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SUBJECT III
ECOSYSTEM SERVICES BASED APPROACHES IN AGRICULTURAL POLICY MAKING

Alder-Based Farming System of Nagaland: Valuating the Eco-Services from Nitrogen Fixing Trees

Limasunep Ozukum*, Sheikh Mohammad Ferozeand Aniruddha Roy***

ABSTRACT

The present study has assessed the economic value of the eco-services provided by the alder-based farming system (AFS) at Khonoma village under Kohima district in Nagaland by covering 60 AFS and 39 non-AFS farms. Direct market price and preventive expenditure method under the revealed preference approach are used to measure the economic value of the services provided by the system. The estimated value of the nitrogen contributed naturally by the alder trees was ₹3208.95/farm and ₹7073.70/ha. The total value of the services provided by the alder trees at Khonoma ranged from ₹14936.81/farm to ₹17169.61/farm and ₹30521.59/ha to ₹35171.82/ha. Thus, the AFS has the potential to be replicated in other *jhum* areas through dissemination of knowledge on alder tree management.

Key words: Alder, valuation, direct pricing, preventive expenditure, services

JEL classification: Q56, Q57

I

INTRODUCTION

Assessing the value of ecological services is crucial for promoting sustainability, evaluating efficiency, and including hard-to-quantify environmental effects in the analysis of costs and benefits (Kiran and Kaur, 2011). Biological systems consist of natural resources that provide both tangible goods, which have monetary value, and intangible services that are challenging to quantify monetarily (Dixon and Pagiola, 1998). Easily measurable environmental goods like food, timber, energy, and materials have established economic markets, making their valuation straightforward. On the other hand, certain environmental services such as water supply from watersheds, pollination of crops by birds and bees, pollution purification by wetlands, coastal safeguarding through vegetation, and aesthetic appreciation lack such market structures. To address this, diverse economic valuation techniques have been developed to assign monetary worth to these non-market benefits (Freeman, 2003; Hackett, 2009).

The alder-based farming system (AFS) is one such man-made ecosystem where the various components possess use or potential use values to the society

* PhD Scholar (Agricultural Economics), Department of Agricultural Economics, SAS, Nagaland University, Medziphema-797 106, Nagaland; Associate Professor (Agricultural Economics), College of Agriculture, Central Agricultural University, Imphal, Manipur-795 004 and Senior Scientist (Agricultural Economics), Division of Social Sciences, ICAR RC for NEH Region, Umiam-793 103, Meghalaya, respectively.

(Mburu *et al*., 2007). Alder (*Alnus nepalensis)* is a deciduous or semi-deciduous tree with a straight trunk, up to 20 m in height and 60 cm (rarely to 2 m) in diameter. Two species of alders are found in the Himalayas viz*.*, *A. nepalensis* in the eastern Himalayas and *A. nitida* in the north western Himalayas (Sharma *et al*., 2002). In Nagaland, the climate is ideal for a non-leguminous tree species. It thrives in moist areas near rivers and can also adapt to rocky sites resulting from landslides or abandoned land. Additionally, it has the unique ability to fix nitrogen (N) through root nodules (Sharma and Ambasht, 1986; Sharma *et al.*, 1998; Rathore *et al.*, 2010).

AFS represents the integration of alder tree species into the methods of *jhum* farming (Cairns, 2007). The AFS technique was notably developed in Khonoma village, situated 20 km to the west of Kohima, the capital of Nagaland. (NEPED and IIRR, 1999). The system offers 57 food crops to complement the nearby wet terrace rice cultivation (NEPED and IIRR,1999). The system promotes traditional crop diversity, monitors environmental health, reduces chemical fertiliser usage, and controls weeds (Mortimer *et al.,* 2015). The key economic components of the AFS are trees, biomass, crops, and the services provided by trees such as soil amelioration, N fixation, and ozone layer preservation (Freeman, 2003; Mburu *et al.*, 2007). Those non-physical services lack monetary representation, hindering the determination of the total value of the AFS (Hanley *et al.,* 2001). Positive externalities must be monetised to emphasise the overall importance of the AFS, considering both its use and non-use values. Thus, this study attempts to evaluate the eco-services rendered by AFS through N fixation.

