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Dynamics of Soil Properties under Jhum Cultivation: A Review

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

A staple of many indigenous cultures, shifting agriculture is coming under more and more scrutiny for its role in soil degradation and deforestation, especially in light of climate change. This study investigates the effects of jhum agriculture in Arunachal Pradesh, with a particular emphasis on the detrimental effects on soil qualities and its contribution to deforestation. Along with considerable

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nutrient loss from frequent forest clearing and burning, jhum farming causes severe soil degradation, including soil erosion and changes in the physical and chemical properties of the soil. In the diverse climates of Arunachal Pradesh, characterized by heavy rainfall, soil fertility and moisture are especially vulnerable. The shortening of fallow periods further destabilizes soil moisture and fertility, despite the potential benefits of carbon dynamics and sequestration during extended fallows. This research underscores the urgent need for sustainable practices, such as improved soil moisture conservation and extended fallow periods, to align traditional agricultural practices with the goals of climate resilience, soil health, and long-term sustainability.

Keywords: Jhum cultivation; soil degradation; soil property dynamics; soil fertility; Arunachal Pradesh.

1. INTRODUCTION

For many indigenous, tribal and marginalized upland communities worldwide, shifting cultivation—a traditional agricultural practice that involves clearing and burning forested hill slopes to cultivate crops remains crucial (Dwivedi, 1992). Despite its strategic resource management aspects (McGrath, 1987), it faces criticism for contributing significantly to tropical forest depletion, accounting for 61% of such destruction. The Food and Agriculture Organization highlights shifting cultivation as a major land use challenge in tropical regions, with an estimated 500 million to one billion people practicing it globally.

Globally, 70 percent of the world agricultural area contains about 20 percent of the world's soil carbon stocks (Conant, 2010). Approximately 1 billion of the world's poorest people rely on it for their livelihoods. By reducing soil organic carbon and depleting nutrients, the conversion of forests to agricultural land under shifting cultivation hastens the degradation of soil (Saha *et al.,* 2020). Soil degradation and erosion significantly reduce soil organic carbon levels, leading to diminished soil fertility and ecosystem productivity. This loss of organic carbon exacerbates eco-environmental vulnerability, increasing the susceptibility of ecosystems to disturbances and climate change impacts (Singh *et al*., 2024, Suryawanshi *et al*., 2023). Shorter periods of fallow land aggravate these problems by lowering soil fertility and causing unfavorable alterations to the physical, chemical and biological characteristics of the soil. Reduced fallow periods result in a decrease in vital elements such as calcium, magnesium, potassium and nitrogen while an increase in soil acidity (Borggaard *et al*., 2003; Singh and Gill, 2014). Furthermore, shifting cultivation impacts carbon dynamics. Although it involves tree-clearing, the practice also includes fallow periods that contribute to carbon sequestration and vegetation recovery (Chaturvedi *et al.,* 2016). However, shortened fallow periods significantly reduce carbon stocks, undermining the potential ecological benefits (Bruun *et al*., 2009). Shifting cultivation practices have the potential to sequester approximately 59,255 t yr^{-1} of carbon while emitting only 2042 t yr^{-1} (Erni, 2015).

In regions like Arunachal Pradesh, *jhum* cultivation remains widespread, but increasing population pressures have led to shorter *jhum* cycles and smaller field sizes, intensifying soil degradation and erosion (Kalita *et al*., 2018). Shifting cultivation (*jhum*) causes rapid soil erosion, decreases soil fertility, and reduces biodiversity. Despite some claims of reduced *jhum* cycles, most areas still maintain extended cycles contributing to soil recovery (Pebam, 2018). Farmers in the region have cultivated a variety of indigenous and traditional soil and water conservation (SWC) practices over the years. However, these measures tend to be location-specific and discrete. Among these are the Zabo or Ruza system, ecosystem management, contour trench farming, the sloping agricultural land technology (SALT) approach, structural and engineering interventions, contour bunding, terracing, and trenching (Choudhury *et al*., 2022; Suryawanshi *et al*., 2024). This review examines the contemporary status of soil properties in *jhum* cultivation, focusing on the impacts of forest depletion and biodiversity loss. It assesses the implications for soil fertility and agricultural sustainability and explores potential interventions to promote sustainable practices in shifting cultivation systems.

