees were excluded from the estimation of the net value. There were 4,665 seedlings that were distributed in the village by the CSV Project with an estimated value of USD 7,741.00 (Table 5). Losses due to seedling mortality may be considered as costs. However, since these were provided free of charge by the Project, the households did not incur any cost at all. Labor in planting and taking care of the plants was provided by the household-beneficiaries themselves. Hence, family labor is considered a noncash cost. (To put a value on their labor the average wage rate of USD 3.70/day (MMK 5,500 @ USD 1 = MMK 1,485) paid to agricultural workers in Myanmar can be applied.) Cow dung was used as organic fertilizer for basal treatment and seedling maintenance. Cattle are important assets in Htee Puu and compost making are traditionally practiced by all households. Organic residues are regularly recycled and used. Cow dung can be collected at no cost. Harvesting of fruits can also be assumed to be performed by the household members or by the buyers of fruits themselves. Thus, the inputs (labor and fertilizer) as well as the cost of seedling mortality are assumed to be noncash costs to the households. It is important to note that most of the farmers are small land holders, with farm areas ranging typically from 1 to 2 hectares. Only a portion of the farm is under the CSV agroforestry initiative. This being the case, the projected Gross Value of the fruits are considered as the Net Value that will be generated by the households.

Table 5. Cost of seedlings distributed by IIRR, Htee Pu Village, Mandalay, in US Dollars, 2018 to 2020

Plant	Cost per seedling (USD)	2018		2019		2020		Total no. of seedlings	Total cost of seedlings (USD)
		No. of seedlings	Cost of seedlings	No. of seedlings	Cost of seedlings	No. of seedlings	Cost of seedlings		
Mango	1.21	1,160	1,404	550	666	900	1,089	2,610	3,158
Lime	0.67			125	83.75	250	168	375	251
Gua-va	0.27	120	444	150	556	100	370	370	1,370
Jack Fruit	3.37	105	354	50	169			155	522
Cus-tard Apple	0.27	105	28	125	34	290	78	520	140
Dra-gon Fruit	0.51	105	206					105	206
Tama-rind	0.20			100	500			100	500
Pom-egranate	0.27	180	667	150	556	100	370	430	1,593
Total		1,775	3,103	1,250	2,563	1,640	2,076	4,665	7,741

Image 4. A Htee Pu farmer caring for a one-year-old mango sapling. Source: IIRR-Myanmar

Investment analysis

The cost of the seedlings which amounted to USD 7,741.00 can be considered as the investment by the CSV Project in the fruit tree CSA initiative. The computed Financial Rate of Return to the investment was 87% annually for the period 2018 to 2035. This figure is relatively high since the households will not be (or minimally) incurring any additional production cost during the duration that the trees are bearing fruits. The FRR did not change after assuming a 5% decrease in Gross Value starting in 2026. This scenario attempted to reflect the possibility that maximum levels of yield may not be achieved by the trees due to the dry climatic condition of the village. Adequate water is needed to enable the fruit trees to reach their maximum fruit bearing capacity.

Environmental benefits from fruit trees

Ecosystem service is a collective term for the life-supporting functions of ecosystems (Ehrlich and Ehrlich, 1981). An ecosystem, on the other hand, is a "community of living organisms interacting with the nonliving components of their environment and functioning together as a system (Smith and Smith, 2012). An agroecosystem is a man-made ecosystem where agricultural crops (perennials and cash crops) as well as poultry and livestock interact with human beings living in the same locality. Garbach, et al. (2014) identified the ecosystem services that are made available by agroecosystems. Provisioning service resulting from the production of food, fuel, fiber, and biochemicals is the main function of an agroecosystem. In addition, carbon sequestration, habitat provision for beneficial organisms, and soil conservation are additional services that are rendered by agroecosystems (Marais, et al., 2019; de Groot et al., 2010).

