J. ISSAAS Vol. 27, No. 2: 81-95 (2021)

AGRICULTURAL TRAMLINE SYSTEM ON THE AGRICULTURAL SUSTAINABILITY OF UPLAND FARMS IN BENGUET, PHILIPPINES

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(Received: February 3, 2021; Accepted: October 14, 2021)

ABSTRACT

The agricultural tramline system (ATS) is a mechanical conveyance system that works similar to the principle of the cable car and is utilized as a transport system of agricultural products and inputs in hard to reach upland areas inaccessible by road. This paper assessed the influence of ATS on the agricultural sustainability of upland farms in terms of social, economic and environmental dimensions. A survey of 310 upland farmers representing "with ATS" and "without ATS" was conducted in 2018 in 3 major farming municipalities of Benguet province, Philippines to generate information on land use allocations, farming systems, rate of organic fertilizer use, hauling methods, average yields, soil and water conservation practices and socioeconomic data. Soil samples were collected from farmers' fields and analyzed for pH, OM, P, and K to determine the effects of the different levels of fertilizer application on soil nutrients. Data were analyzed using descriptive statistical methods, t-test and partial budget analysis. The ATS improved the working conditions of upland farmers by eliminating the drudgery of manual hauling through mechanizing transport of agricultural products and inputs. ATS also leads to increased productivity through higher crop yields and increased farmers' income by reducing transport costs and thus influenced positively agricultural sustainability on the aspects of social and economic dimensions. This positive influence however, was made possible through intensified use of fertilizers and opening up of forest and idle areas for agricultural land use and contrariwise created undesirable environmental effects which may threaten agricultural sustainability in the long run. The ATS has indirect neutral effect on OM, P and K soil content but has a positive indirect effect on soil pH because farms serviced with ATS used significantly higher amount of organic fertilizer. To maximize the potential of ATS as a sustainable mode of transport while mitigating its undesirable effects, strict land use zoning must be implemented while putting up of ATS adjacent to forest areas and fragile ecosystems should be prohibited. Soil and water conservation innovations in the uplands must also be an integral part of the farming systems.

Key words: agricultural sustainability, land use, transport system, upland farms

INTRODUCTION

In the mountainous regions of the Philippines, access is one of the barriers that until now hindered these regions from reaching its potential productivity. In these areas, road infrastructure and access to market is inadequate because of technical challenges and limitations owing to its rugged terrain, high cost and maintenance of paved road (Dela Cruz et al. 2000; Estigoy 2006; Idago and Ranola 2009; 2012; Tesorero 2017). The traditional method of manual hauling agricultural products remains the predominant mode of transport. In these mountainous regions, hauling cost contributes as high as 30% of the total production cost while postharvest losses due to handling and delay of movement of highly perishable products ranges from 20-50% (Estigoy 2006).

The uplands represent about 55% of the Philippines' total land area (Cruz et al. 1986) which why it is considered by the Philippine government as a latent resource that can significantly contribute to food security and as well as poverty alleviation amidst the challenges of climate change. Social, economic and environmental aspects are central considerations in the design of rural development programs in these mountainous regions, and require efforts to strike a balance amongst the composite dimensions of agricultural sustainability. It is also generally recognized that the uplands play a vital role in the lowlands in terms of the flow of energy, materials, information and other ecosystem services. The uplands is considered a fragile ecosystem, and production in steep slopes would expose the system to environmental problems such as soil erosion, water contamination, sedimentation of river system (Briones 2005; Rola 2004). Hence, any innovation that can alter or influence the different dimensions of economic, social and environmental sustainability must be identified, quantified and projected for the purpose of enhancing the positive impacts while mitigating the unintended and undesirable effects.

One of the popular technological innovations adopted towards the development of the uplands is the agricultural tramline system (ATS) in the past two decades. It is a mechanical conveyance system that works similar to the principle of cable car and is utilized as a transport system of agricultural inputs and products in areas inaccessible by road. The ATS is an offshoot of an old technology that was once applied in the 1970s in mining and logging operations (Idago and Ranola 2009). The closure of these industries for obvious reasons of unsustainability, opened up and cleared areas were devoted for agricultural production while displaced labor force from mining and logging operations adapted the technology for agricultural application. This later paved the way for the development of the ATS technology that is being established in mountainous regions under the lead of the Department of Agriculture. To date more than 200 units of ATS have been established across the mountainous regions engaged in the production of high value crops nationwide (Paz et al., 2017).