2. METHODOLOGY

2.1 Study Area

Arunachal Pradesh, situated in the Northeastern Himalayan (NEH) region of India, covering an area approximately 8.37 million hectares situated between the latitudes 26°30' to 29°28' N and longitude 91°25’ to 97°24' E (Fig. 1). It shares borders with China and Tibet to the north, Assam to the south, Myanmar and Nagaland to the east, and Bhutan to the west, and is divided into 28 administrative districts. The annual rainfall ranging from 1380 to 5000 millimeters, with 139 rainy days. The region falls within the Eastern Himalayan Ecozone-II. Winter temperatures in areas like Bomdila and Tawang often drop to around 0°C, while in the Namsai and Tezu regions of Lohit district, summer temperatures can rise to 35°C. The average annual temperature is 23.8°C in lowland areas and 16.2°C in the mountainous regions. Different kinds of soils are present in Arunachal Pradesh, due to a wide variability in vegetation) factors (climate, physiography, that influence the geology and ecosystems. Data revealed that 86 soil family associations are spread over the lnceptisols followed state. Four soil orders predominate. are dominant (covering 37 percent of TGA), by Entisols (35 percent), Ultisols (14 percent) and Alfisols (0.5 percent) (Maji et al., 2001).

2.2 Climate and Soil

Numerous plant species have speciated in the Northeastern Himalayan (NEH) region of India due to its unique agro-ecological conditions. (Mishra & Sarkar, 2020). Arunachal Pradesh, situated in this region, is predominantly characterized by its mountainous landscape, covering 94.6% of its geographical area. The elevation in the state ranges from 100 to 7300 meters above sea level, resulting in diverse climate conditions. The average annual rainfall varies from 700 to 3500 mm, while winter temperatures range from 15°C to 21°C and during the monsoon months from 22°C to 33°C. The region falls under the Eastern Himalayan Ecozone-II according to agro-ecological classification, exhibiting a prevailing Humid Subtropical climate influenced by monsoons. Agro-climatically, the state is divided into five distinct zones: Alpine, Temperate, Sub-tropical Hill, Mid-tropical Plain, and Mid-tropical Hill, covering 18.6%, 27.2%, 25.8%, 20.6%, and 7.8% of the geographical area, respectively (Bhagawati *et al.,* 2018). Northeastern India's Arunachal Pradesh state is bordered by the latitudes of 26°30'N and 29°31'N and the longitudes of 91°30'E and 97°30'E. Altitude changes and the Himalayan system are the main factors influencing the state's climate. The temperature drops sharply when one ascends higher into the atmosphere. Rainfall in Arunachal Pradesh is among the highest in the country, with an average of around 3500 mm per year (Drema *et. al.*, 2024). The average number of rainy days has decreased to 102 over the past ten years, compared to 144 over the past 30 years, indicative of intensified rainfall patterns, as reported by the ICAR Research Complex, Arunachal Pradesh Centre, Basar (Fig. 2). There is regular decrease in rainy days and increase in rainfall intensity leading to increase in frequency of extreme rainfall events (Fig. 2). Across India, there's a noted uptrend in the frequency and intensity of high-intensity rainfall events (Cruz *et al.,* 2007). The onset and duration of the southwest monsoon exhibit variations (Ramesh and Goswami, 2007 and Chilwal *et al.,* 2024), leading to seasonal droughts and water stress in the region. Approximately 66.5% of the annual rainfall is concentrated in the southwest monsoon season, primarily in July and August. Winter experiences an average of 11.4% of the total rainy days, contributing 5.3% to the overall annual rainfall (Bhagawati *et al.,* 2018).

