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Assessment of Pre-Burn Forest Litters Biomass and Nutrient Quality at Different Fallow Lengths in Traditional and Alder-Based *Jhum*

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Abstract Traditional agroforestry system popularly known as *Jhum* cultivation, shifting cultivation or Swidden agriculture is historically associated as the basic way of livelihood and sustenance among rural masses throughout North East India. Earlier a longer period of fallow length in *Jhum* cycle was practiced which was ecologically viable and friendly as it had less detrimental effect on the environment. An alarming hike in the tribal population for the last two decades had drastically shortened the fallow length in *Jhum* cycle to fulfill their basic requirements. As a result, the pressure on forest ecosystem for agriculture has been increased abruptly. The present study focused on comparative analysis of soil Bulk Density (BD), Forest Floor Litters (FFLs) biomass and their nutrient concentration at different fallow length viz. 2, 4 and 8-years for both traditional (T-JFs) and alder-based (*Alnus nepalensis* D. Don) *Jhum* (AB-JFs) in Kohima, Nagaland. FFLs biomass, FFLs concentration of Nitrogen (N) in both *Jhum* fallows was found to increase significantly (at $p<0.05$, one-way ANOVA) in relation to increasing *Jhum* fallow year (2 < 4 < 8-years) which was contrary to BD (2 > 4 > 8-years). However, with respect to *Jhum* types, AB-JFs showed higher values in terms of FFLs biomass, FFLs (N), phosphorus (P) and potassium (K) and lower in BD at $p < 0.05$ (Two-way ANOVA). Their interaction study show cased significant difference only in FFLs (N). Result of this investigation shows the specific advantage of alder-based (symbiotic relationship of free-living N_2 fixing actinomycete, *Frankia* and *A. nepalensis*) over traditional *Jhum* cultivation in fallow management.

Keywords *Jhum* fallows, Forest Floor Litters, Biomass nutrient concentration, Bulk density.

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Introduction

Jhum or shifting cultivation is an essential part of hill cultivation/agricultural system, where forest covers are slashed and burned down to convert into cultivable plots (cropping phase) temporarily and thereafter, left to regain the forest cover (fallow phase) and soil fertility (Filho et al. 2018). Globally, 280 Mhaarea is under *Jhum* cultivation (including currently cultivated field with all stages of fallows) where largest share lies in Africa, followed by America and Asia (Heinimann 2017). In NE India, about ~3,869 km^2 out of ~1,41,652 km^2 forest area is under *Jhum* (Saha et al. 2012). This traditional shifting cultivation required an appropriate fallow length of 10 to 20 years or more to prevent soil erosion, loss of soil fertility and water balance, as well as to allow forest regeneration and co-existence of agriculture and hill forest ecosystem. Normally, this practice is functional when the population densities is of less than 20 persons per km^2 (Inter Ministerial Task Force 2008). However, with the ever-increasing population and their growing demands for food, the length of fallow phase is compromised to 3 to 4 years in the recent year (Rathore et al. 2010). Thus, land degradation is the most severe constraint of higher productivity of *Jhum* agro-ecosystem. In spite of knowing its impact on the environment, this practice cannot be totally neglected as it has been sole agricultural resource for the hill community owing to its tough topography and terrain.

Forest floor litters (FFLs) is composed of dead plants materials lying on the soil surface. Some types of FFLs have more labile carbon (C) while other may have higher concentrations of lignin or recalcitrant C which cannot be easily decomposable (Gessner et al. 2010). In *Jhum* cultivation, the length of fallow phase had positive impact on chemical composition of FFLs (Cornwell 2008). This FFLs had important role in retaining the microbial population and maintain healthy soil nutrient cycling. Exploration of the early successional plants i.e., fast growing N_2-fixing trees and herbs which have narrow CN ratio that easily decompose from the adjacent forest ecosystem is a major concerned for the said cultivation practice (Thakuria and Sharma 2014). *Alnus nepalensis* D. Don, an alder tree species is a short rotation forest crop successfully grown in North-Eastern Himalayan of *Jhum* forest area (Das 2012, Ramakrishnan 2007, Rathore et al. 2010). The fundamental advantage of this species is that it has a symbiotic relationship with the free-living nitrogen fixing actinomycete, *Frankia* (Benson 1982, Rathore et al. 2010). Thus, escalating soil Nitrogen (N) by fixation. Alder leaf is rich in N and its mineralization is known to modify community-level of microbial functions and accelerates the cycling of essential soil nutrients (Ramakrishnan 2007, Selmants et al. 2005). The potential return of N in the soil by monoculture of *A. nepalensis* depend on different duration of its growth and can return 29 to 117 kg ha^{-1} $year^{-1}$ to the soil (Sharma and Ambasht 1987). Nonetheless, there is no such information on pre-burnt FFLs biomass and their nutrient quality with respect to varied fallow length of *Jhum* cultivation after burning. Therefore, this study was aimed to make a comparative difference on these parameters between traditional and alder-based *Jhum* cultivation system on varied fallow length.

