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Impact of traditional farming systems on soil properties under Hill Agroecosystem of NEH Region: A Review

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ABSTRACT

The North Eastern Hill Region (NEHR) of India is recognized for its varied agro-climatic situations and the traditional farming practices (TFS) adopted by the people of this region. This article reviews the impact of these traditionally applied practices on soil properties of this region. Different traditional methods such as shifting cultivation, *Zabo* farming system, terrace farming and *Apatani* system have been reported to sustain livelihoods while nurturing soil health. The role of various cropping patterns, organic residue incorporation, minimal tillage operation, and terrace systems practised helps in promoting soil structure stabilization, enhanced nutrient cycling, and controlling erosion. Moreover, this article highpoints the influence of practices like fish farming in rice paddies and zero tillage methods on soil fertility as well as carbon sequestration. The nutrient dynamics and microbial activity in soils under traditional farming systems are also gaining importance in terms of its enhancement by these systems. Overall, emphasis on preserving and integrating these traditional knowledge-based farming systems with scientific advancements is encouraged for sustainable soil health management in the NEHR of India.

1. Introduction

The North Eastern Hill Region (NEHR) of India, extending over a geographical area of 26.3 million hectares (Das *et al.,* 2021) is characterised with varied agro-climatic conditions starting from subtropical humid and warm to temperate up to alpine climate. The North Eastern Region contributes about 8% of the India's total area, constituting with eight states, i.e., Assam, Arunachal Pradesh, Mizoram, Manipur, Nagaland, Tripura, Sikkim and Meghalaya have prime rainfall period from May to November ranging within 2,000-4,000 mm, annually (Das *et al*., 2012). The agriculture of these states is chiefly practised through adoption of traditional practices, providing a balance between meeting the needs of the people and resource conservation and environment protection with an aim in betterment of the future generations.

Traditionally, inventive approaches for resources conservation, for instance, combination of rice cultivation with fish farming in *Apatani* technique, Bamboo based drip irrigation systems in Jaintia Hills of Meghalaya, *Panikehti* in Nagaland, Manipur, Sikkim, and Arunachal Pradesh, Alder-based farming systems in Sikkim, Nagaland, rotational cowshed practices in Sikkim, and pond-based farming systems in Assam, Manipur, Meghalaya, and Tripura have long been employed by the farmers of NEHR (Das *et al*., 2012).The cropping in slashed and burnt forest land without tillage followed by fallow period, known as shifting cultivation or known locally as Jhuming, is one of the major forms of cropping approaches in the North Eastern Region of India.

Such kinds of traditional farming systems are gaining tremendous attention as a sustainable alternate to industry-based farming (Fraser *et al.*, 2015). Use of various naturally available inputs in these systems promotes soil health by enriching nutrients and soil microbiome diversity (Koohafkan and Altieri, 2010). The management of crop

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residues and minimum or reduced tillage in the traditional farming systems are reported to ameliorate sequestration of carbon in soil (Aguilera *et al*., 2013) which are potentially mitigating the GHGs emissions (Sanz-Cobena *et al.*, 2017). Giri *et al* (2018) found increase in soil active microbes and nutrient concentration through traditional alder-based Jhum cultivation in Nagaland increasing the soil productivity. The agroforestry systems of Sikkim were reported by Sharma *et al.* (2007) as an enhancer of soil fertility, nutrient cycling, soil biodiversity conservation, erosion control and as carbon sink.

2. Effect on soil chemical properties

Traditional farming systems in the NE hill region of India could have significant impacts on soil chemical properties due to the practices and techniques employed by farmers over generations. Shifting cultivation/ *Jhum* which is a form of traditional agroforestry system that constitutes the fundamental means of livelihood among the ethnic communities in NE hill regions. Kalidas-Singh *et al*., (2021) found that after burning, there were significant changes in soil parameters. The values of soil pH, electrical conductivity, available phosphorus, and available potassium were increased in order, whereas, the values of soil organic carbon, available nitrogen, and potential mineralizable nitrogen were observed to be reduced. The pH of the soil tends to become basic in older fallows due to the comparatively higher amount of forest floor litter accumulation there compared to younger fallows (Saplalrinliana *et al.*, 2016). This is because of the accelerated release of cations in older fallows due to the burning of more biomass. Older fallows released substantial amounts of cations into the soil through root exudate and dried slashed vegetation, which was responsible for the increase in soil pH and electrical conductivity relative to younger fallows (Nye 1960; Certini 2005). This has a significant and beneficial impact on acidic soil by improving cation availability and lowering the toxicity of iron and aluminium. Ashes from the consequent slash-and-burn operations in *Jhum* cultivation serve as a liming agent in extremely acidic conditions and accelerate the turnover rate of bases such as Mg, Ca, Na, and K above and below the soil surface (Kalidas-Singh *et al.*, 2021).