2.3 Land use and Vegetation Composition of Arunachal Pradesh

The region's flora and fauna are notably diverse yet remain largely unexplored. Plant species distribution varies significantly between the *Jhum* system and forested areas, reflecting differences in topography. In *Jhum* fallows, tree species richness gradually increases from 13 to 40 species, while old-growth forests boast a richness of 131 tree species. Shrub and herb species richness peaks in young *Jhum* fallows (less than 5 years old) and declines as the fallows age. Interestingly, both shrub and herb species richness are lower in old-growth forests compared to any *Jhum* fallows (Gogoi *et al.,* 2022, Wangchu *et al*., 2024). In the subtropical hills of Arunachal Pradesh, common tree species include *Ailanthus grandis, Canarium strictum, Cinnamomum tamala, Dillenia indica, Dipterocarpus macrocarpus, Duabanga sonneratiodes, Ficus spp., Mallotus philippensis, Punica granatum, Terminalia myriocarpa,* and *Terminalia bohera* (Arunachalam, 2002). Trees like *Litsea monoptera, Calliandra umbrosa* and *Castanopsis tribuloides* dominate old-growth forests in other northeastern regions, such as the Mizoram-Manipur-Kachin rainforest. The three most common species among juvenile *Jhum* fallows (less than five years old) are *Trema orientalis, Albizia procera* and *Callicarpa arborea*. *Tectona grandis, Macaranga denticulata, Schima* *wallichii* and *Macaranga indica* become more common as the fallows reach the age of 6–10 years (Fig. 3). *Callicarpa arborea, Rhus chinensis* and *Trema orientalis* are predominant in Jhum fallows that are 11–15 years old, but *Mesua ferrea*, *Albizia procera* and *Callicarpa arborea* are more prevalent in *Jhum* fallows that are 16–20 years old. The most common tree species in the oldest *Jhum* fallows (ages 21 to 25) are *Bauhinia purpurea, Duabanga grandiflora, Ficus bengalensis* and *Litsea salicifolia* (Gogoi, 2019).

