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ORIGINAL ARTICLE

Effects of *jhum* (shifting) Cultivation Fallow Period on Soil Physicochemical Properties, West Garo Hills District, Meghalaya, India

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Abstract

Objective: To evaluate the effects of different fallow periods on soil properties under jhum cultivation and also determine the minimum fallow duration required for restoring soil fertility level in the West Garo Hills District, Meghalaya. **Method:** Soil samples were collected from 23 jhum cultivation plots with fallow periods ranging from 1 to 15 years, along with two natural forest patches for comparison. Soil samples were obtained from a depth of 0–15 cm and analyzed for physical and chemical properties. **Findings:** The study revealed that longer fallow periods (7–15 years) resulted in higher proportions of fine soil particles (silt and clay), along with increased levels of organic carbon, available nitrogen, phosphorus, and potassium. Soil fertility was found to be lowest in areas with less than 4 years of fallow and showed significant improvement from the 7th year onward. **Novelty:** This study provides empirical evidence supporting the importance of extended fallow periods in restoring soil fertility under jhum cultivation. It highlights the threshold fallow duration (7–8 years) necessary to regain soil health and sustain productivity, offering critical insight for sustainable land management practices in jhum cultivation method.

Keywords: Jhum cultivation; effects; fallow period; soil physicochemical properties; soil fertility

1 Introduction

Shifting cultivation is one of the major forms of cropping system practiced in the hilly parts of north-east India. Shifting cultivation consists of three phases, i.e. clearing a forest area by slashing natural vegetation and burning, cultivation of crops for a year or more and a variable fallow period [1]. Locally, this practise is called jhum and the cultivators are known as the jhummias [2]. Forest Survey of India reported 1.73 million ha of forest was affected by jhum cultivation in Northeast India [3]. National Remote Sensing Centre also reported about 0.76 million ha under jhum cultivation in 2008-09 [4]. In 2010, the area under jhum cultivation in north-eastern region accounted to be of 8771.62 sq. km which constituted 85 % of the total of jhum cultivated area in India [5]. Jhum cultivation is traditionally and cultural integrated form, ecological and economically viable system of agriculture and jhum cycles are long enough to maintain soil fertility as long as population densities are low[6]. During the study period (2016-2023), jhum cycles in West Garo Hills district of Meghalaya showed that area under long jhum cycle (> 6 years) represented around 41.49 %, followed by the area under medium (4-6 years) and short cycle (<=3 years) which is 36.05 % and 22.46 % respectively (based on satellite image data analysed by the researcher). The jhum cycle of the study area are slowly shifting from long to short jhum cycle that affects the soil properties which are the keys for human activities and sustenance of natural ecosystems. The soil properties such as pH, organic carbon, and available nutrients have been found to decrease due to shortening of jhum fallow period to 2-3 years in northeastern region[7]. In this background the present investigation attempted to have a look on the soil health under different jhum cycle fallow periods to put forward a step towards sustainable jhum practice amidst the emerging alternate land use practices in one of the jhum cultivation dominated districts i.e. West Garo Hills district of Meghalaya.

1.1 Objectives

1. To analyze the effect of different fallow periods on the physical and chemical properties of soil under jhum cultivation.
2. To determine the minimum fallow period required for restoring soil fertility.

2 Methodology

2.1 Study area

West Garo Hills district is situated approximately between the latitudes 89°50' E and 90°27' E, and the longitudes of 25°13' N and 26°1' N. It is bounded by the North Garo Hills district on the northeast, the East Garo Hills on the east, South Garo Hills on the southeast, the Goalpara district of Assam on the north and west, Southwest Garo Hills towards southwest and Bangladesh on the south (Figure 1). The topography is mostly hilly with plains fringe covering the north, west and south-west borders of Tura, Arbella and Ranggira mountain. The district occupies an area of 2811 km^2 [8]. Soil types of West Garo Hills district are mostly red gravelly and red sandy loam in the hilly slopes and clayey loam in the plains. Soils of the hills are moderately deep to deep, loamy skeletal to fine and excessively drained subject to slight to very severe erosion hazards. Soils of hilltops and upper hill slopes are moderately deep-to-deep, fine loamy to fine, excessive drained, subject to very severe erosion hazards and strong stoniness[9].