II

MATERIALS AND METHODS

Study Area

The research was carried out in Khonoma village, positioned to the west of the Kohima district in Nagaland, situated about 20 km away. This village is categorised within the Sechu-Zubza block of Kohima and spans an approximate area of 123 square kilometers. Its elevation varies between 1200 meters and 2868 meters above sea level. The village's woodland covers an extent of 20 square kilometers. The village itself is home to around 3000 individuals, distributed across 600 households. The village's topography consists of 58.53 per cent hilly terrain, with the remaining 41.47 per cent of the land being utilised for agricultural activities (Government of Nagaland, 2015). Agriculture is the main occupation for the people of Khonoma. Natural forests, alder based *jhum* cultivation and wet terrace paddy cultivation together represents the predominant traditional land use systems. Alder based *jhum* among the *Angamis* is well developed at Khonoma village. Wet terraced paddy cultivation is practiced in hilly areas at different elevations and paddy fields thrive with the help of farm yard manure (FYM) and nutrients from the hill slopes.

Sampling Technique

Alder tree (*Alnus nepalensis*) is prevalent in the eastern Himalayan region, including Nepal, Sikkim, Darjeeling, Bhutan, Arunachal Pradesh, Meghalaya, and Nagaland. In Nagaland, the local farmers have traditionally integrated alder trees into their *jhum* fields for crop cultivation. Therefore, in the first stage, Nagaland state was chosen purposively for this reason. Khonoma village under Kohima district of Nagaland was selected purposively as the study area because the AFS is primarily confined in this area where the villagers have perfected the system than any other village in the area and it has the highest area under the AFS (Kithan, 2014). Two AFS *khels* were selected purposively based on the population engaged in AFS. A total of 60 AFS farms were selected randomly. For comparing soil parameters, Mokokchung district was selected purposively as the control district as the district has 123063 ha of area under *jhum* (Longkumer and Jamir, 2012). After discussion with the district Agriculture Development Officer, Waromung village was selected as it was a *jhum* dominant village. Primary data was collected from 39 farms (*i.e.*, 65 per cent of 60) from this village (Murphy and Spray, 1983). Hence, a sample of total 99 farms was covered.

III

ANALYITCAL TOOLS

Soil Sample Collection

Soil sampling was conducted within the AFS *jhum* field located at Khonoma, specifically at coordinates 25°38'14.3" N and 94°32'37.3" E. Around each alder tree, a grid measuring 5 m by 5 m was established. Within this grid, soil samples were collected at a depth ranging from 15 to 20 cm, employing a 'Z' pattern to select random sampling points. Care was taken to avoid the outer sections. Subsequently, the collected soil samples were thoroughly mixed to create a unified composite sample. This procedure yielded four composite soil samples in July 2017 and an additional five in February 2018, aligning with the different ages of the trees within the AFS *jhum* fields.

Additionally, five soil samples were procured from a non-AFS jhum field situated at coordinates 25°38'13.6" N and 94°01'21.6" E. These samples were obtained from five random spots within the field. The non-AFS *jhum* field, located in Warumong village within the Mokochung district of Nagaland, was positioned 224 km away from Khonoma. This field served as a control plot, allowing for the comparison of N content variations in soils under the AFS and non-AFS farming systems after a fallow period of 10 years.

Laboratory Experiment

Soil Nitrogen Estimation: Soil samples were air-dried, crushed, and sieved through a 1.4 mm sieve. The N availability was determined using the Kjeldahl method. Physico-chemical properties were analysed following standard procedures

(Jackson, 1973). Alder trees' impact on soil N was assessed by comparing available N levels in AFS *jhum* fields and non-AFS *jhum* fields.

Soil pH and SMP Buffer Test: Soil samples' pH was measured with a glass electrode pH meter, and lime requirements for both farming systems were estimated using the SMP buffer test method.