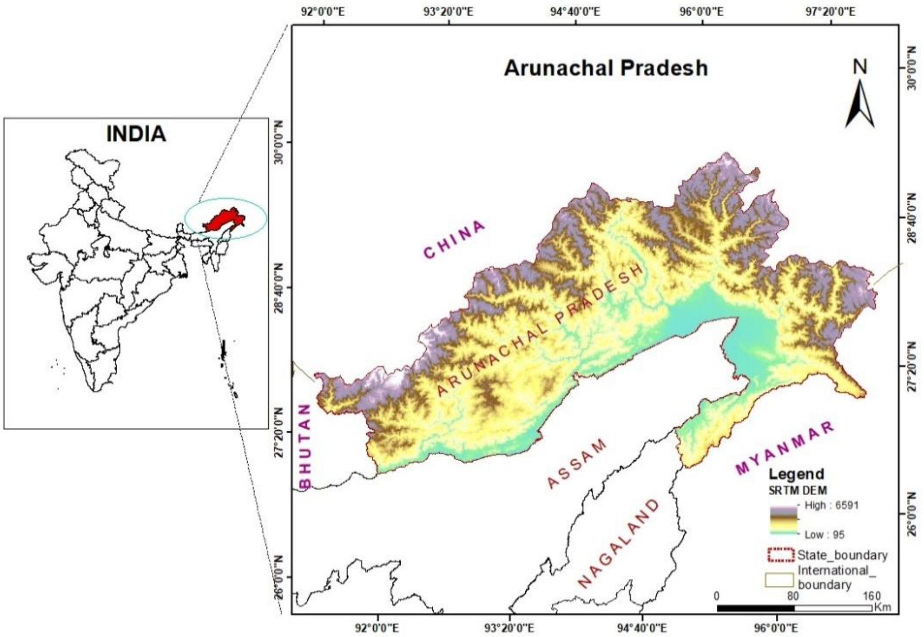

Fig. 1. Study area map

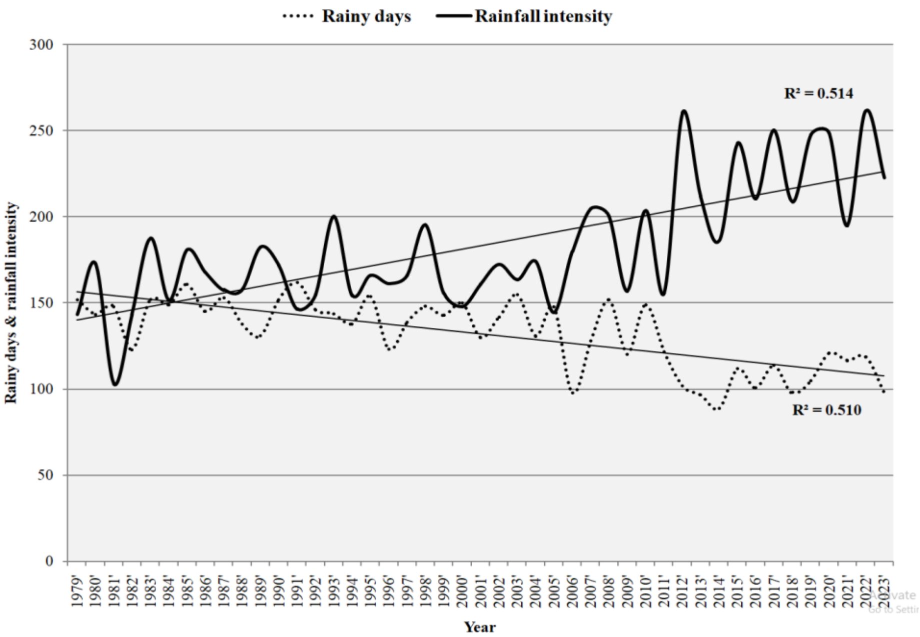

Fig. 2. Number of rainy days and rainfall intensity of Arunachal Pradesh during 1979-2023
(Source: Bhagawati et al., 2018)

Table 1. Traditional *Jhum* calendar

Traditional *Galo* Month	English Month	Natural Indicators	Activities
Deechi	Dec/Jan	Calls of *Chou Pou* bird signal felling of trees, jungle cutting continues till there is chirping of *Tuk pi pipi* bird.	Selection of new sites for *Jhum*. Jungle cutting and slashing of undergrowth, shrubs, twigs, and trees.
Agloo	Jan/Feb	Calls of *Pipiar* bird indicate time for burning the fields. Abundant flowering of *Sanglo* (*Bombay ceiba*) and chirping of *Pako tabo* signals, sowing of early paddy *(Nincho).*	Jungle cutting & slashing continues. Removing the charred remains and burning the slash. The resultant ash acts as fertilizer and reduces the acidity of the soil. Maize (*Tapio*) and millets are sown along with *Nincho* (early paddy) in *Naga* and *Aripata*. Maize is sown to aid in soil binding along the terraces' higher slopes, borders, and bunds.
Lukww	Feb/Mar	Singing of *Pakyo tabo* bird indicates jungle cutting for *Rakteh* plots. The jhumias go for taking omens by observing egg yolk or chicken liver (*Rosin*). Flowering of *Mekahi* (*Phoebe cooperiana*) indicates sowing of *Ningte* paddy.	Terracing (*Panbe*) of steep slopes and higher areas, along contours, with old logs, weeds, stems, etc to prevent run off and to help retain humus. The terraces are normally 9. 5 or 3 ft long and placed 5 m vertically apart. Soil preparation and sowing of maize in *Rakteh* plots.
Lumii	Mar/Apr		Other crops such as cucumber (*Mekong*), cucurbits (*Tarok*), chillies (*Yamdak*), ginger (*Take*), beans (*Tape*), tapioca (*Anmg*), yam (*Aningye*), leafy vegetables (*Yangkya* & *Giang*), Okra and White Sesame (*Tanam*) are later sown randomly. Different tuber varieties are sown along the peripheries. Being non browsable, they act as a live fence for protection against goats & cattle. However if planted with rice, leads to lowering of productivity of rice.
Luchir	Apr/May	Chirping of *Tuk pi pipi* and *Pinchung* bird's signal, onset of *Rakteh* paddy sowing that goes on till the time the *Gaga* (frog) starts croaking. Sowing of late paddy also coincides with the flowering of *Takuk changne* (*Gynocardia odorata*).	Under growth and weeds cleared by scraping with a hand held tool (*Avek*) consisting of a metal strip shaped in the fig of open 8. Broadcasting of millets (*Maruah, Piyok* & *Tia*). *Rakteh* (late paddy) varieties such as *Ranchi, Rongje, Ramak pe, Rakhiya pe* and *Radang* are later hand-sown in

Traditional *Galo* Month	English Month	Natural Indicators	Activities
			holes dug with a hand-held hoe (*Chaughku*). Each hole is seeded with 3 to 5 seeds to prevent germination and damage by field mice and cut worms. In order to prevent clustering and reduce competition for paddy, paddy is sown after millets.
Ilo	May/June		Using a bent bamboo strip in the shape of an open 8 or a dibble with an iron spoon, the first round of weeding is done after 20 to 30 days, depending on the growth of the weeds (*Tabupe*).
Tenlo	June/July		Second weeding. Leafy vegetables and cucurbits are ready for harvest.
Hoo	July/Aug		Harvesting other vegetables and early paddy. Paddy is harvested by physically removing the grains from the panicles or by slicing the panicles with a knife (*Geisk*). The panicles are gathered and placed in a cane basket (*Ege*).
Hwwtv	Aug/Sep		After harvesting, the paddy is threshed in the field protection huts (*Rag Biyon*) by spreading it out on a mat and scrubbing it with your feet. The family granary serves as storage (*Nasung*). In paddy fields, weed growth persists. Harvesting millets & corn. The locally fermented beer, *Apong*, is made from the millets.
Pwra	Sep/Oct		Harvesting maize becomes more popular, along with other pursuits including fishing, hunting and gathering bamboo shoots etc.
Lube	Oct/Nov		*Rakteh* paddy crop along with other vegetables are also harvested.
Ratv	Nov/Dec		After the *Rakteh* Paddy crop has been harvested, tubers and other subterranean crops are dug up. During this time, new long houses are also being constructed.