Carbon, in the form of carbon dioxide, is one of the predominant greenhouse gasses (GHG) in the atmosphere. It is responsible for 50% to 60% of the global warming from GHGs produced by human activities (Miller, 1998). One method to reduce atmospheric carbon is by increasing carbon sequestration globally. Carbon sequestration is defined as the "long term storage of carbon in oceans, soils, vegetation, and geologic formations" (ESA, 2000). Trees and other types of vegetation absorb carbon dioxide through photosynthesis and sequester carbon in their biomass (tree trunks, branches, foliage, and roots) (Rajan, R. et al., 2019). Carbon sequestration falls under the regulating service of an ecosystem (MEA, 2005). Similarly, soil conservation such as preventing or minimizing soil erosion is another form of regulating service of trees. Soil erosion is prevented by the root system of trees by holding soil particles together. Habitat provision by trees is another service which can be readily appreciated when potential pests of crops are controlled by natural enemies that reside in trees such as "birds, spiders, wasps, fungi and bacteria" (DeBach, 1974). The presence of these organisms helps farmers save on pest control expenses (Reid, 1999).

This study attempted to estimate the quantity and value of the provisioning and regulating services of the fruit trees in Htee Pu, particularly the production of fruits for food and carbon sequestration.

Provisioning service of fruit trees in Htee Pu Village

In an agroecosystem setting, agricultural crops such as fruit trees and cash crops deliver provisioning service through the production of food (Garbach et al.). In Htee Pu Village, the 3,267 trees that were planted and would survive to reach their fruit-bearing age are expected to produce 142,020 Kg of fruits per year for the first five years of fruiting (Table 6). Beyond five years, as the trees reach full maturity, they have the potential to yield 212,290 Kg/year. Mango, being the tree with the most number that were planted in Htee Pu, has the potential to produce 18,270 Kg of fruits during the first five years and eventually 36,540 Kg/year after five years of fruiting. The trees that will bear fruits in three years (custard apple, pomegranate, dragon fruit) ahead of the other perennials will have a combined yield of 7,020 kg/year during the first five years of fruiting and 8,673 kg/year thereafter.

Table 6. Provisioning service: Fruit production, in kg/year, Htee Pu Village, Nyaung-U Township, Mandalay

Perennials	No. of trees at 70% survival rate	Potential fruit production (Kg)	
		Within 1st 5 years of fruiting	After 5 years of fruiting
Mango	1,827	18,270	36,540
Lime	263	26,300	52,600
Guava	259	5,180	5,180
Jack fruit	109	81,750	98,100

Custard apple	364	3,640	3,640
Dragon fruit	74	370	518
Tamarind	70	3,500	11,200
Pomegranate	301	3,010	4,515
Total	3,267	142,020	212,293

Carbon sequestration (regulating service) of fruit trees in Htee Pu Village

Carbon dioxide (CO2) is sequestered through the process of photosynthesis wherein CO2 from the atmosphere is absorbed by the trees and combined with water (H20) and sunlight to produce glucose and oxygen. Carbon is stored in the above ground (tree trunk, branches, foliage) and below ground (root system) biomass of the trees as well as in the quantity of soil organic matter (SOM) under the tree canopy. The amount of carbon sequestered by a number of fruit trees have been estimated and reported in published literature. These data were used as the basis for the estimation of carbon stocks in this study. Using past data for a current analysis is founded on the concept of the Benefit Transfer Method (Plummer, 2009; Boutwell and Westra, 2013). Guiabao (2016) estimated the carbon stock of a mango plantation in the Philippines as 47.66 to 62.33 tCO2/ha while Chavan and Rasal (2012) gave a higher estimate (206.6 tCO2/ha). Other studies reported varying estimates of carbon stocks for mango trees: 45 to 85 tCO2/ha (Ganeshamurthy, et al., 2019), 80.74 tCO2/ha (Selvaraj, et al., 2016) and 1.5 tCO2/ha (Sharma, et al., 2021). Selvaraj, et al. also provided the potential carbon stock of Anona squamosa (custard apple) to be 0.14 tCO2/ha while Chavan and Rasal (2012) gave an estimate of 0.3 tCO2/ha for the same fruit tree. Jana, et al. (2009) estimated that jackfruit can sequester 26.7 tons of CO2 per hectare. Shine et al. (2015) gave their estimates of CO2 sequestration for guava and mango on a per tree basis, i.e., 0.012 tCO2/tree and 0.21 tCO2/tree, respectively. Unfortunately, no data for dragon fruit, pomegranate, and tamarind could be found even through a random internet search.