A number of studies and published articles on ATS already exist, which looked into its financial and economic viability (Idago and Ranola 2009), farm productivity (Idago and Ranola 2012) performance under different management models (Tesorero 2017) and effects on land use (Idago and Rebancos 2020). There is limited if none on published reference that investigated its contribution and influence on agricultural sustainability, which is central to the design of rural development programs. With the increasing demand for this innovation, information that cut across the dimensions of agricultural sustainability will be useful for crafting of policy direction, programming, planning and allocation of scarce resource. This paper aims to address this information gap by assessing the influence and contribution of ATS on the agricultural sustainability of the uplands at the farm level.

METHODOLOGY

Conceptual framework. The influence of ATS on agricultural sustainability in the farming uplands was established by comparing the "with" and "without" ATS. The conceptual framework of the study shows the system boundary confined at the farm level where the ATS will have its most significant impact (Fig. 1). Agricultural sustainability was assessed based on three dimensions: social, economic and environmental aspects (Yunlong and Smit 1994). Indicators of agricultural sustainability were based on the work of Hayati et al. (2010)

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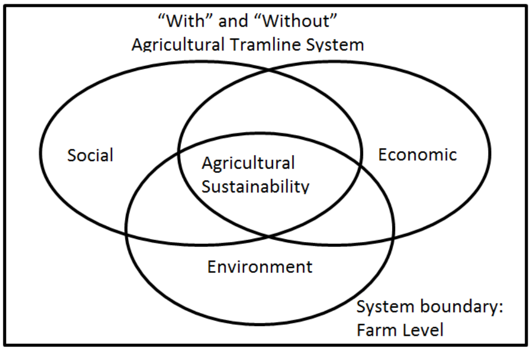

Fig. 1. Conceptual framework of the study.

Time and location of the study. The study was conducted in Benguet province in the municipalities of Kabayan, Tublay and Atok in 2018 (Fig. 2). Benguet province is situated geographically between 16^0 33' N latitude and 120^o 34' to 120^o 52' E longitude and is bound by Mt. Province on the north, Pangasinan on the south, Ifugao and Nueva Vizcaya on the east and by La Union and Ilocos Sur on the west (PDPFP 2018). Benguet province was selected as the study area as it has the highest number of ATS across the mountainous provinces of the Philippines and is considered one of the first adopters of this transport technology.

Fig. 2. Map of Benguet showing the municipalities of Tubaly, Atok and Kabayan as study sites.

Sampling and data collection. The study used formal survey method with the aid of structured questionnaires to obtain primary data on farmers' socioeconomic profile and land use systems. Two types of farms and farmer-respondents were selected for purposive sampling, representing the "with ATS" and "without ATS" to measure the difference using the pre-identified indicators of the different dimensions of sustainability. The required sample size was determined using Slovin's formula:

$$n = N / (1 + Ne^2)$$

where: n = *sample size*
N = *population size*
e = *error tolerance (0.05)*

The estimated population (N) of farmers "with ATS" is about 250, the sample size for each classification of farmer-respondents was computed as:

$$n = 250/ (1 + 250 (0.05)^2$$
$$=250/ (1 + 0.625)$$
$$= 153.8, \text{ or about 155 farmer-respondents}$$

Soil samples from 30 farms each for “with ATS” and “without ATS”, were randomly selected for soil fertility analysis.

Agricultural sustainability assessment. Assessing the ATS’ influence on agricultural sustainability in the uplands compels some conceptual framing how this specific innovation contributes towards the broad concept of “agricultural sustainability”. “Sustainability in agriculture is a complex concept and there is no common viewpoint among scholars as to its dimension” (Hayati et al. 2010). Moreover, the precise measurement of agricultural sustainability is impossible as it is site-specific and a dynamic concept (Ikerd 1993). Therefore, selection of indicators should be location specific and must be based on the contemporary biophysical and socioeconomic conditions prevailing in the study area (Dumanski and Pieri 1996). Using system theory (Rambo 1983), the boundary of the system under consideration in this study is confined at the farm level but implications were made for the whole landscape.