(Source: Bam, M. 2015)

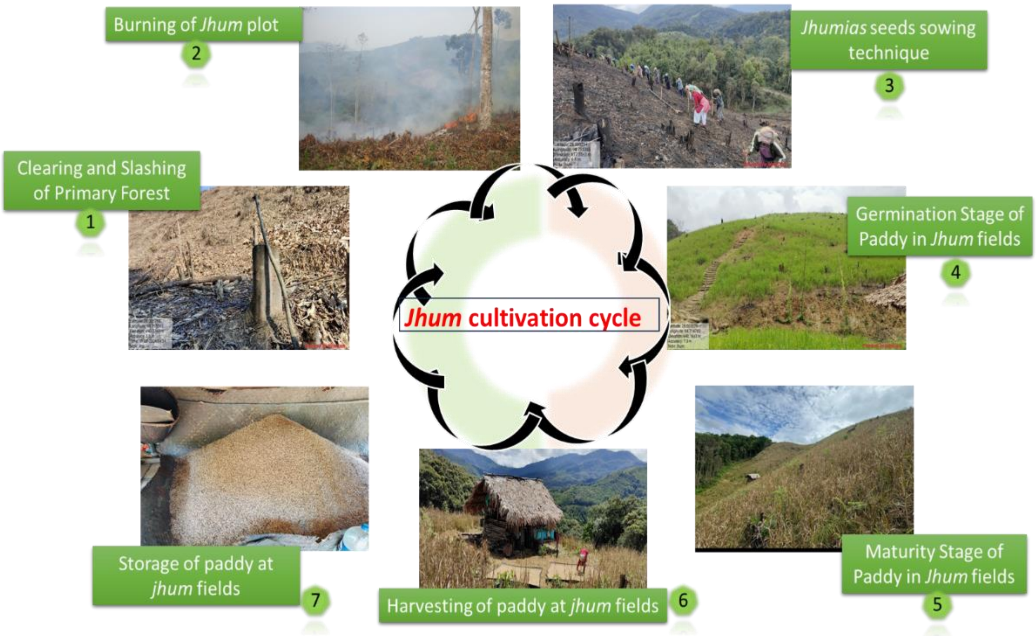

Fig. 3. Traditional *Jhum* Cycle Practiced by Tribal Communities in Arunachal Pradesh

2.4 Status of *Jhum* in Northeastern Region States

The changes in *Jhum* cultivation across Northeast India from 2005-06 to 2015-16 is significant. Buragohain (2022) stated that in Arunachal Pradesh, the area under *Jhum* decreased from 102,507 hectares (50% of net sown area) in 2005-06 to 50,911 hectares (22%) in 2015-16. Manipur also saw a reduction, with its *Jhum* area falling from 75,210 hectares (33.4%) to 49,996 hectares (13.1%). Similarly, Mizoram's area under *Jhum* dropped significantly from 102,853 hectares (105%) to 69,155 hectares (31.6%). Other states like Meghalaya, Nagaland, and Tripura experienced varying degrees of decline in *Jhum* cultivation.

The land use in Arunachal Pradesh, is generally, divided into crop land, shifting cultivation, and forest plantation. Lohit district has the largest crop land area at 708.61 sq. km and also significant shifting cultivation at 60.28 sq. km. Lower Subansiri shows substantial forest plantation at 13.79 sq. km. The overall distribution for Arunachal Pradesh includes 2,657.64 sq. km of crop land, 688.54 sq. km of shifting cultivation, and 28.36 sq. km of forest plantation, reflecting diverse land use patterns across districts (NRSC-ISRO, 2017). In the annual cycle of *Jhum* cultivation, three distinct types of fields are cultivated: *Pel lek, docho*, and *rigne*. Occasionally, the same field is cultivated for multiple years, known as *riga*. The term "*pel lek*" originates from the combination of "*tepe*" (maize) and "*allek*" (full of), signifying a field exclusively designated for maize cultivation. "*Docho*," on the other hand, stems from "*donam*" (to eat) and "*acho*" (to come first), representing a field cultivated primarily for immediate consumption, accommodating both maize and rice cultivation due to its slightly larger size than *pel lek*. "*Rigne*" refers to the main field, derived from "*rik*" (field) and "*ane*" (mother or main), symbolizing the primary or central field (Mima Bam, 2015). All essential agricultural rituals are conducted during the cultivation of the main field (Table 1).