Monetary Value of N, Lime and Environmental Damage

Direct Pricing Method

An alternative source of nitrogenous fertilizer was taken up which can be used to supplement the N to the AFS *jhum* field in the absence of the soil N contributed naturally by the alder trees in the AFS *jhum* field. Urea was chosen as the alternative N source in India due to its widespread use as a fertiliser. The total cost of urea per kg, along with the expenses for handling and transporting it to the AFS *jhum* field, was used to represent the monetary value of the N provided naturally by the alder trees. *i.e.,*

Value of N supplied naturally = cost of urea/kg …. (1)

Preventive Expenditure Method

Soil Amelioration Cost: The amount of lime to be applied for soil amelioration per farm and per hectare was calculated using two methods.

1. The first method applied to calculate the amount of $CaCO_3$ was using the SMP buffer test developed by Shoemaker, McLean, and Pratt (SMP) in 1961 and cited by Anderson *et al.* (2013). Lime requirement for adjusting soil pH is determined by measuring soluble and exchangeable hydrogen and aluminum. The lime amount needed for the AFS field in Khonoma was estimated based on the SMP chart recommendation to raise the initial soil pH to a target pH of 5.6.
2. The second method estimated the required amount of CaCO3 using literature estimates from Bolan and Hedley (2003) and Upjohn *et al*. (2005). According to their findings, applying 50 kg/ha/year of urea-N fertiliser requires approximately 100 kg CaCO3/ha/year to improve the soil.

Environmental Damage Cost: The use of synthetic and organic fertilisers add N to soils, thereby increasing natural emissions of N_2O (OPPE, 1994). The environmental damage cost from application of synthetic nitrogenous fertiliser (urea) is about ₹8.21/kg N_2O or ₹0.069/kg urea (Blotnnitz *et al.,* 2006, Bhat and Umesh, 2016). The avoided cost can be reflected by the amount of soil N supplied naturally by the alder trees in rupees. The environmental damage cost prevented by the presence of the alder trees can be reflected as the value of the service the trees provide is shown as:

Prevented Expenditure = Cost of soil amelioration using lime + N_2O emissions (in kg) X ₹8.21 …. (2)

Other cost = transportation cost of urea and lime + handling charges + opportunity cost of labour (wage) (Refer Appendix Table 1) .... (3)

Hence, adding equation (i), (ii) and (iii) we get the total value of the service provided by the AFS *i.e.*,

Value of service = Direct Valuation + Preventive Expenditure + Other cost …. (4)

IV

RESULTS AND DISCUSSION

The alder tree engages in a symbiotic relationship with Frankia within its root nodules, facilitating the conversion of atmospheric N into a usable form (Sharma *et al*., 1998). This interaction also plays a role in sustaining the population of soil microorganisms, thereby enhancing soil fertility and contributing positively to the ecosystem (Bhat and Umesh, 2016). The alder tree's contribution extends to the enrichment of soil fertility through N accumulation and the production of organic litter, representing a valuable ecological service. The contrasting levels of available soil N in both the AFS *jhum* field and non-AFS *jhum* field are outlined in Table 1.

Estimation of Available Soil N

The study involved determining the average soil N content across different age groups of alder trees. The difference between the estimated N content in agroforestry system (AFS) jhum fields and non-AFS jhum fields was considered residual, attributed to alder trees through processes like root accretion and litter accumulation. The estimated available soil N content in AFS jhum fields was found to be 438.74 kg/ha (as shown in Table 1). Among the alder trees, those aged less than 21 years exhibited a soil N content of 514.76 kg/ha, followed by trees aged between 21 and 70 years with a content of 441.17 kg/ha. Alder trees older than 70 years had the lowest soil N content at 221.07 kg/ha. Sharma *et al.* (1998) reported that the amount of N fixed by 17-year, 30 year and 46-year-old alder trees was 56 kg/ha, 45 kg/ha and 37 kg/ha, respectively and the total N accumulated from the litter were 212 kg/ha, 237 kg/ha and 252 kg/ha, respectively, but Chase and Singh (2014) reported much lower N content *i.e.*, 159.49 kg/ha in the *jhum* fallows (3-5 years) of Khonoma.