Almost all of the published estimates of CO2 sequestration were reported by the authors on a per hectare basis, i.e., kCO2/ha or tCO2/ha. On the other hand, this study required that the carbon stocks be expressed on a per tree basis because the fruit trees in Htee Pu were not planted together in a contiguous area. The conversion of the values to per tree basis was achieved by adopting a 15m x 15m tree spacing of an orchard containing 25 trees in one hectare. All per hectare estimates were converted to a per tree basis by dividing the estimated values by 25. Table 7 presents a summary of the carbon sequestration potentials of each fruit tree planted in the village of Htee Pu. The values have been converted from a per hectare to a per tree basis. In the absence of sequestration values for dragon fruit, pomegranate and tamarind, values contained in Table 7 of other fruit trees with similar physical characteristics in terms of trunk and branch diameters, height, and foliage were used as substitutes to complete the estimation of CO2 sequestration for all trees. The average sequestration value of custard apple

(0.01 tCO2/tree) was assigned as substitute for tamarind and pomegranate. Dragon fruit, on the other hand, is a cactus and, therefore, could not be likened to the other fruit trees. However, observing that the dragon fruit has thin stems and can profusely grow vegetatively, its biomass could be similar to that of the lime tree. Hence, the sequestration potential of a lime tree (0.001 tCO2/tree) was assigned to the dragon fruit.

It is worth noting that the mango tree has the largest CO2 absorption potential based on the average of the different values that were taken from different independent studies. The estimates varied in values depending on the location (climate and altitude) and soil quality of the plantations where the studies w conducted. The age of the mango trees could also be considered as a determinant factor in measuring carbon absorption.

Table 7. CO2 absorption potential of fruit trees, Htee Pu Village, Nyaung-U Township, Mandalay

Perennials	CO2 absorption potential		Authors
	(tCO2/ha)	(tCO2/tree)	
Mango	47.66	1.91	Guiabao (2016)
	62.33	2.5	Guiabao (2016)
	206.6	8.26	Chavan & Rasal (2012)
	45	1.8	Ganeshamurthy, et al.
	85	3.4	(2019)
	80.74	3.23	Selvaraj, et al, (2016)
		0.21	Shine, et al. (2015)
Average: mango		3.04	
Guava		0.012	Shine, et al. (2015)
Jack fruit	26.7	1.07	Jana, et al. (2009)
Lime/Citrus		0.001	Mota, et al. (2010)
Custard apple	0.14	0.006	Selvaraj, et al, (2016)
	0.3	0.012	Chavan & Rasal (2012)
Ave: custard apple		0.01	

Table 8 presents the total amount of CO2 that can be sequestered by the fruit trees annually. A total of 5,682 tCO2 could be sequestered by 3,266 fruit trees that were planted in Htee Pu Village. The mango tree, being the dominant perennial in Htee Pu and having a higher CO2 absorptive capacity, would be able to sequester 5,564 tCO2/year. The combined amount of CO2 that can be sequestered by the other trees sums up to 127.42 tCO2/year.

Table 8. Carbon sequestration potential of fruit trees, Htee Pu Village, Mandalay, Metric tons CO_2/year

Perennial	Total number of trees	Total CO_2 to be sequestered (tCO_2/Year)
Mango	1,827	5,554
Lime	263	0.26
Guava	259	3.11
Jack Fruit	109	116.63
Custard Apple	364	3.64
Dragon Fruit	73	0.07
Tamarind	70	0.70
Pomegranate	301	3.01
Total	3,266	5,682

Economic value of ecosystem services

The economic value of the provisioning and regulating (carbon sequestration) services of fruit trees was estimated using the Market Price Method of valuation. This method is suitable for tradeable ecosystem goods or services wherein the applicable market price is used for determining economic value (Aisbet and Kragt, 2010; Carson and Bergstrom, 2003). In measuring the value of provisioning services, the market price is multiplied by the quantity of the ecosystem good to estimate the total market value (Bouwer et al., 2013). For the provisioning service of fruit trees, the farmgate prices of the fruits to be harvested was used for the economic valuation. In the case of the regulating service (carbon sequestration) of the fruit trees, this study referred to the carbon prices of 22 countries that were published in April 2021. The prices ranged from USD 1.00/tCO_2 to USD 137.00/tCO_2. Taking a conservative position, this study took the average of the CO_2 prices that did not exceed USD 20.00/ton. The average that was obtained was USD 8.40/tCO_2.