3. RESULTS AND DISCUSSION

3.1 Impact of *Jhum* on Soil Moisture Content

The soil moisture dynamics of *jhum* cultivation lands are understudied (Kumar *et al.,* 2023). The *jhum* cropping cycle begins in February-March and lasts until August, whereas the monsoon season starts in June and ends by late September (Fig. 2). The onset and cessation of the monsoon are crucial for maintaining soil moisture. Post-monsoon, the region receives minimal precipitation, insufficient for crop growth (Bhagawati *et al.,* 2018). Soil moisture in *jhum* lands is unstable due to reliance on rainfall. Post-harvest, soil moisture content is 29.3% in the top 0-20 cm layer and 30.7% at 20-24 cm depth (Singh *et al*., 2017). The water holding capacity (WHC) of *jhum* fields is lower than forest lands (Singh *et al*., 2017), leading to rapid erosion and moisture loss. This variability explains the practice of mono-cropping, with no winter crops. However, soil moisture conservation techniques like mulching and contour trenches (Habtemariam *et al*., 2022, Suryawanshi *et al*., 2023) can enable double cropping. Growing a second crop, such as French beans, can increase cropping intensity, enhance farm returns (Paudel, 2016), and promote sustainable and climate resilient farming in Arunachal Pradesh.

3.2 Impact of *Jhum* System on Soil Physiochemical and Biological Properties

According to Rodrigo-Comino *et al*. (2020), soils are essential for human activity and natural ecosystems. As such, it is critical that researchers develop appropriate indicators to evaluate the quality of soils (e.g., Colantoni, Ferrara, Perini, & Salvati, 2015; Sanchez-Navarro *et al*., 2015). However, due to the vast range of human activities and the approaching impact of climate change affecting main soil physicochemical features, unambiguous regional methodological methods remain relatively unknown (Keesstra, & Blancquaert, 2021).

To give an example of this intricacy, consider the practice of "shifting cultivation" (Parmar *et al*., 2014), which involves converting forest land through slash and burn to annual crops. After burning, Sarkar *et al*. (2015) found that the amount of soil organic carbon (SOC) significantly decreased and that the concentrations of plant-available phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) increased. Texture, structure, density, color, moisture retention and temperature were identified by Ribeiro Filho, Adams and Murrieta (2013) as the primary physical soil properties; on the other hand, pH, macronutrient dynamics, Cation Exchange Capacity (CEC), Soil Organic Matter (SOM), total carbon (Total C) and total nitrogen (Total N) were important chemical indicators (Table 2). In addition to extrinsic elements like management approaches, variations result from inherent processes including weathering, erosion, deposition, and soil formation. (Pulido and colleagues, 2020; Vasu and colleagues, 2016).

High rainfall and uneven terrain lead to severe soil erosion, harming the ecosystem. Annually, shifting cultivation in the northeastern hills causes a soil loss of about 181 mt (Mandal, 2016). Burning vegetation during agricultural transitions converts organic nutrients to mineral form, often lost through drainage. This process negatively impacts soil properties, as shown in laboratory studies. Short *jhum* cycles, like five years, result in low soil fertility, making *jhum* cultivation increasingly uneconomic and necessitating a shift to settled farming. Arunachal Pradesh hosts over 20,000 medicinal plant species. Shifting farming causes significant loss of biodiversity. The *jhum* cycle length impacts vegetation; short cycles favor grasses, while long cycles support tree species (Arunachalam, 2022). In North-Eastern India, around 300 native plants are used for food, with 25 providing tubers, 170 fruits, and 50 greens (Mandal *et al*., 2023).