2.2 Site selection for soil sampling

Jhum areas having fallow years ranging from 1 to 15 years along with 2 patches of forest area (total 25 samples) were selected from different parts 6 blocks of West Garo Hills district as a part if field investigation with the help of local people and farmers (Figure 1). The sample jhum patches are selected from diverse heights, such as 100 to 1400 meters above mean sea level. Then each polygon in the selection for each fallow years were crosschecked with the Landsat satellite imageries and jhum polygons of the succeeding years. GPS points of fallow patches were gathered, and with the use of the Google Earth platform and Arc GIS 10.8, the locations of all the sampling sites were plotted on the map.

2.3 Soil sample collection and laboratory analysis

For each of the jhum fallow years samples were collected at 0-15 cm depth using standard procedure. Samples were air-dried at room temperature before being passed through a 2 mm sieve to remove rocks, pebbles and plant materials (e.g., roots, coarse woody debris, etc.). Subsamples were oven dried (105°C for 48 h), and all calculations are reported on an oven-dry weight basis.

Soil texture (% sand, silt, and clay) was determined by the International Pipette method. Soil pH in a 1:2.5 soil/water ratio was measured using a glass electrode pH meter, and EC was measured in the same supernatant solution using an EC meter[10]. Organic carbon was determined by the chromic acid wet digestion method[11], and available nitrogen was determined by the alkaline potassium permanganate method[12]. Available phosphorus was extracted by Bray's P-1 extractant (0.03 N NH 4 F + 0.025 N HCl) and determined calorimetrically by the ascorbic acid method[13]. The available potassium was extracted using a 1N ammonium acetate solution and determined using a flame photometer[10].

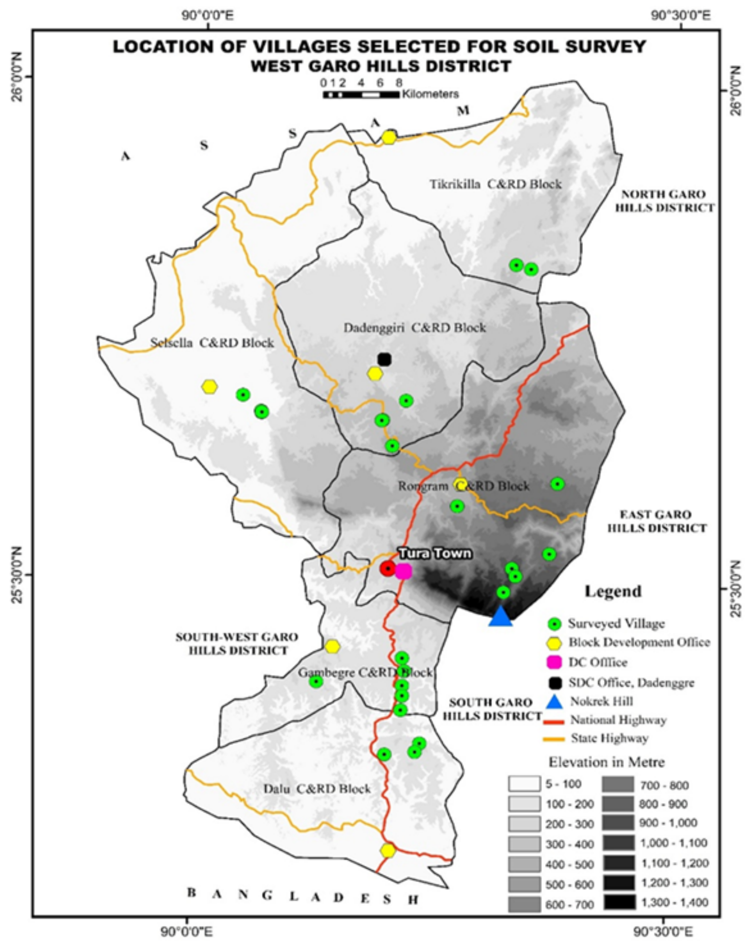

Fig 1. The study area, terrain and sample sites

3 Results and discussion

The soil parameter-wise values obtained from soil analysis in the laboratory are tabulated for presentation and analysis (Table 1). The soil parameter values are plotted against the fallow years in order to know the relationship between fallow years and soil qualities in the soils of the sampled jhum plots.

3.1 Soil chemical quality

3.1.1. Soil reaction (pH)

Soil reaction is an indication of nature of soils whether it is acidic, neutral, or saline/alkaline and controls the nutrient availability to the plants. Soils of all the 23 study sites were found moderately acidic to slightly acidic [14] in nature with a pH range of 4.71-5.81. As the fallow period increases, the pH values of the soils are found increase slightly. It means, as fallow period increases, the soils tend to become gradually strongly acidic to slightly acidic, which is good for soil environment of the area. The r value between pH level and increasing fallow years is found to be 0.8747, stating the significant positive correlation of the parameters.