TABLE 1: ESTIMATED AVAILABLE SOIL N IN AFS *JHUM* FIELD AND NON-AFS *JHUM* FIELD

Sample No.	AFS *jhum* filed			Non-AFS *jhum* field	
	Soil sample collection date	Age range of the tree (years)	Available soil N (kg/ha)	Soil sample collection date	Available soil N (kg/ha)
(1)	(2)	(3)	(4)	(5)	(6)
1.	18/07/2017	<10.0	439.32	26/01/2018	188.82
2.	18/07/2017	10.0 -15.0	689.92	26/01/2018	250.88
3.	18/07/2017	50.0 – 60.0	276.32	26/01/2018	62.72
4.	18/07/2017	90.0–100.0	65.83	26/01/2018	156.80
5.	06/02/2018	2.0 – 2.5	627.20	26/01/2018	219.52
6.	06/02/2018	2.5 – 3.0	627.20		
7.	06/02/2018	3.5 – 4.0	376.32		
8.	06/02/2018	12.5 – 13.0	439.04		
9.	06/02/2018	13.5 -14.0	407.68		
Mean			438.74		175.74

As alder trees in AFS jhum land mature, the soil N content experiences a gradual decline. With each passing year of alder tree growth, there is a reduction of 5.13 kg/ha in the quantity of accessible soil N. Farms hosting alder trees of a younger age (15 years) exhibit higher levels of available soil N per hectare when compared to farms with more mature alder trees. Furthermore, the amount of available soil N is subject to variation based on the timing of soil sample collection. Soil samples obtained in July demonstrate an elevated estimation of available soil N, reaching 689 kg/ha. In contrast, samples collected in February from alder trees of similar age display lower estimated available soil N levels, ranging from 439.04 kg/ha to 407.68 kg/ha (Figure1 and Figure2).

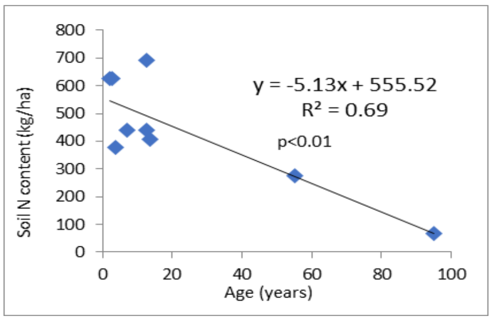

Figure 1. Trend in estimated available soil N across different age category

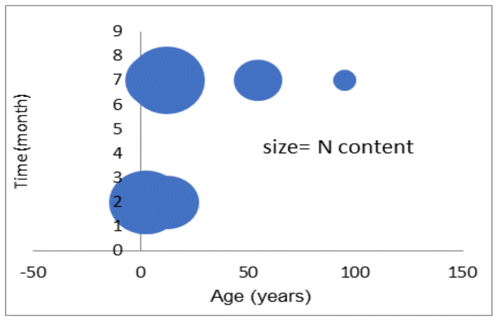

Figure 2. Relationship between estimated soil N, age of alder trees and month of soil sample collection

The average estimated available soil N was 175.74 kg/ha in the non-AFS *jhum* field at Waromung (Table 2). But, Henry *et al*. (2016) reported that the available N was 278 kg/ha in burned *jhum* field (non-AFS) soil following a 10 year of fallow period at Changki village in Mokokchung district of Nagaland. The estimated available N in the soils of two farming systems differed by 216.93 kg/ha. The highest difference of 339.36 kg/ha was observed for alder trees aged less than 21 years, while the lowest difference of 45.67 kg/ha was observed for alder trees aged more than 70 years. This suggests that the available soil N decreased with increasing age of alder trees in AFS *jhum* fields.