Economic value of the provisioning service of fruit trees

The Gross Value of fruits to be harvested from 2021 to 2035 represents the value of the provisioning service of the fruit trees in the village of Htee Pu. To wit, the estimated Gross Value from 2021 to 2035 was USD 1.07 Million. Table 9 presents a summary of the economic value of the provisioning service of the fruit trees. This service will continue until the fruit trees reach the end of their fruit bearing capacity. However, the value of the provisioning service of the fruit trees could be less than USD 1.07 Million if the dry climatic condition in Htee Pu would constrain the maximum fruit production potential of the trees.

Table 9. Economic value of the provisioning service of fruit trees, Htee Pu, Nyaung-U Township, Mandalay in US Dollars, 2021 to 2035

Perennial	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031 to 2035	TOTAL
Mango												
Gross revenue			3,410	5,027	7,673	7,673	7,673	11,084	12,701	15,347	76,734	147,323
Revenue/household			114	72	63	63	63	91	104	126	630	1,325
Lime												
Gross revenue			5,896	17,621	17,621	17,621	17,621	23,517	35,242	35,242	176,210	346,591
Revenue/household			236	229	229	229	229	305	458	458	2,290	4,662
Guava												
Gross revenue			564	1,270	1,740	1,740	1,740	1,740	1,740	1,740	8,702	20,979
Revenue/household			47	24	22	22	22	22	22	22	110	312
Jack fruit												
Gross revenue			22,200	32,700	32,700	32,700	32,700	37,140	39,240	39,240	196,200	464,820
Revenue/household			1,057	711	711	711	711	807	853	853	4,265	10,679
Custard apple												
Gross revenue	249	544	1,226	1,226	1,226	1,226	1,226	1,226	1,226	1,226	6,132	16,736
Revenue/household	12	12	10	10	10	10	10	10	10	10	50	152
Dragon fruit												
Gross revenue	124	124	124	124	124	174	174	174	174	174	870	2,362
Revenue/household	6	6	6	6	6	8	8	8	8	8	40	111
Tamarind												
Gross revenue						1,400	1,400	1,400	1,400	1,400	22,400	29,400
Revenue/household						70	70	70	70	70	350	700
Pomegranate												
Gross revenue	844	1,548	2,017	2,017	2,017	2,439	2,791	3,025	3,025	3,025	15,125	37,872
Revenue/household	47	86	35	23	23	28	32	35	35	35	175	556
TOTAL REVENUE	**1,217**	**2,216**	**35,438**	**59,986**	**63,102**	**64,974**	**65,326**	**79,307**	**94,749**	**97,395**	**502,374**	**1,066,084**
TOTAL/household	**65**	**104**	**1,504**	**1,075**	**1,063**	**1,141**	**1,145**	**1,349**	**1,560**	**1,581**	**7,910**	**18,497**

Economic value of carbon sequestration by the fruit trees

The fruit trees in the village of Htee Pu can potentially sequester 5,682 tCO_2 e per year. Using the average CO_2 price of USD 8.40/tCO_2, the economic value of the carbon sequestration service of the trees was estimated to be USD 47,725.00/year (Table 10).

Table 10. Economic value of carbon sequestration potential of fruit trees, Htee Pu Village, Nyaung-U Township, Mandalay, USD/year

Perennial	Total CO_2 to be sequestered (tCO_2/Year)	Value of CO_2 to be sequestered (USD/Year)
Mango	5,554	46,654
Lime	0.26	2.21
Guava	3.11	26.11
Jack Fruit	116.63	980
Custard Apple	3.64	30.58
Dragon Fruit	0.07	0.61
Tamarind	0.70	5.88
Pomegranate	3.01	25.28
Total	5,682	47,725

Note: CO_2 values are averages of CO_2 quantities measured at different stages of growth of fruit trees.