Recognizing that there is no straightforward or standard indicators to measure agricultural sustainability, the indicators used by the study are those that exhibits the characteristics of being observable, measurable, and exhibits interaction between ATS and upland farms, and can be representative of the different dimensions of agricultural sustainability. Sustainability in agriculture is not a final product but rather a process and direction (Hayati et al. 2010), hence the indicators applied by the study are indices to assess whether or not the introduction of ATS in the uplands is contributing towards agricultural sustainability. To simplify, the study disaggregated agricultural sustainability into three major dimensions: environmental, social and economic aspects (Yunlong and Smit 1994).

Hayati et al. (2010) provided an easy reference for selecting the most relevant indicators in relation to ATS and the upland farms. With these indicators the study can now assess whether certain trends are steady, going up or going down (Pretty 1995) which will determine how ATS is contributing to agricultural sustainability. Table 1 presents the dimensions, indicators and measurement units of agricultural sustainability used in the study.

Table 1. Dimensions, indicators and measurement units of agricultural sustainability used by the study.

Sustainability dimensions	Indicators	Measurement units
1. Social sustainability	• Working condition[a] (manual labor replaced)	• Person-days/ha;
2. Economic sustainability	• Average crop yield[b] • Incremental income[c]	• kg/ha • Php/ha
3. Environmental sustainability	• Usage of organic fertilizer[d] • Land use type conversion • Soil nutrients: pH, OM, P, K • Fossil fuel use[e] • GHG emission[f]	• bags/ha • % • pH level, %, ppm • Li of diesel/ha • CO_2 eq/ha

[a] (Ingels et al. 1997; Van Cauwenbergh et al. 2007)
[b] (Hayati 1995; Nambiar et al. 2001; Rasul and Thapa 2003)
[c] (Herzog and Gotsch 1998; Nijkamp and Vreeker 2000; Pannell and Glenn 2000; Van Cauwenbergh et al. 2007)
[d] (Bosshard 2000; Hayati 1995; Norman et al. 1997; Saltiel et al. 1994)
[e] (Ingels et al. 1997; Nambiar et al. 2001; Norman et al. 1997; Senanayake 1991; Van Cauwenbergh et al. 2007)
[f] (Volenzo et al. 2019)

These indicators were obtained from upland farms representing “with ATS” and “without ATS” and were later compared and analyzed using different statistical analytical methods with the aid of Statistical Package for Social Sciences (SPSS) software.

Measurement of agricultural sustainability indicators

Social sustainability. Improvement in the working condition due to ATS was measured by quantifying the manual labor that was spared from the drudgery of manual hauling by mechanizing transport**.** The number of manual labor force (Lr) replaced by ATS was computed as**:**

$$Lr = (p \times d)/A$$

Where:
Lr= manual labor replaced, in person-days/ha
p= number of persons performing manual hauling
d= days to accomplish hauling @ 8hr per working day, in days
A= farm area, in hectare

Economic sustainability. The computation of average yield and incremental income representing the economic sustainability indicators are presented below:

1. *Average yield (AY)* Average yield refers to the average weight of harvest of specific crop per unit area. The crops considered in the study included the temperate vegetables that are commonly grown in the farmers' field such as cauliflower, potato, cabbage, carrot and chayote. Average yield (AY) was computed using the formula:

$$AY = \frac{C}{A}$$

Where:
AY = average yield of crop, in kg/ha
C = crop yield, in kg
A = farm area, in hectare

2. *Incremental income (I)* Incremental income was computed based on the changes in revenue and costs arising from the use of ATS over the traditional method of hauling. Incremental income (I) was computed using the formula:

$$I = (Ra + Cr) - (Rr + Ca)$$

Where:
I = incremental income, in P/ha
Ra = added revenue, in P/ha
Cr = reduced cost, in P/ha
Rr = reduced revenue, in P/ha
Ca = added cost, in P/ha

Environmental sustainability. The effect of ATS on the environmental indicators was measured by comparing the "with" and "without" ATS. The description and formula used for the measurements of these environmental indicators are presented below.