TABLE 2: AVERAGE AVAILABLE SOIL N (KG/HA) IN AFS *JHUM* FIELD AND NON-AFS *JHUM* FIELD ACROSS DIFFERENT AGE CATEGORY OF ALDER TREES

Sl. No. (1)	Age of the trees (years) (2)	AFS *jhum* land (3)	Non-AFS *jhum* land (4)	Difference in the N content (5)
1.	<21	514.76	175.74	339.36
2.	21-70	441.17		265.77
3.	>70	221.07		45.67
	Overall	438.74		216.93

Valuation of N: Direct Pricing Method

The soil N contribution in kilograms per farm (kg/farm) by alder trees across different AFS farm size categories is given in Table 3. The soil N contributed by the alder trees was highest (243.51 kg/farm) in the case of medium farms with average land size of 1.30 ha and lowest (28.33 kg/farm) for the marginal farms with average land holding size of 0.11 ha. This was due to the presence of higher number (101) of older alder trees (>70 years) in medium farms (Appendix Table 2) which contributed significantly lesser amount of N (45.67 kg/ha) as compared to the alder trees of younger age (<21 years) category (339.36 kg/ha).

TABLE 3: ESTIMATED SOIL N (KG/FARM) CONTRIBUTED BY THE ALDER TREES ACROSS AFS FARM SIZE CATEGORY AND REQUIRED QUANTITY OF UREA AND COST (KG/FARM)

AFS farm size category (ha)	N	Average land holding size (ha)	N (kg/ farm)	Quantity of required urea (kg/farm)	Cost of urea ₹/farm*
(1)	(2)	(3)	(4)	(5)	(6)
Marginal (<0.33)	30	0.11	28.33	61.58	923.70
Small (0.33 – 0.76)	16	0.53	102.86	223.60	3354.00
Medium (>0.76)	14	1.30	243.51	529.36	7940.40
Overall			98.41	213.93	3208.95
	-	-	216.93#	471.58##	7073.70@@

Notes: # indicates N in kg/ha and ## indicates urea in kg/ha.
@@cost of urea at open market in Dimapur (in ₹/ha)

The estimated average N contribution by the alder trees was 98.41kg/farm and 216.93 kg/ha. Hypothetically, in the absence of alder trees, if the farmers of Khonoma would have applied inorganic fertiliser viz., urea (N = 46 per cent) they would have needed about 213.93 kg of urea/farm and 471.58 kg of urea/ha (Table 3). The estimated cost of urea was ₹3208.95/farm and ₹7073.70/ha. This is the alternative value of the N supplied naturally. Bhat and Umesh (2016) studied on the positive externalities of N fixation by pulses and found out that on an average growing of pulses can possibly save cost incurred on N fertilisers (urea) to the tune of ₹466 - ₹699/ kg of N/ha.

Valuation of Soil Amelioration and Environmental Damage: Preventive Expenditure Method

Soil Amelioration

Excessive N fertiliser lowers pH, causing soil acidity (Bolan and Hedley, 2003). Without alder trees, Khonoma farmers would have required lime (CaCO3) or bio-char to counteract soil acidity if they used the estimated urea amount. The determination of lime requirement through SMP Buffer Test is presented in Table 4.

TABLE 4: LIME REQUIREMENT USING SMP BUFFER TEST

Jhum soil	Soil ph	Lime requirement test value (SMP)	Quantity of lime required (t/ha)+	Difference in the lime requirement (t/ha)
(1)	(2)	(3)	(4)	(5)
AFS	4.95	5.20	11.63	0.74
Non-AFS	4.60	5.10	12.37	

Note: +Target pH = 5.6

The pH estimated for the soils of the two farming systems were 4.95 and 4.60, i.e., both the soils were acidic (Table 4). Bier and Singh (2018) also reported that soils of Nagaland are moderately to strongly acidic. Singh and Munth (2013) studied the fertility status of soil under forest and cultivated land use system of Nagaland where they collected soil samples from both cultivated soil and forest soil at Khonoma. Soil pH of 5.2 was reported for both cultivated soil and forest soil. Chase and Singh (2014) found that the soil pH in three traditional land use systems of Khonoma, including natural forest, paddy field, and jhum fallow, was acidic, with an average pH of 5.16. Henry *et al.* (2016) reported pH of 4.53 in the soils of burnt non-AFS *jhum* fields opened a gap of 10 year of fallow period in Changki village under Mokokchung district of Nagaland.