3.1.2. Electrical conductivity (EC)

Soil electrical conductivity (EC) is a measure of the amount of salt in soil. It is an important indicator of soil health. It affects crop yields, crop suitability, plant nutrient availability, and activity of soil microorganisms. Electrical conductivity is found normal [15] in all sites. Values are found to be between 0.04 – 0.24 (d Sm^{-1}) for all the 23 soil samples. However, it is observed that with the increase in fallow period electrical conductivity of the soils go on decreasing. The r value between electrical conductivity and fallow years of jhum cultivation is -0.2206. However, decreasing electrical conductivity with increasing fallow period is a good combination for soil environment. If the amounts of salt in soil increase, then it is becoming harmful for many crops[15]. The relation between electrical conductivity and fallow years is negatively correlated in the district, but it is good for the soil environment.

Table 1. Soil physical properties of the fallow jhum patches of West Garo Hills district

Sl. No.	Vill. Name	Fallow Year	pH	EC (d Sm^{-1})	SOC (%)	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})	Clay (%)	Silt (%)	Sand (%)
1	Makbilkolgri	1	4.71	0.2	0.49	311.48	20.8	112	24.16	32.34	43.5
2	Kangklagre	1	4.84	0.14	1.62	315.53	21.5	114	25.74	32.1	42.16
3	Sasatgre	2	4.86	0.24	3.02	331.67	29.7	115	25.7	31.44	42.86
4	Robilbragre	2	4.89	0.09	1.07	335.53	24	103	27.85	28.95	43.2
5	Kherapara	3	5.19	0.14	1.31	316.11	23.5	118	28.45	30.95	40.6
6	Achugre	3	5.21	0.19	2.29	379.33	24.7	121	25.9	33.17	40.93
7	Dolwakgre	3	4.97	0.16	0.71	397	23.2	138	30.44	30.7	38.86
8	Dalugre	4	5.46	0.22	1.37	316.11	24	144	31.8	36.42	31.78
9	Rongbretgre	4	5.47	0.17	0.76	446.9	26.5	136	30.75	40.77	28.48
10	Makbilkolgri	4	4.87	0.16	1.01	372.3	31.5	138	31.85	37.66	30.49
11	Makbilkolgri	5	5.12	0.23	1.37	379.33	32.5	145	31.1	36.84	32.06
12	Addinggre	5	5.21	0.04	1.86	337.18	30.3	149	36.6	38.75	24.65
13	Addinggre	6	5.32	0.13	2.23	330.16	37.8	178	33.4	37.76	28.84
14	Rongjigre	6	5.53	0.15	0.78	381	36	189	31.84	42.1	26.06
15	Agalgre	6	5.51	0.14	2.21	394	34	196	32.16	40.1	27.74
16	Balmagre	7	5.46	0.12	0.88	337.18	32.7	239	40.95	39.48	19.57
17	Ganolgre	7	5.54	0.11	2.65	334	35	241	40.76	40.4	18.84
18	Tebonggre	8	5.58	0.08	2.47	428.5	43	240	40.25	40.9	18.85
19	Jebalgiri	9	5.65	0.11	3.01	405	44	239	42.48	39.95	17.57
20	Daribokgre	10	5.67	0.16	2.77	525.53	45.5	251	50.25	31.85	17.9
21	Bibragre	10	5.69	0.15	3.02	547	45.2	248	54.61	27.45	17.94
22	Sosotpara	12	5.77	0.13	3.74	495.03	45.5	249	55.47	27.78	16.75
23	Wakkolnang-gre	15	5.81	0.16	3.19	414.45	44.8	251	56	27.37	16.63
24	Forest (Daribokgre)		5.97	0.18	3.01	551	48.12	261	60.25	21.85	17.9
25	Forest (Sadolpara)		5.91	0.12	3.99	549.01	49.1	269	60.74	25.9	13.36

N.B.: Soil samples are tested in NBSS and LUP lab., Jorhat, Assam

3.1.3. Soil Organic Carbon (SOC)

Soil organic carbon (SOC) is most essential constituent of soil for maintaining its quality, sustaining biological activity, regulating water flow, buffering, storing, cycling of nutrients, and sustain soil productivity etc.[16]. Organic carbon of the soil samples is medium to high in percentage in the West Garo Hills district[14]. The values are between 0.49 to 3.74%. Except some fallow plots, organic carbon increases with increasing fallow years. The present study clearly indicates that the percentage of organic carbon with the increases in fallow period of jhum fields. The r value between organic carbon and fallow years of jhum stands at 0.6831, i.e. significant positive correlation. This means, the increase of fallow period gives rest to the soil and favouring the growth of vegetation cover. Thus, the soils are not much washed away due to runoff and soils are thereby allowed to retain their chemical properties.