3.2.1 pH

Soil pH varies significantly among different land use systems such as *Jhum*, natural forest, and *Jhum* fallow, reflecting the diverse ecosystems they represent. Natural forest soils typically exhibit higher pH values compared to *Jhum* lands, with pH increasing with soil depth. Soil organic carbon content follows a similar pattern, being highest in natural forests, followed by fallow *Jhum*, and lowest in *Jhum* (Table 2). Forest soils tend to register acidic to slightly acidic pH values, while *Jhum* land and fallow *Jhum* soils are slightly acidic to neutral (Gaurav Mishra *et al.,* 2021; Leskiw, 1998). Soil pH remains relatively stable during the initial years of *Jhum* fallow but starts to increase after around 12 years. This increase is attributed to the deposition of organic matter and in situ-deposition of grasses, leading to enrichment with bases (Devi and Choudhury, 2013).

3.2.2 Bulk density

Jhum lands generally exhibit higher mean bulk density (BD) values compared to forest and fallow *jhum* lands (Sharma *et al.,* 2019; Gaurav Mishra *et al.,* 2021). It is well established that there is an inverse relationship between BD and soil carbon content. (Post & Kwon, 2000; Pulido *et al.,* 2013). As *jhum* fallow ages, bulk density decreases, indicating that soils under fallow *jhum* are relatively more porous compared to those under other land uses.

3.2.3 Soil Organic Carbon (SOC) content

The effects of converting forests into short-term agricultural lands (*jhum*) and then fallowing have drawn attention because of their effects on the dynamics of soil organic carbon (SOC) (Tasung *et al*., 2023; Tasung *et al*., 2017) and soil health (IPCC, 2007). Earlier reports from the Northeastern Himalayan (NEH) region suggest that forest conversion to *jhum* lands and subsequent fallowing negatively affects soil physicochemical properties, resulting in SOC loss (Arunachalam, 2002; Lungmuana *et al.,* 2023; Ramakrishnan and Tokyo, 1981). However, studies indicate that SOC increases with increasing fallow cycle duration, with higher SOC recorded in longer fallow periods (Mishra and Saha, 2007; Datta and Bhowmik, 2014). The slashing and burning associated with shifting cultivation lead to topsoil loss and soil quality degradation, but appropriate fallow management can increase crop yield (Borthakur *et al.,* 1983; Ramakrishnan, 1992; Yadav *et al.,* 2012). Increasing fallow periods (>8 years) with suitable land use practices can restore soil fertility in *Jhum* fields, with the optimum fallow period found to be 5-7 years in the northeastern region (Devi and Choudhury, 2013; Lungmuana *et al.,* 2017). The C/N ratio of forest soil remains more stable in terms of fertility, while fertility decreases with increasing cropping duration (Arunachalam, 2002).

Table 2. Physiochemical properties of the soil under different land use systems

Soil parameter (unit)	Forest Mean		*Jhum* Mean		Fallow *jhum* Mean	
	2021	2023	2021	2023	2021	2023
BD (Mgm^{-3})	1.02	1.11	1.06	1.28	0.89	1.24
Silt (%)	25.7		31.7		42.7	
Clay (%)	27.0		21.8		14.7	
Sand (%)	47.1		46.3		42.5	
Porosity (%)	61.5		59.8		66.2	
pH (1:2)	5.26	5.42	5.93	4.91	5.13	4.94
SOC (%)	1.2	2.09	1.00	1.12	1.60	1.19
Exch. Ca (cmol (p+) kg^{-1})	1.69		1.45		1.67	
Exch. Mg (cmol (p+) kg^{-1})	0.87		1.61		2.11	
Exch. Na (cmol (p+) kg^{-1})	0.70		0.85		0.58	
Exch. K (cmol (p+) kg^{-1})	0.93		0.83		0.75	
CEC (cmol (p+) kg^{-1})	5.39		4.46		3.93	
Ca/Mg	1.87		1.14		0.93	
Av. N (kg ha^{-1})	423		359		408	
Av. P (kg ha^{-1})	26.8		27.9		26.0	
Av. K (kg ha^{-1})	256		221		244	

Source: Gaurav Mishra et al. (2021) and Kumar et al., (2023)

Table 3. Microbiological properties of the soil under different land use systems

Parameters	Forest Stand	*Jhum* field (8-year *jhum* cycle)		
		20 Days after burning	2 Months after sowing	After harvest
Population (no. of colonies g^{-1} dry soil)				
Bacteria	118310	24310	62310	84310
Fungi	54310	18310	49310	51 310
Biomass (mg g^{-1})				
MBC	286 (1.75)	184 (1.06)	202 (1.31)	224 (1.58)
MBN	41.9 (2.33)	26.2 (2.02)	22.3 (2.03)	18.2 (2.02)
MBP	16.4 (48.1)	10.1 (28.0)	10.0 (30.5)	8.43 (25.9)
MBC/MBN	6.84	7.04	9.06	12.3
MBN/MBP	2.55	1.80	2.01	3.11
MBC/MBP	17.4	18.2	20.1	26.6