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Materials and Methods

Site selection and sampling

Jhum fallows with two, four and eight-year-old fallow length were selected in each traditional (Dzulekie village) and alder-based (Khonoma village) *Jhum* Kohima district of Nagaland, India for this study (Table 1). All selected *Jhum* fallows had already been used by farmers and selected sites have been engaged by them for the next cropping season. In alder-based *Jhum* cultivation, farmers managed these fallows by pollarding the Alder trees at the height of 2 to 3 m above ground level and about 5-6 coppices were retained on the main trunk. During cultivation farmer used to cut the remaining coppices and finally burned it. Sprout of new coppices on the tree trunk were allowed to mature during the fallow period, which were pollarded at the next *Jhum* cycle.

The study area had humid sub-tropical climate with average temperature of 27—32 °C, where coolest month being December to February (winter) and highest temperature prevails during June-August (summer) with heavy rainfall. As a usual practice, during the dry season (last week of December) usually the farmers slashed the forest and then dried it for next three months (before first rain coming). So, samplings of FFLs were done just before burning. The southern slope of the hill, approximately 0.5 ha area under each of the identified *Jhum* follows have been divided into three hill slopes (upper, middle and lower). From each

Table 1. Back ground information of study area.

′		Traditional *Jhum*			Alder-based *Jhum*		
Fallow length		2 years	4 years	8 years	2 years	4 years	8 years
GPS coordinate	N	25°37′19.64′′	25°37′15.19′′	25°37′38.66′′	25°38′44.23′′	25°38′11.67′′	25°38′43.59′′
	S	93°57′2.42′′	93°56′55.49′′	93°55′53.90′′	94°1′21.89′′	94°1′27.95′′	94°1′29.20′′

of the three slopes, FFLs had been collected from five random plots (1 sq m area). Thus, 15 FFLs samples were obtained from each *Jhum* fallows, therefore a total of 90 samples were taken for six *Jhum* fallows. Similar, sampling was done for soil to determine soil bulk density (BD) using a core sampler (5 cm in diameter, 8 cm in length, Jackson 2005). All the FFLs samples were oven-dried at 65°C to constant weight and measured the dry biomass weight. For the determination of total N concentration in FFLs sample, 0.5 g finely ground litter sample was put in the digestion tube and added 6 mL of conc. H_2SO_4 followed by 1 g digestion mixture. After digestion at about 350°C for 3 h, the content was cooled and distilled for 6 min in an automated distillation chamber (Classic DX, Pelican Equipment, Chennai). Ammonia generated during distillation was collection in 2% boric acid containing few drops of mixed indicator (Composition of mixed indicator: 0.1 g bromocresol green with 0.07 g of Methyl red and dissolved this mixture in 100 mL ethanol) in a conical flask and finally amount of boric acid used for absorption of ammonia was determined by titrating with standard 0.02 N H_2SO_4 (Bremner and Mulvaney 1982). Nitrogen was expressed in percentage (%). Total P and K concentration in litter sample was determined by sulfuric-nitric-perchloric acids (at a ratio of 5:2) digest (Prasad 1998). After digestion, the residue was mixed with distilled water and filtered through Whatman No. 42 and volume made up 30 mL of the aliquot was taken and mixed with 10 mL vanadate-molyb date solution and diluted to 50 mL with distilled water for measurement of tissue (FFLs) P concentration. After 10 min, the absorbance was read at 420 nm using ELISA plate reader (Multiskan, Thermo Scientific, USA). And total K was measured by flame photometry. Both total P and K concentration was expressed in percentage (%).