1.1. Land use-agriculture (LUa)

This refers to areas devoted for growing different crops, mostly temperate vegetables. *LUa* was computed using the formula:

$$LUa = \frac{Aa}{TA} \times 100$$

Where:
LUa = land use for agriculture, in percent
Aa = area devoted for agriculture, in hectare
TA = total land area, in hectare

1.2. Land use-forest (LUf)

Forest land use refers to areas that are under natural cover not engaged by human activity except as a source of water and fiber materials. *LUf* was computed using the formula:

$$LUf = \frac{Af}{TA} x\ 100$$

Where:
LUf = Forest land use, in percent
Af = forest area, in hectare
TA = total land area, in hectare

1.3. Land use-idle land (LUi)

This refers to lands that were cultivated before but for a long period of time is now in a state of disuse, abandoned or in a state of fallow. *LUi* was computed using the formula:

$$LUi = \frac{Ia}{TA} x\ 100$$

Where: LUi = Land use as idle, in percent
Ia = idle land area, in hectare
TA = total land area, in hectare

2. Organic fertilizer utilizaton (OfU)

Organic fertilizer utilization refers to the average number of bags (50 kg) of organic fertilizer, particularly chicken manure, used per unit area per crop per season. Organic fertilizer utilization (*OfU*) was computed using the formula:

$$OfU = \frac{F}{A}$$

Where:
OfU = fertilizer utilization, in bags per hectare per crop
F = no. of bags of organic fertilizer applied, in bags of 50kg
A= farm area, in hectare

3. Soil nutrients

The study followed the protocol of Bureau of Soils and Water Management (BSWM) for soil analysis. Ten representative farms each from the three project sites were used as sampling points. During soil sampling, approximately a slice of 15 cm depth with 2cm thick and 5cm wide of soil sample were taken from the surface or topsoil from each point using shovel. The levels of OM, P, K and pH were used to determine the difference in soil nutrient levels between farms "with" and "without" ATS (Table 2).

Table 2. Methods used in the measurement of soil pH, organic matter, P, and K.

Soil chemical parameters	Methods used[a]
pH	1:1 Soil: H_2O
Organic matter	Walkley and Black Method
P	(pH<5.5, Olsen Method), (pH>5.5, Bray #1 Method)
K	Cold H_2SO_4 Method

[a] Regional Soils Laboratory of the Bureau of Soils and Water Management of the Department of Agriculture.

4. *Energy use*. Energy used for hauling refers to two sources of energy: human energy for manual hauling and the energy used to power the engine or prime mover of the ATS. The computation of the energy use was based on the average distance of the upland farms to the nearest road, total weight of agricultural inputs and outputs, and the time spent to accomplish the hauling operation. Energy used for both modes of transport is expressed in megajoules *(Mj)* which is computed using the formula:

$$E = P \times t \times 1x10^6 s$$

Where: E = energy, in Megajoules
P=power, in watts
t=time, in second

Power (P) is computed using the formula: $P = W/t$

Where: P=power, in watts
W= work, in newton-m
t= time, in second

Work (W) is computed using the formula: $W = f \times d$

Where: W = work, in newton-m
f = force, in newton
d = distance, in m

5. *Greenhouse gas emission (GHG)*

GHG emission refers to the emission contributed by the internal combustion engine that powers the ATS. GHG is computed using formula (Kramer et al.; 1999) presented below:

$$GHG = GWP \times Mi$$

Where: GHG = greenhouse gas emission in kg CO_2 *eq ha-1*
GWP = global warming potential, 1 for CO_2*;*
Mi = mass of emission gas, in kg

METHODS OF ANALYSES

Descriptive analysis. This analysis was used on socioeconomic characteristics and farm profile of the farmer- respondents. Quantitative data such as rate of inputs utilization, percentage allocation of land uses, size of area, household income, distance of farm to market center, yield per hectare, etc. were presented using mean values. For qualitative data such as types of land uses, vegetable crops grown, land tenure, types of irrigation, etc., frequency distribution was applied.

T-test. Paired t-test was used in this study and the two groups or populations were represented by the “with ATS” and “without ATS”. This analysis was used to determine if there is significant difference on the observed changes on selected indicators. The study could have extended further the analysis by running regression analysis to isolate the predictors of some of the indicators of agricultural sustainability. The issue of heteroscedasticity (unequal variance) however in the observed data prevented the use of such analysis and therefore the study was limited to t-test.