When the plant cover is removed from the soil surface, major depletion of nutrients from the agricultural system is recorded. In Jhum farming the burning of slashed plant materials aims to release plant nutrients in a single burst after the fire (Table 1). This method capitalizes on the nutrient release by cultivating a mixture of crop species for a year or two, after which the land is returned to its natural vegetation to restore soil chemical fertility and enhance its physical properties. However, various disturbances in the soil system occur like, cultivation, including slashing, burning, hoeing, ploughing, introduction of crop species, weeding, and crop harvest. These disturbances contribute to rapid nutrient depletion, which continues through the early phases of secondary succession. The primary physical factors contributing to nutrient loss from jhum fields in the northeastern region include erosion via wind (blown off), water runoff, and leaching through the soil (deep percolation) (Table 2). Additionally, the burning of fields leads to the volatilization of carbon and nitrogen, resulting in their loss (Ramakrishnan, 1992). According to Ramakrishnan, 1992, when the burning temperature exceeds 150° C, there's a significant reduction in organic carbon content. Despite this, burning increases the soil's pH, potassium, exchangeable calcium, and magnesium content, as indicated in Table 2. However, there's little change observed in the available phosphorus content post-burning (Chauhan, 2000). In the first cropping year, the loss of organic carbon, phosphate, and potash during jhum cultivation show substantial nutrient loss, with 84.7 kg/ha, 0.1 kg/ha, and 1.6 kg/ha respectively, (Table 3). In the second year of cropping, these losses escalate significantly to 1,321.0 kg/ha, 0.2 kg/ha, and 12.5 kg/ha respectively (Chauhan, 2000). Such nutrient losses indicate that jhum cultivation practices adversely affect soil fertility, especially with shorter jhum cycles. Throughout the cropping phase, most of the nutrients are absorbed by crops and weeds. While some are recycled back into the system as plant residues, a considerable amount is removed through crop harvest and weed removal from the plots. These input/output dynamics often result in a net loss of nutrients from the system and a decrease in soil fertility.

The Zabo system, is also known as zero tillage or no-till farming. When compared to traditional tillage methods, the Zabo technique may result in higher amounts of soil organic matter. Blanco-Canqui *et al*. (2015) observed that continuous no-till farming boosted soil organic carbon content by 5.5%. No-till farming led to greater soil nitrogen levels than conventional tillage. This might be due to a decrease in nitrogen losses through denitrification and leaching (Pittelkow *et al*., 2015). Derpsch *et al.* (2014) found that long-term Zabo systems outperformed conventional tillage in terms of cation exchange capacity and nutrient availability.

The traditional cultivation practices of the *Apatani* tribe, indigenous to the Ziro Valley in Arunachal Pradesh, India, have drawn attention due to their unique agricultural methods and their impact on soil chemical properties. This agricultural system involves the integration of fish farming in rice paddies, which significantly influences soil chemical properties. Studies showed that *Apatani* fields tend to have higher levels of soil organic carbon compared to adjacent non-taungya fields (Boruah *et al*., 2015). The incorporation of fish culture in rice paddies created a closed-loop nutrient cycling system. Fish excreta and decomposing organic matter from aquatic plants served as natural fertilizers, enriching the soil with essential nutrients like nitrogen, phosphorus, and potassium. This nutrient enrichment improves soil fertility and supports healthy crop growth (Sarkar *et al*., 2018). The continuous addition of organic matter and nutrient cycling in *Apatani* fields helped to regulate soil pH levels. Organic acids released during decomposition processes can buffer soil pH, maintaining it within an optimal range for crop growth. Additionally, the presence of carbonates from fish shells might influence soil pH, contributing to the alkalinity of *Apatani* soils (Tangjang *et al*., 2019). Ghosh *et al.* (2017) revealed that the bamboo drip system resulted in greater nutrient concentrations in soil solution, which enhanced nutrient availability for plant uptake.