Statistical analysis

Statistical analysis were performed using SPSS v 21.0 (Statistical Packages for Social Science Inc, Chicago, IL, USA). To test the statistical significance among different values of FFLs and BD in six *Jhum* fallows, one-way ANOVA was performed which was followed by pair-wise comparison among means using Tukeys Honestly Significance difference test. The effects of *Jhum* type, Fallow length and their interaction were determined by 2-factorial analysis of variance (ANOVA) with in the analysis tab for General Linear Model for Univariate test.

Results and Discussion

Increasing period of fallow length in both AB-JFs and T-JFs, increased the dry biomass weight of FFLs and litter N (2 < 4 < 8 - Year), but contrasting trend was observed in case of BD in the order (2 > 4 > 8 - Year, Table 2). In brief, all the value of dry biomass weight of FFLs was significantly different at $p < 0.05$ (one-way ANOVA) and recorded maximum in 8-year AB-JF (113.1 g m^{-2}) followed by 4-year AB-JF (106.5 g m^{-2}) and minimum was observed in 2-year T-JF (48.8 g m^{-2}). Two-way ANOVA exhibited that fallow length (FL) and *Jhum* types (JT) were significantly different while their interaction (FL × JT) was non-significantly different at $p < 0.05$ (Table 2). Arunachalam et al. (1998) stated that litter production was strongly related (r=0.931) to the age of the forest regrowth. Prolong photosynthesis in older fallows then younger results in more accumulation of biomass FFLs in the former. Also, Lawrence and Foster (2002) found that in older fallow which had increasing litterfall, decomposition rate was much slower than younger fallow. Similar, results were reported in previous findings (Filho et al. 2018, Rossi 2010, Sharma 1993, Sharma and Ambasht 1987). *A. nepalensis* in Ab-JFs provided more biomass accumulation than T-JFs due to free N_2 fixing with *Frankia* in nature (Sharma et al. 1994). A study on net primary production and nutrient cycling in agro-forestry systems of cardamom grown

Table 2. Effect of the length of fallow phase on FFLs and soil BD under-based and traditional J*hum* cycles. Values are means ± standard errors. Within a column, values followed by different letters indicate statistically significant difference at $p < 0.05$, one-way ANOVA incorporating Tukey's Honestly Significant Difference for multiple pair-wise comparisons. The interaction effect was determined by 2-way ANOVA. BD–Bulk Density, NS–Non-Significance and *Significant at 0.05%.

Management system	Fallow length (Year)	Dry litter biomass (g/m^2)	Litter N %	Litter P %	Litter K %	BD
Alder-based	2	88.3 ± 3.0c	1.80 ± 0.04c	0.40 ± 0.03b	1.22 ± 0.08b	1.28 ± 0.02c
	4	106.5 ± 2.9d	2.01 ± 0.03d	0.43 ± 0.03b	1.30 ± 0.07b	1.19 ± 0.01b
	8	113.1 ± 3.3d	2.16 ± 0.05e	0.44 ± 0.03b	1.29 ± 0.05b	1.11 ± 0.01a
Traditional	2	48.8 ± 2.2a	1.23 ± 0.03a	0.25 ± 0.03a	0.73 ± 0.05a	1.61 ± 0.01e
	4	56.5 ± 2.0a	1.62 ± 0.03b	0.25 ± 0.02a	0.82 ± 0.05a	1.55 ± 0.01d
	8	72.5 ± 2.2b	1.81 ± 0.04c	0.29 ± 0.02a	0.83 ± 0.05a	1.52 ± 0.02d
Fallow length (FL)		*	*	NS	NS	*
Jhum types (JT)		*	*	*	*	*
FL × JT		NS	*	NS	NS	NS

under Alnus and mixed tree species (non-N_2-fixing) in Sikkim shows that non--N_2-fixing plant produced 69% of annual net primary productivity of *A. nepalensis* biomass (Sharma et al. 1994). This increased in biomass under alder remains effective only up to 15-year stand age but, decreased after that.