Partial budget analysis. The viability of the tramline system from upland farmer’s viewpoint was assessed using partial budget analysis. Partial budgeting is an instrument that measures the effects of marginal changes on overall profitability and, in particular, choosing between technologies and enterprises (SEARCA undated) A positive change in income implies that a farmer is better off using the ATS. On the other hand, a negative change in income will imply otherwise suggesting that farmers will be better-off status quo. In the partial budget analysis the change in income (I) is computed using the formula:

$$I = (Ra + Cr) - (Rr + Ca)$$

where: I = change in income, in PhP
Ra = added returns
Cr = reduced cost
Rr = reduced returns
Ca = added cost

RESULTS AND DISCUSSION

Study site. Benguet province is geographically mountainous, characterized by rugged, irregularly patterned ridges, canyons and peaks, many of which are above 2,400 meters above sea level (masl) in elevation. The slope classification of Benguet ranges from gently sloping to very steep. Of the total land area, more than half have very steep slopes (slope gradient of 84% and above) while almost one-seventh belong to the steep slope (51-84%) category (PDPFP 2018). There are three major land use systems prevailing in the study areas: a) vegetable-based annual crops, b) perennial crops and c) upland rice-based annual cropping, which are all under agricultural land use. Areas not included in this land use system generally fall under grasslands and other land use types.

Upland farms and farmers characteristics. The average size of upland farms in the study sites is 3500 and 3900 m^2 for "without ATS" and and "with ATS", respectively. Majority of the farms are irrigated (67%) through sprinkler system tapped from natural spring and more than half of the farms are situated less than 2 km away from the road. Majority of the upland farmers both for "with ATS" and "without ATS" own the land. The average age of upland farmers interviewed is 44 years old. Majority are male (83%), have primary (43%) to secondary (40%) schooling, have been farming for 11 to 20 years (34%) and more than three-quarters of their family income are derived from farming (77%).

Technical description and nature of establishment of ATS. The ATS prime mover is powered by 80 hp internal combustion engine that runs on diesel fuel, the system is built with combinations of pulleys, towers, wire rope cables and a single carrier that can carry 200-300kg load (Fig. 3). The ATS has a hauling capacity of 3 to 5 tons per hour depending on the distance which can range from 200 to 1500 meters between the main station and the farthest loading/unloading stations. Organized group of upland farmers operate, maintain and manage the system.

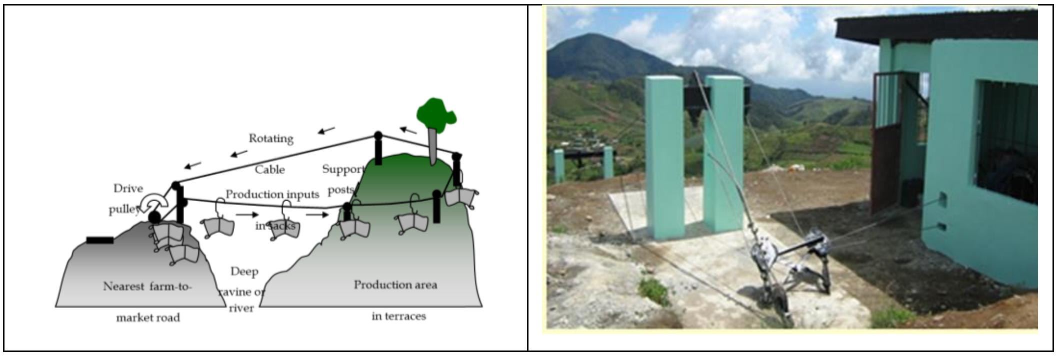

Fig. 3. Schematic diagram of an agricultural tramline system and a template of its structural components (Source: Idago and Ranola 2012; Idago and Rebancos 2020)

About three-quarters (72%) of the existing ATS in Benguet were established by the government as public infrastructure while the remaining by private individuals and farmers group.

The effective service area can range from 3 to 16 hectares. ATS with service areas ranging from 3 to 5 hectares are mostly put up by well-off farmers or group of farmers.

Social sustainability. Apparently the most significant contribution of ATS in relation to social sustainability is its direct contribution to the elimination of the drudgery of manual hauling. This alone contributed directly to improved working conditions in the upland farms. With ATS around 14 person-days are spared from the drudgery of manual hauling of agricultural products in one hectare per season (Table 3) compared to a separate study which had a higher estimate at 17 person-days/ha/season (Dela Cruz et al. 2000). Ninety five percent (95%) of the farmers interviewed claimed that with the ATS they were relieved from the drudgery of transport which they exaggeratedly described as *trabahong kalabaw* (work of a carabao). ATS which is a form of agricultural mechanization contributed to improvement in the working conditions on-farm by eliminating the drudgery of manual hauling, which is one of the benefits of agricultural mechanization (Olaoye and Rotimi 2010; Verma 2008).

Table 3. Hauling duration of vegetables and inputs between manual and ATS.