The estimated quantity of lime required to ameliorate the soil was 11.63 t/ha and 12.37 t/ha for AFS *jhum* fields and non-AFS *jhum* fields, respectively (Table 4). But, Singh and Munth (2013) suggested 8.6 t/ha of lime for neutralising the soil of Khonoma. The estimated difference in the quantities of lime required in AFS and Non-AFS field was 0.74 t/ha. Alder trees in AFS *jhum* fields save lime, preventing soil acidity compared to non-AFS *jhum* fields.

In order to determine the lime requirement using the SMP buffer test for various AFS farm sizes categories to estimate the cost of lime is given in Table 5. The lime requirement is estimated at 355.20 kg/farm and 740.00 kg/ha. For medium-sized farms, the lime requirement can be as high as 962 kg/farm. The estimated cost of lime is ₹10656/farm and ₹22200/ha which the farmers of Khonoma have actually avoided due to the presence of the alder trees in their *jhum* fields. The estimated quantity of lime requirement based on estimates cited by Bolan and Hedley (2003) and Upjohn *et al.* (2005) was about 427.86 kg/farm and 891.38 kg/ha. The estimated cost of lime is about ₹12835.80/farm and ₹26741.25/ha (Table 5).

TABLE 5: LIME REQUIREMENT USING THE SMP BUFFER TEST ACROSS DIFFERENT AFS FARM SIZES CATEGORY AND THE ESTIMATED COST OF LIME

AFS farm size category (ha)	Average AFS farm size (ha)	SMP buffer test		Estimates using references	
		Lime required (kg/farm)	Cost of lime (₹/farm)[1]	Lime required (kg/farm)[2]	Cost of lime (₹/farm)
(1)	(2)	(3)	(4)	(5)	(6)
Marginal (<0.33)	0.11	81.40	2442.00	123.16	3694.80
Small (0.33 - 0.76)	0.53	392.20	11766.00	447.20	13416.00
Medium (>0.76)	1.30	962.00	28260.00	1058.72	31761.60
Overall	0.48	355.20	10656.00	427.86	12835.80
	-	740.00^{+}	22200.00^{++}	891.38^{+}	26741.25^{++}

Notes: 1. unit cost of lime at open market in Dimapur is ₹30/kg;
2. 50 kg/ha/year urea-N = 100 kg $CaCO_3$/ha/year
3. $^{+}$lime required per ha and $^{++}$cost of lime per ha.

Environmental Damage

The emission of N_2O (in kilograms) resulting from the application of urea and the assessed environmental damage cost in Indian Rupees (₹) is shown in Table 6.

The estimated N_2O emission would be 1.81kg/farm and 3.99 kg/ha. The emission of N_2O would be higher (4.48 kg/farm) for medium sized farms. The estimated associated average environmental damage cost is ₹14.86/farm and ₹32.53/ha. The estimated environmental cost would be ₹36.78/farm for medium category of AFS farm (Table 6).

TABLE 6: EMISSION OF N_2O (KG) FROM APPLICATION OF UREA AND THE ENVIRONMENTAL DAMAGE COST (₹)

AFS farm size category (ha) (1)	Emission of N_2O (kg/farm)[1] (2)	Environmental cost (₹/farm)[2] (3)
Marginal (<0.33)	0.52	4.27
Small (0.33 - 0.76)	1.89	15.53
Medium (>0.76)	4.48	36.78
Overall	1.81	14.86
	3.99[#]	32.77[##]

Notes: 1. *1 kg of N = 0.0184kg of N_2O* (OPPE, 1994)
2. *1 kg of N_2O = ₹8.21 as environmental damage cost* (OPPE, 1994)
[#]*per ha N_2O emission,* [##]*per ha environmental damage cost ₹*

Valuation of Total Services (Direct Price + Preventive Expenditure)

The tabulated data in Table 7 presents the monetary quantification of services rendered by alder trees. The projected outlay for preventive measures per farm falls within the range of ₹10,670.86 to ₹12,850.66, and per hectare spans from ₹22,232.77 to ₹26,774.02. Supplementary expenses encompassing the conveyance of urea and lime, operational charges, and labor's opportunity cost, vary from ₹1,057.00 to ₹1,110.00 per farm and ₹1,215.05 to ₹1,324.03 per hectare.