3.1.4. Available Nitrogen (N)

Nitrogen is one of the important predictors of soil fertility as it influences soil health primarily through changes in organic matter content, microbial life, and acidity in the soil[15]. The level of nitrogen in the soil samples of the district are 311.48-547 (kg ha^{-1}) which represents medium to high range (Table 1). The r value between nitrogen and increasing fallow years of jhum is found to be 0.2369 which is a positive. In the case of nitrogen content of the soils, it is found that as fallow period increases, the nitrogen content also slightly increases showing a positive correlation.

3.1.5. Available Phosphorus Pentoxide (P_2O_5)

Phosphorus pentoxide is a crystal form of phosphorus that occurs in soil. It's a key nutrient for plants, and is essential for cell functioning, DNA, and overall growth. It is applied to soil as a fertilizer to help plants receive the phosphorus they need[14]. The level of phosphorus pentoxide in the soil samples of the district is found between 20.8- 45.5(kg ha^{-1}), which is low to medium range (Table 1). The r value between phosphorus pentoxide in soil and fallow years of jhum is 0.6089 which show a positive relationship. As regards phosphorous pentoxide content, it is seen that as the fallow period (years) increases the phosphorous content of the soils go on increase, showing a significant positive correlation.

3.1.6. Available Potassium Oxide (K_2O)

Potassium strengthens plant root systems, which fortifies disease resistance in plants, increases yields and overall quality of crops, prevents wilt, and improves drought tolerance of crops[17]. The level of potassium oxide in the soil samples of the district is assessed as low to medium range which is found 103- 251 (kg ha^{-1}). The r value between potassium and increasing fallow years of jhum cultivation is 0.2355 which is a positive. It seems that with the increment of fallow period, potassium content of soils also slightly increases.

3.2 Soil physical properties

3.2.1. Soil Texture (Clay, Silt, Sand)

In texture of soil is characterized by its composition i.e. amounts of clays (small), silts(medium) & Sand (large) particle size. Soils are the upper layer of earth, typically consist of loose mineral or organic materials, rock particles and clay in which plants grow. Particularly, soils are made up of about 25% air, 25% water, 45% mineral and 5% organic matter (i.e. plant residues, humus as well as living micro-organisms). Soil texture plays a vital role in its gradation, water transport processes (infiltration), controlling quality and productivity, so texture is called as an important land environmental variable[18]. Texture of soil (i.e. Sand, silt, clay) is one of the key indicators for sustainable agriculture management. Therefore, soil texture is considered as an important environment factor for agricultural growth.