Note: Values in parentheses are the contributions of the respective nutrients to the total nutrients; Source: Arunachalam (2002)

Table 4. Economics of different land use systems

Particulars/Land use systems	B-C Ratio	References
Paddy (*jhum*)	1.43	Ninan *et al.,* (1992)
Paddy (WRC)	1.20	Dwarikadhish *et al.,* (2015)
Mandarin	3.80	Madarakhandi *et al.,* (2015)
Pineapple	1.77	Swett and Bera, (2018)

3.3 Impact of *Jhum* System on Soil Biological in Arunachal Pradesh

Soil Microbial Biomass Carbon (SMBC) and Dehydrogenase Activity (DHA): *Jhum* cultivation strategies have a considerable impact on biological parameters such as soil microbial biomass carbon (SMBC) and dehydrogenase activities (DHA) (Table 3). In the soil profile, both SMBC and DHA consistently decline with depth; the concentrations of SMBC are much higher in soils under natural forest than in fallow *Jhum* and *Jhum* land use. Likewise, soils with natural forest land use tend to have the highest dehydrogenase activity, whereas soils with fallow *Jhum* and *Jhum* land show similar amounts of DHA (Kumar *et al.,* 2023).

3.4 Economic Study of the *Jhum* System Compared to Other Land Use Systems in Arunachal Pradesh

The Benefit-Cost (B-C) Ratio, a key economic indicator, quantifies the relationship between the benefits accrued from agricultural production and the associated costs. In the context of *jhum* cultivation and other land use systems in Northeast India, the B-C Ratio provides insights into the efficiency and profitability of different agricultural practices. For instance, paddy cultivation under the *jhum* system demonstrates a B-C Ratio of 1.43, indicating that for every unit of cost incurred, there is a benefit of 1.43 units (Table 4). Similarly, paddy cultivation under the Wet Rice Cultivation (WRC) method yields a B-C Ratio of 1.20. Mandarin cultivation, on the other hand, boasts a notably higher B-C Ratio of 3.80, suggesting greater economic returns relative to input costs. Pineapple cultivation follows suit with a B-C Ratio of 1.77, further illustrating the economic viability of diversified agricultural practices in the region. These B-C Ratios serve as valuable metrics for evaluating the economic sustainability and profitability of various land use systems, guiding agricultural decision -making and resource allocation in Northeast India.

4. CONCLUSION

The study described *Jhum* cultivation and its diverse effects on our environment. The research indicates that *Jhum* cultivation is harmful as it causes significant environmental degradation. Although people are increasingly aware of these adverse effects, many have practiced *Jhum* for decades and find it challenging to shift to other farming methods. Additionally, the topsoil in these regions is often only compatible with *Jhum* cultivation, limiting options for traditional farming. However, there is a growing acceptance among *Jhum* cultivators of more sustainable agricultural practices, driven by the recognition of the harmful impacts of *Jhum* on their own lives. *Jhum* cultivation causes rapid land degradation, soil erosion, nutrient depletion and reduce biodiversity. Therefore, it is crucial to develop, implement and test new strategies for the sustainable management of *Jhum* cultivation. With time, it is hoped that farmers will adopt more modern agricultural methods. In Arunachal Pradesh, where *Jhum* cultivation is prevalent, the shortening of fallow periods has exacerbated soil fertility declin e, increased erosion, and adversely changed soil properties. While shifting cultivation offers potential benefits like carbon sequestration during fallow periods, these benefits are undermined by shorter cycles. Despite some efforts to extend *Jhum* cycles, soil recovery and agricultural sustainability remain critical concerns. The farmers should Implement Sustainable Practices, Extend Fallow Periods, Diversify Cropping Systems, Research and Development and Community Engagement and Education. By integrating these methods, it is possible to reduce the negative impacts of shifting cultivation while preserving the livelihoods of the communities that rely on this traditional practice.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

The author(s) hereby confirm that no generative AI technologies, including Large Language Models (such as ChatGPT, Copilot, etc.) or text-to-image generators, were employed in the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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