TABLE 7: VALUATION OF TOTAL SERVICES PROVIDED BY THE ALDER TREES

(₹)

(1)	Particulars (2)	(3)	Per farm (4)	Per ha (5)
A	Value of N fixed naturally		3208.95	7073.77
B	Total prevented expenditure			
(i)	Cost of lime amelioration	Method 1[1]	10656.00	22200.00
		Method 2[2]	12835.80	26741.25
(ii)	Environmental damage cost avoided		14.86	32.77
	Sub-total (i + ii)	Method 1	10670.86	22232.77
		Method 2	12850.66	26774.02
C	Other cost[3]	Method 1	1057.00	1215.05
		Method 2	1110.00	1324.03
D	Total (A+B+C)	Method 1	14936.81	30521.59
		Method 2	17169.61	35171.82

Notes: 1. SMP buffer test method.
2. Using estimates from sources cited from Bolan and Hedley (2003) and Upjohn et al. (2005).
3.includes transportation cost of urea and lime, handling charges and opportunity cost of labour.

In line with Blotnnitz *et al*. (2006) findings, the environmental detriments associated with synthetic N fertiliser approximated 0.3 €/kg N. This valuation encompasses the broader climatic ramifications attributed to N_2O and CO_2 emissions during the manufacturing of fertilisers, along with N2O emissions originating from treated fields. The collective evaluated value of alder tree services in the context of Khonoma ranged between ₹14936.81 and ₹17169.61 per farm, and ₹30521.59 to ₹35171.82 per hectare (Table 7).

Actual observations indicate that, due to the presence of alder trees, farmers obviated the necessity for fertiliser application. Consequently, this led to the preservation of costs related to fertiliser procurement, transportation, and concurrently, the mitigation of expenses linked to soil enhancement and ecological harm (arising from N2O emissions) linked to inorganic fertiliser application.

V

CONCLUSIONS AND POLICY IMPLICATION

In our current era, the overexploitation of our environment and precious natural resources has reached concerning levels. Addressing this critical issue, environmental economists have embarked on a mission to not only assign tangible value to these resources but also underscore their fundamental significance. This undertaking has led to a noteworthy endeavor: quantifying the worth of the services bestowed upon us by our ecosystems. One such compelling case is the role of alder trees. These magnificent trees contribute an invaluable service by enhancing the soil with N, a vital nutrient. The remarkable aspect is that they do so naturally and without charge. This intrinsic capability eliminates the necessity for synthetic fertilizers, thereby safeguarding soil vitality and curbing potential environmental harm—such as the emission of N_2O gas, a potent greenhouse gas. By advocating for the responsible management of alder trees, we hold the potential to replicate this ingenious approach in other regions practicing traditional shifting cultivation, like jhum areas. The ripple effect of this could be transformative. Not only would it mitigate the adverse impacts often associated with traditional practices, but it would also yield substantial cost savings while nurturing our environment. In essence, championing the nurturing of alder trees emerges not just as a localized solution, but as a beacon of hope and a replicable model to counter the pervasive issues of resource depletion and environmental degradation. This is a prudent investment not only in our present well-being but in the sustainable legacy we leave for generations to come.

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APPENDIX TABLE 1: COST STRUCTURE FOR TRANSPORTATION AND HANDLING OF UREA AND LIME

Per farm/per ha	Transport cost (₹)		Opportunity cost of labour (₹/day)	Total cost[1] (₹)	
	Using estimates from sources 1	SMP buffer test method 2	3	1+3	2+3
Per farm (₹)	710.08	657.77	400	1110.00	1057.77
Per ha (₹)	924.03	815.05	400	1324.03	1215.05

Note: [1]Total cost of transportation is = ₹320 (to and fro per person bus fare to Dimapur) + weight of the urea and lime (₹ 1/q/km. (first 1q free)) x distance travelled (km).

APPENDIX TABLE 2: NUMBER OF ALDER TREES PER FARM BASED ACROSS DIFFERENT AGE CATEGORIES

Age category (years)	Reported			
	Mean	Minimum	Maximum	Median
<21	29	2	102	23
21-70	34	2	136	30
>70	46	2	204	36