A study by Saha *et al.* found that areas with shifting cultivation had the lowest soil microbial carbon value of 192 mg/kg, while soil under *Michelia oblonga* plantation had the highest value of 478 mg/kg. The soil microbial carbon to total soil organic carbon ratio was between 0.76% and 1.96% across all the systems. The use of multipurpose tree species, such as *P. kesiya, A. nepalensis, P. roxburghii, M. oblonga, and G. arboria,* with greater surface cover, consistent leaf litter fall, and extensive root systems, increased soil organic carbon by 96.2%. These tree species also improved soil structure, soil moisture, and reduced soil erosion (Table 4).

Table 1. Nutrients accumulated (kg/ha/year) through burning and their loss form different jhum fields and different cash crop plantation

	Jhum cycle			**Cash crop plantation**			
	30-years	**10-years**	**5-years**	**Coffee**	**Tea**	**Pineapple**	**Ginger**
Ash							
Released	17.4	13.8	6.9	-	-	-	-
Blown off	8.2	8.2	1.9	-	-	-	-
P Released	313.0	262.2	150.7	–	–	–	–
Blown off	147.1	155.6	42.7	–	–	–	–
Run-off	1.1	1.3	0.9	0.59	2.56	0.61	1.68
Percolated	0.1	0.1	0.1	0.22	0.30	0.19	1.0
Released	1,739.0	2,070.0	685.0	–	–	–	–
Blown off	817.0	1,228.5	194.0	–	–	–	–
Run-off	64.7	91.2	51.0	22.01	54.67	15.15	41.03
Percolated	15.1	21.2	13.7	9.45	5.90	3.80	15.86
Ca Released	956.5	193.2	116.5	–	–	–	–
Blown off	449.4	114.7	33.0	–	–	–	
Run-off	15.1	15.9	13.8	10.83	26.0	8.01	12.94
Percolated Mg Released	5.3 208.7	4.9 151.8	4.6 113.7	3.84 –	3.0 –	2.33 –	6.56 –
Blown off	98.0	90.1	32.2	–	–	–	–
Run-off	6.3	5.4	9.5	8.97	36.94	6.37	10.86
Percolated	2.5	2.1	2.3	2.33	4.55	1.62	5.58

Source: Toky and Ramakrishnan 1981, 1982

Table 2. Changes in surface soil before and after burning in different jhum cycle

Properties	5-year		10-year		5-year	
	Before	After	Before	After	Before	After
pH	5.1	7.5	5.3	7.6	5.5	7.5
Carbon (%)	1.9	1.6	1.8	1.7	1.6	1.6
Nitrogen (%)	0.26	0.25	0.26	0.25	0.21	0.20
Phosphorus (%)	3.5	3.6	3.4	3.6	3.3	3.5
K (mg/100 g soil)	13.0	61.0	11.0	56.0	12.0	51.0
Ca (mg/100 g soil)	10.0	32.0	12.0	28.0	9.0	21.0
Mg (mg/100 g soil)	8.0	23.0	10.0	21.0	9.0	20.0

Source: Mishra and Ramakrishnan, 1982

Table 3. Loss of organic carbon and plant nutrients in jhum cultivation

Year	OC (kg/ha)	P_2O_5	K_2O
First year	84.70	0.08	1.60
Second year	1,321	0.21	12.50
Average	702.90	0.15	7.10

Source: Chauhan (2000)

Table 4. Growth, litter production, fine root biomass of promising MPTs in humid tropics, and their contribution on soil organic carbon content.

Multipurpose Tree	Annual litter production (g/m^2)	Time required for decomposition (Days)	Total fine root biomass (g/m^2)	Organic C (g/ kg)
P. kesiya	621.5	718	496.75	35.4
A. nepalensis	473.75	350	435.50	32.2
P. roxburghii	341.75	385	415.50	23.1
M. oblonga	512.25	390	462.00	33.6
G. arboria	431.75	360	419.00	28.6

Source: Shah *et al.* (2010)

3. Conclusion

The present review underlined the essence of diverse traditional agricultural methods of the NE India in standings of management and conservation of soil quality. The traditional farming systems of NEHR of India are the intricate tapestry of agricultural techniques profoundly woven with the varied ecological and cultural legacy prevailing in the region. Such traditional techniques, refined over generations after generations, support livelihoods while also nurturing the soil and maintaining its physio-chemical and biological qualities. These conventional methods improve water retention, encourage soil structure, and reduce erosion increase the nutrient availability and thereby has profound effect in maintaining soil health. They exhibit a deep awareness of the environment, operating on ecological processes and natural resources to enhance soil health and production. Therefore, in order to conserve the soil of the hill region of NE India, sustainable use and management of these traditional agricultural methods infused with scientific knowledge using a multi-stakeholder approach is the need of the hour.