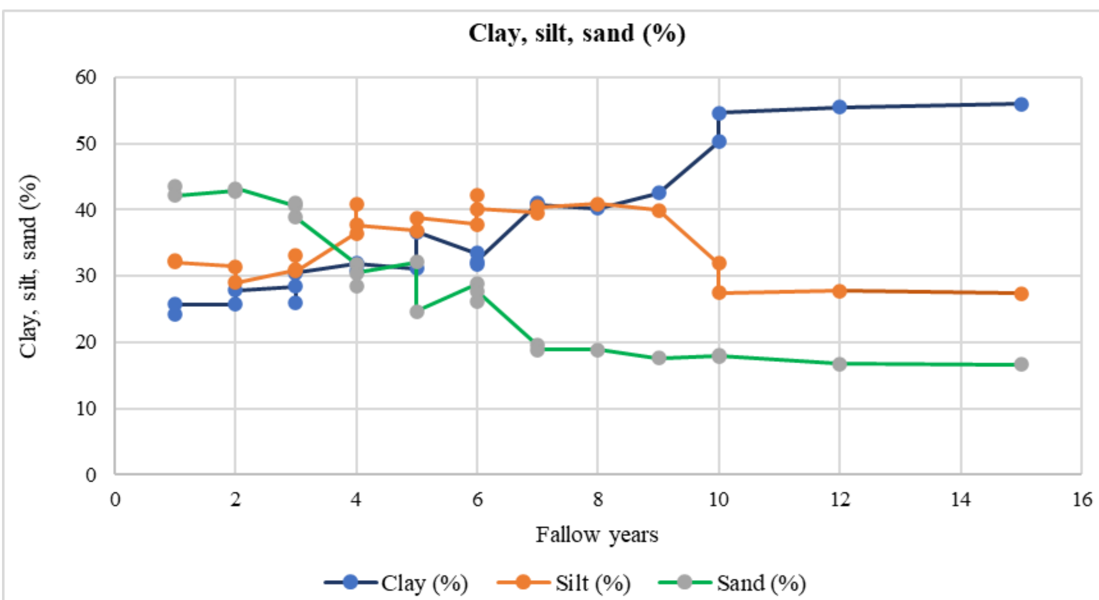

Fig 2. Relationship between fellow period of jhum and soil constituents

An attempt has also been made in the work to examine the relationship between the status of soil textural (clay, silt and sand) and the fallow period of jhum. Initial 3 to 7 years have shown relatively higher coarser (sand) over finer (clay) fraction compared to longer duration fallow periods (10 to 15 years). In longer fallow periods of jhum, i.e. 10-15 years have relatively higher finer content (clay) compared to short term fallow periods (3 years) (Figure 2). It is seen that in the jhum plots with decreasing fallow period, the soils become sandy as sand proportion increases. This implies that due to sandy character of soils, water retaining characteristics reduced and subsequently leading to a low fertile condition. However, with the increasing fallow years, the amount of clay and silt also increase. Based on the traditional knowhow formers used to keep the jhum plots as fallow for longer period in the past to make this traditional mode of production more supportive. But, over time, with the increasing population, reducing jhum period making the as old tradition less fruitful and environ unfriendly.

Work relating to Dima Hasao district of Assam for a period of 1 to 10 years of fallow, the soil properties showed strong to moderate acidity, with a pH range of 4.45 to 5.00, soil organic carbon (SOC) between 0.98 and 1.55%, nitrogen (N) levels between 269.30 to 350.11 kg ha^{-1}, phosphorus (P) levels between 9.33 to 12.61 kg ha^{-1}, and potassium (K) levels between 169 to 264 kg ha^{-1}. The soil texture, i.e. sand (54.92 to 46.33%), clay (23.24 to 29.60%) and silt (17.81 to 24.15%)[19]. These differences indicate that both the spatially isolated regions have acidic soils, but the West Garo Hills district demonstrates higher nutrient variability. Similarly, in a village level study of soils in Muallungthu village, Mizoram, showed the presence of strong to moderate acidic during in a 3-10 year dormancy period. The pH range was found to be 4.63–5.26, with relatively high soil organic carbon (SOC) between 1.90 to 2.27% and available phosphorus ranging from 5.87to 8.76 mg kg^{-1}[20]. This comparison highlights that both regions share acidic soil conditions, but the West Garo Hills district exhibits more diverse and nutrient-rich soils, likely influenced topographical variation, parent material and differing land-use practices.

Findings:

1. The soils are comparatively rich in organic matter (SOC) and nitrogen (N).
2. The district's soil has a lower concentration of potassium oxide (K_2O).
3. With the increased fallow years, the proportion of clay is found to increase in soil.
4. The amount of sand is decreased in soil with the increase in fallow years.
5. In the forested areas, soil retains the chemical properties intact over time as the vegetative cover restricts washing out of the soil nutrients. But, in the case of soils of the jhum plots being exposed to washing effects, the soil nutrients are less in amount as they are washed away down slopes. This fact clearly confirms that the jhum cultivation in the present context with a short cycle influence the natural growth of vegetation on one hand reduced the soil nutrients on the other.

4 Conclusion

The reduction of the jhum cycle to 3 to 4 years and the intermittent agricultural production system are undoubtedly contributing factors of the acceleration of land degradation over natural homeostatic processes and becoming the cause of the overall degradation of the health of ecosystem. In the respect of soil carbon and nitrogen the West Garo Hills district found to be rich. However, the K_2O level is found to be low in comparison to the other research findings. It can be said that soil health restoration and reclamation are important for degraded jhum lands, especially in the West Garo Hills district, Meghalaya, where short jhum cycles are adapted. It could be wise to implement an agroforestry system, provided that the trees and crops are so selected that they complement each other and restore the soil loss and degradation process. Terrence cultivation may one among the several methods that can be used. With an understanding of jhuming practices and their fallow season, scientific management mechanism may control such degradation. It may be concluded that the minimum length of the jhum fallow period should be at least 7-8 years in the context of the district at present to make jhum practice sustainable.

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