Item	Mean Hauling Duration (person-days/ha/season)		Mean difference
	ATS	Manual	
1. Inputs	0.84	2.64	-1.8**
2. Vegetables	2.31	14.04	-11.73**
			-13.53

**significant at 1% level of significance

Economic sustainability

Average crop yields. Farms “with ATS” had significantly higher yield compared to farms “without ATS” (Table 4). It can be deduced that higher crop yield is attributable to higher rate of organic fertilizer use particularly chicken manure which is corroborated by the findings of Idago and Ranola (2012). This is also consistent with the study of Ismaeil et al. (2012) that the use of chicken manure has a positive effect on growth attributes and average yield.

Table 4. Average yield of selected crops from farms “with ATS” and “without ATS” Benguet, 2018.

Crops	Average yield, kg/ha		Mean Difference
	With ATS	Without ATS	
1. Cabbage	14,738	18,212	3,474 ns
2. Cauliflower	40,734	28,650	12,084**
3. Carrot	27,595	15,111	12,484ns
4. Chayote	1,918	1,496	422**
5. Potato	14,350	11,089	3,261ns

** significant at 5% level of significance
ns - not significant at 10% level

Incremental income. Replacing traditional manual hauling with ATS resulted in a increase in income of P55,631/ha/yr (Table 5). This suggests that a farmer will be better-off adapting the ATS over the traditional manual hauling practice. Productivity is increased through higher yields and savings from hauling costs.

Table 5. Partial budget analysis (per hectare per year) using ATS against manual hauling; Benguet; 2018.

Added Costs (A)		Added Returns (B)	
1. Additional Fertilizer – Organic 134 bags @ P150/bag	P20,100	1. Increased yield of vegetables, 10,768kg @ P15.00/kg	P161,520
– Inorganic 33 bags @ P1,200/bag	P39,600		
2. Transportation cost of additional fertilizer, 167 bags @ P50/bag	P8,350		
3. Hauling Cost of additional fertilizer using Tramline, 167 bags @ P25/bag	P4,175		
– Additional yield 216 bags x P50/bag	P10,800		
4. Labor cost of fertilizer application, 137 bags @ P50/bag	P6,850		
5. Labor cost of harvesting additional yield, 0,768 @ P5.00/kg	P53,840		
6. Opportunity cost, 8% of items 1 to 5	P11,497		
Reduced Returns	(nil)	Reduced Costs 1. Savings from manual hauling	
		– Fertilizer, 351bags @ P23/bag	P8,073
		– Vegetables, 1218 bags @ P25/bag	P30,450
		2. Time saved from manual hauling – 36 man-days/yr @ P300/day	P10,800
Subtotal	A = P155,212	B = P210,843	
Change in income (B-A)	= P 55,631/ha/yr or P 27,816/ha/season		

Environmental Sustainability

Usage of organic fertilizer. Farms "with" ATS applied significantly higher amount of organic fertilizer (Table 6). This finding was consistent with the study of Dela Cruz et al. (2000) which revealed that farms serviced with tramline facility increased utilization of production inputs by 30 percent. This was further corroborated by the findings of Idago and Ranola (2012) and Idago and Rebancos (2020) that improving access encourages increase use of production inputs as well as cropping intensity if the production area is complemented with irrigation facility. Based on survey, the cost (94%) and drudgery (95%) of transport are the major barriers that restrict organic fertilizer use.

Table 6. Average organic fertilizer usage in selected crops of farms “with ATS” and “without ATS” Benguet, 2018.

Crops	Fertilizer utilization rate (bags/ha)		Difference
	with ATS	without ATS	
Cauliflower	102	150	48 ns
Potato	180	90	90**
Cabbage	163	106	57*
Carrot	98	42	56 ns
Chayote	74	70	4 ns

** significant at 5% level of significance
* significant at 10% level of significance
ns - not significant at 10% level

Land use type. Based on the study of Idago and Rebancos (2020) areas serviced with ATS had significantly higher land use for agriculture (Table 7). However, areas serviced by ATS have significantly lesser forest area (4%), suggesting that the presence of tramline encouraged expansion of agriculture by converting forested/naturally covered areas for agricultural production. Facilitating the movement of agricultural products provided incentives for land owners to engage more areas for agricultural production by opening up forest lands.

Table 7. Comparison of land use type allocations between farms with and without ATS in the municipalities of Atok, Kabayan and Tublay; Benguet; 2018.