4. References

Aguilera, E., Lassaletta, L., Gattinger, A. and Gimeno, B.S. (2013). Managing soil carbon for climate change mitigation and adaptation in Mediterranean cropping systems: a meta-analysis. *Agriculture, Ecosystems and Environment,* 168: 25-36.

Blanco-Canqui, H., Lal, R., & Owens, L. B. (2015). Soil structural changes over 25 years under continuous no-till and occasional tillage in south-central Nebraska. *Soil and Tillage Research*, 150:72-81.

Boruah, P., Bhattacharyya, P., & Sharma, S. (2015). Organic carbon dynamics under shifting cultivation, taungya, and natural regeneration in hilly terrain of Northeast India. *Agroforestry Systems* 89(1), 113-124.

Certini, G. (2005). Effects of fire on properties of forest soils: a review. *Oecologia*, *143*, 1-10.

Chaudhuri, K. N. and Chaudhuri, S. (2022). The Art of 'Organic Living: Lessons from Apatani Women in Ziro Valley of Arunachal Pradesh in Northeast India. *Back to Basics: A Multidisciplinary Approach to Organic Living and Waste Management*, 3:75-90.

Chauhan BS (2000) Economics of ecosystem degradation due to shifting cultivatin in North Eastern region, India. J Assam Sci Soc 141(3):145-162

Das, A., Ghosh, P., Yadav, G., Layek, J., Babu, S., Singh, R., & Ansari, M. (2021). Conservation Agriculture in North-eastern Hill Region of India: Potential and Opportunities for Sustainable Development. *Journal of Agricultural Physics* 21(1), 113-134.

Das, A., Ramkrushna, G.I., Choudhury, B.U., Munda, G.C., Patel, D.P., Ngachan, S.V., Ghosh, P.K., Tripathi, A.K., Das, S. and Kumar, M. (2012). Natural resource conservation through indigenous farming systems: Wisdom alive in North East India. *Indian Journal of Traditional Knowledge* 11(3): 505-13.

David Raj, Anu & Kumar, Suresh. (2024). Investigating Traditional Farming Practices in Conserving Soils against Erosion Using Fallout Radionuclide - 137Cs in Northwestern Himalayas.

Derpsch, R., Friedrich, T., Kassam, A., & Li, H. (2014). Current status of adoption of no-till farming in the world and some of its main benefits. *International Journal of Agricultural and Biological Engineering*, 7(1), 1-25.

Dollo, M., Samal, P. K., Sundriyal, R. C. and Kumar, K., (2009). Environmentally sustainable traditional natural resource management and conservation in Ziro Valley, Arunachal Himalayas, India. *Journal of American Science* 5: 41 – 52.

Fraser, J.A., Frausin, V. and Jarvis, A. (2015). An intergenerational transmission of sustainability? Ancestral habitus and food production in a traditional agroecosystem of the Upper Guinea Forest, West Africa. *Global Environmental Change* 31: 226–238.

Ghosh, A., Saha, J. K., & Das, S. K. (2017). Effect of drip irrigation on soil nutrient status and productivity of wheat in red and lateritic soils of West Bengal, India. *International Journal of Chemical Studies*, 5(5), 981-984.

Giap, D. H., Yi, Y. and Lin, C. K. (2005). Effects of different fertilization and feeding regimes on the production of integrated farming of rice and prawn Macrobrachium rosenbergii (De Man). *Aquaculture Research* 36: 292 – 299.

Giri, K., Mishra, G., Jayaraj, R.S.C. and Rajesh Kumar. (2018). Agrobio-cultural diversity of alder based shifting cultivation practiced by Angami tribes in Khonoma village, Kohima, Nagaland. Current Science 115(4): 598-599.

Halwart, M., Gupta, M. V., 2004. Culture of fish in rice fields. FAO, Rome.

Jeeva, S. R. D. N., Laloo, R. C. and Mishra, B. P. (2006). Traditional agricultural practices in Meghalaya, North East India. *Indian Journal of Traditional Knowledge* 5(1) :7-18.

Jobbágy, E. and Jackson, R. (2000). The Vertical Distribution of Soil Organic Carbon and Its Relation to Climate and Vegetation. *Ecological Applications* 10: 423-436.