Total value of the ecosystem services of fruit trees in Htee Pu Village

The provisioning and regulating services of the fruit trees, when taken together, has a total value equivalent to USD 118,797.00 (Table 11). This excludes the value that can be attached to other types of ecosystem services made available by the fruit trees such as providing a habitat for beneficial organisms as well as soil conservation.

Table 11. Economic value of the provisioning and regulating services of fruit trees, in USD/year, Htee Pu Village, Nyaung-U Township, Mandalay

Value of provisioning service (Fruit-bearing)	Value of Regulating service (Carbon sequestration)
USD 71,072/year Ave. of 15 years Gross Value	USD 47,725/year
Total: USD 118,797.00	

Environmental benefits of using manure as organic fertilizer

In addition to the ecological benefits that the village of Htee Pu can derive from planting fruit trees, the farmers' method of using cow manure as an organic fertilizer deserves to be underscored as another environmentally sustainable agricultural practice. Without attempting to estimate its economic value, it is worthwhile mentioning that this practice offers a number of benefits to the environment. Manure increases the formation of large soil aggregates which reduces water run-off and soil erosion (Koelsch, 2017). Soil aggregation is triggered by the addition of manure because it is colonized by bacteria that produce polysaccharides that act like glue which bond soil particles together into large aggregates (Graham et al, undated). In contrast, the use of chemical fertilizers increases soil acidity which in turn decreases soil cohesion by killing soil microbia making it vulnerable to erosion. In addition, fields fertilized by manure exhibited increases in water retention. Vengadaromana and Jasothan (2012) showed that compost fertilizer and cow dung applied separately increased the mean water holding capacity (WHC) of the soil samples that they were testing. Cow dung "doubly increased the WHC of the soil samples". Increased WHC renders the soil more drought tolerant.

Conclusion

Planting fruit trees in the village of Htee Pu offers a number of benefits to the village community. An estimated total Gross Value of USD 1.07 Million from 2021 to 2035 or an average of USD 71,072/year can be generated by the village from the fruits that will be harvested from the trees. Per household, average benefit could amount to USD 47,398.00 over the 15-year time period or USD 3,160.00 per year.

The Gross Value of USD 71,072.00 per year represents the annual economic value of the provisioning ecosystem service of the fruit trees to the village community. In addition, the fruit trees planted in Htee Pu can store 5,682 tCO_2 per year with an estimated value of USD 47,725.00. Fruit production and carbon sequestration have a combined economic value of USD 118,797.00 per year. These figures are indicative of the value of the fruit trees to the village ecosystem.

This study has highlighted the value of the provisioning and regulating services of mango trees which was the dominant tree in terms of number planted in the village. It seems that it was the number one choice among the villagers. However, it can be assumed that the households did not choose them because of their environmental benefits but because of their preference towards mangoes for family consumption as well as the high consumer demand and market opportunities. While environmental benefits and consumer preference are two different dimensions in choosing what tree to plant, they complement each other, helping achieve the wider adaptation and mitigation objectives of the CSV Project. The Project was able to incorporate both income generation and sequestration of CO_2 in one activity.

There is an upsurge in global interest in ecosystem restoration, rehabilitation of degraded landscapes, and in regenerative agriculture. The findings of this study are relevant to environmental agencies tasked to help stabilize the central dry zone of Myanmar: they might also consider including dryland horticulture and small farm agroforestry into their portfolio. Development and agricultural agencies, on the other hand, can include fruit tree-based agroforestry as a trajectory for addressing degradation on small farms and associated landscapes. Agroforestry, relying on biodiverse, small holder systems also delivers on nutrition, income, and environmental outcomes. Achieving scale-numbers of adopters- within each village can help provide the scale necessary for fostering market links, enriching local food systems while also delivering environmental services. Integrating fruit bearing perennials in small scale agriculture can also help improve the resilience of smallholder farming systems by improving adaptation to the local impacts of climate change. Valuation methods, which consider both financial and environmental outcomes can provide the basis for increasing the investment in small holder, fruit- tree based, climate smart agroforestry.

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