Land use type	Percentage allocation		Mean Difference
	With ATS n=155	Without ATS n=155	
Agriculture	90	82	8***
Forest	5	9	-4***
Idle & other land use types	5	6	-1 ns

*** significant at 1% level of significance
ns - not significant at 10% level
Source: Idago and Rebancos (2020)

Soil nutrients. The soil series in the study sites are Paoay loam soil, ambassador silt loam and mountain soil (undifferentiated) for Atok, Tublay and Kabayan, respectively. There were no significant differences in the levels of OM, P and K between farms with and without ATS. The level of pH however on farms without ATS is significantly higher than in farms with ATS (Table 8). This can be attributed to the higher amount of organic fertilizer applied in farms with ATS (Table 6). The results suggest that the presence of ATS has indirect neutral effect on OM, P and K and has a positive effect on the level of pH because of the influence of ATS on fertilizer use. Note that no further analysis was conducted beyond comparison of “with” and “without” ATS because the soil nutrient levels was associated directly to the amount of fertilizer used where ATS has direct influence. Given this limitation, a more in depth study on this aspect can be done to accurately isolate this effect.

Table 8. Soil chemical characteristics of farms with and without ATS in Kabayan, Atok and Tublay, Benguet; 2018.

Soil chemical parameters	With ATS (n=32)	Without ATS (n=30)	Mean difference
pH	5.47	5.02	0.45**
OM (%)	2.08	1.92	0.16^{ns}
P (ppm)	125.99	110.40	15.59^{ns}
K (ppm)	324.53	346.08	-21.55^{ns}

** significant at 1% level of significance
ns - not significant at 10% level

Energy use. The study established that using manual labor to transport 548,950 kg of agricultural inputs and outputs, the average total load per year, at an average distance of 948 m requires 5,153Mj. This is the energy equivalent exerted by manual labor. Using the same volume of agricultural load, the same travel distance and considering the ATS hauling capacity, fuel consumption and energy equivalent of diesel fuel that powers the system, the ATS requires 21,875Mj. This implies that ATS consumed greater amount of energy than human labor to transport the same volume of agricultural load. This shows the need for the design of the system to be further improved to make it more energy efficient.

GHG emission. On the aspect of greenhouse gas emission specifically looking into the CO_2 equivalent, ATS that runs on diesel fuel generates 1,635kg CO_2 per hectare per year. This was established by computing the amount of diesel consumed per year which is 610 Li and multiplied by its CO_2 equivalent which is 2.68kg CO_2/Li. This suggests the need to improve ATS' environmental performance, in terms of GHG mitigation, by using a cleaner source of energy to run the system such as the use of solar power.

CONCLUSION AND RECOMMENDATIONS

ATS positively influenced the social dimension of sustainability as indicated by the improvement in working conditions of farmers by eliminating the drudgery of moving products through mechanization of transport. It also positively contributed to the economic sustainability at the farm level as exhibited by its indirect positive effect on crop yield resulting to higher productivity of upland farms. ATS however has a downside as it encourages conversion of forests and idle areas to agricultural land use resulting in deforestation which can threaten agricultural sustainability in the long run. Also, there is a need for cleaner source of energy to run the ATS. Findings from the study can be used as criteria in selecting specific locations where the potential of the facility can be maximized and sustained. The negative impacts of land use intensification must be seriously addressed to attain agricultural sustainability. The influx of inputs and outputs from the farm would maximize and sustain the tramline operations since underutilized facility leads to poor maintenance and sustainability of its operation. Assuming all dimensions of sustainability to have equal weights, we can say that two out of three aspects of sustainability are influenced positively by ATS. To mitigate its negative effects on the environment, the study recommends strict land use zoning implementation and prohibiting the establishment of ATS adjacent to forest areas and fragile ecosystems. Soil and water conservation innovations in the uplands must also be an integral part of the farming systems. Agricultural sustainability in the uplands can only be attained by striking a balance among the social, economic and environmental aspects of sustainability.

ACKNOWLEDGEMENT

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The authors would like to thank the Department of Science and Technology under the Accelerated Science and Technology Human Resource Development Program for funding the research. Thanks is also due to the upland farmers and the Office of the Municipal Agriculturists of Tublay, Atok and Kabayan, Benguet, Philippines for sharing their experiences and information during the conduct of the survey.

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