Kalidas-Singh, S., Bora, I. P., Thakuria, D., Changkija, S., Puyam, A., & Khwairakpam, L. (2021). The comparative soil fertility in traditional and alder-based shifting cultivation of varied fallow lengths in Eastern Indian Himalayas. *Soil Science and Plant Nutrition* 67(6), 681-692.

Koohafkan, P. and Altieri, M.A. (2010). Globally important agricultural heritage systems: a legacy for the future. Rome: UN-FAO.

Mertz, O., Padoch, C., Fox, J., Cramb, R.A., Leisz, S.J., Lam, N.T. and Vien, T.D. (2009). Swidden change in Sotheast Asia: understanding causes and consequences. *Hum Ecol*, 37:259-264.

Mishra BK, Ramakrishnan PS (1982) Energy flow through a village ecosystem with slash and burn agriculture in North-Eastern India. *Agric Sys* 9:57–72

Mohanty, Shilpa & Swami, Sanjay & Singh, N.J. & Singh, Arvind & Ray, Lala. (2023). Characterization of soils under zabo farming system of Nagaland. 15:392-396.

Nye, P. H., & Greenland, D. J. (1960). The soil under shifting cultivation.

Pittelkow, C. M., Liang, X., Linquist, B. A., van Groenigen, K. J., Lee, J., Lundy, M. E., & van Kessel, C. (2015). Productivity limits and potentials of the principles of conservation agriculture. *Nature*, 517(7534), 365-368.

Ramakrishnan PS, Toky OP (1981) Soil nutrient status of hill agroecosystems and recovery pattern after slash-and-burn agriculture (*jhum*) in north-eastern India. *Plant Soil* 60:41–64

Ramakrishnan PS (1992) Shifting agriculture and sustainable development (Man and Biosphere series: V.10). The Parthenon Publishing Group, Paris, p 424

Rechlin, M. A. and Varuni, R., (2006). A passion for pine: forest conservation practices of the Apatani people of Arunachal Pradesh. *People and Environment: Conservation and Management of Natural Resources across the Himalaya*, 26: 19 – 24.

Saha, R., Tomar, J. M. S. & Ghosh, P. K. (2007). Evaluation and selection of multipurpose tree for improving soil hydro-physical behavior under hilly eco-system of north east India. *Agroforestry Systems*, 69(3): 239-247.

Saha, R., Ghosh, P. K., Mishra, V. K., Majumdar, B. & Tomar, J. M. S. (2010). Can agroforestry be a resource conservation tool to maintain soil health in the fragile ecosystem of north-east India? *Outlook on Agriculture*, 39(3), 191–196.

Sanz-Cobena, A., Lassaletta, L., Aguilera, E., Del Prado, A., Garnier, J., Billen, G., Iglesias, A., Sanchez, B., Guardia, G., Abalos, D., and Plaza-Bonilla, D. (2017). Strategies for greenhouse gas emissions mitigation in Mediterranean agriculture: A review. *Agriculture, Ecosystems & Environment* 238: 5-24.

Saplalrinliana, H., Thakuria, D., Changkija, S., & Hazarika, S. (2016). Impact of shifting cultivation on litter accumulation and properties of Jhum soils of North East India. *Journal of the Indian Society of Soil Science*, 64(4):402-413.

Sarkar, A., Borah, M., & Sharma, B. (2018). Traditional rice–fish–vegetable farming system in Arunachal Pradesh, India: a resilient model for livelihood security and sustainable agriculture. *Agriculture & Food Security* 7(1): 21.

Sharma, R., Xu, J. and Sharma, G. (2007). Traditional agroforestry in the eastern Himalayan region: Land management system supporting ecosystem services. *Tropical Ecology*, 48 (2):1-12.

Swami S. (2020). Soil health management under organic production system. *International Journal of Chemical Studies*, 8(2): 330-339.

Tangjang, S., Borah, P., Hazarika, S., & Bhattacharyya, P. (2019). Impact of shifting cultivation and traditional agroforestry practices on soil quality of northeast India: a case study in Apatani plateau. *Environmental Monitoring and Assessment*, 191(12), 1-15.

Upadhaya, K., Barik, S. K., Kharbhih, V. M., Nongbri, G., Debnath, G., Gupta, A. and Ojha, A. (2020). Traditional bun shifting cultivation practice in Meghalaya, Northeast India. *Energy, Ecology and Environment* 5: 34-46.