Different types of fallow succession in *Jhum* can have varied species diversity which can bring differences in nutrient contents (Lawrence and Foster 2002, Sariyildiz and Anderson 2005). But, increasing fallow length could also differ litter quality which can affect significant changes in N, P and K concentration in FFLs. A study on nutrient accumulation in surface litter of *Austroeupatorium inulaefolium* dominated fallows showed increase in N, P and K content with respect to increasing fallow length (Cairns 2007). However, the value of N, P and K concentration in FFLs was higher in AB-JFs then T-JFs and significantly different at $p < 0.05$ (one-way ANOVA, Table 2). Unlike other N-Fixing trees, Alder has an extensive lateral root system with heavy concentration of *Frankia* around nodules that fix atmospheric nitrogen and produce N rich biomass on the ground. This will be the obvious reason which had maximum N in 8-year AB-JF (2.16%), subsequently next in 4-year AB-JF (2.01%) and minimum was in 2-year T-JF (1.23%). Analysis with two-way ANOVA, also showed fallow length (FL) and *Jhum* types (JT) and their interaction (FL × JT) to be significantly different at $p < 0.05$ (Table 2). But result of P and K concentration had significant differences in *Jhum* type only. Unlike N, P and K can not volatilize after burning, they just remain on soil in the form of ash. Many studies have reported increasing in available soil P and K after burning from younger to older fallows in *Jhum* cultivation (Certini 2005, Mishra et al. 2017, Osman et al. 2013, Saplalrinliana et al. 2016). This difference might be due to increase of biomass with the increased in fallow length, not in concentration different on FFLs. However, our finding clearly shows the advantage of alder-based *Jhum* cultivation which had higher concentration of P and K in FFLs over traditional (Table 2). A study on rice cultivation by green manuring with *A. nepalensis* leaf which had 0.41% P and 1.37% K gives significant amount of yield (Tomar et al. 2013).

The length of fallow period showed a distinct influence on soil BD, increasing fallow time decrease their soil BD (Table 2, 2 > 4 > 8-year at one-way ANOVA $p < 0.05$). Saplalrinliana et al. (2016) found similar trend of decreasing BD in Nagaland (1.58 g cm^{-3} in 5-year secondary forest to 1.46 g cm^{-3} in 15-year secondary forest) with increasing age of secondary forest stand. Since, soil organic carbon (SOC) is an important role in BD changes. With lower value of BD, SOC values increases (Biswas et al. 2012). SOC is also dependent on the amount of litters/vegetative parts present in the soil environment which is clearly understand from the outcome of this experiment. Increased biomass FFLs value in older fallows as compared to younger one clearly explained the lower value of BD in older fallows. Additionally, when secondary forest (fallows) was slashed, burnt and subsequently brought under cultivation (2–3 years), it accelerates turnover rate of the active carbon pools in soil. For the obvious reasons, in younger fallows, the rate of SOC oxidation to CO_2 increases as compare to the older ones, that means it increases significantly with the loses of SOC and decreases in BD (Sarkar et al. 2015). This trend also clearly corroborates our observation i.e., lower values of BD in AB-JFs.

Conclusion

A form of agro-forestry system which is so called the *Jhum* cultivation contributes enormously on food and nutritional security of the hilly communities. One should not ignore the fact of its negative impact on the environment due to shortening of fallow period for the last two decades yet this practice cannot be totally neglected as it has been the sole form of agriculture for the hill community owing to the tough topography in which they reside. Therefore, fallow management with *Alnus nepalensis* which can shorten fallow length period is a striking example of sustainable land-use intensification evolved through centuries of farmer experimentation. This present study clearly highlights the advantages of alder-based *Jhum* cultivation in terms of soil physical, FFLs biomass and their nutrient concentration properties over traditional *Jhum* ecosystem. This study is a part of understanding the co-existence both forests and agro-forestry for sustainable food production in short duration of *Jhum* system and restoring soil health.

References

Arunachalam A, Arunachalam KM, Pandey H, Tripathi R (1998) Fine litterfall and nutrient dynamics during forest regrowth in the humid subtropics of North Eastern India. For Ecol Manage 110 : 209—219.

Benson DR (1982) Isolation of *frankia* strains from alder actinorhizal root nodules. Appl Environ Microbiol 44 : 461—465.

Biswas A, Alamgir M, Haque S, Osman K (2012) Study on soils under shifting cultivation and other land use categories in Chittagong Hill Tracts, Bangladesh. J For Res 23 : 261—265.

Bremner JM, Mulvaney C (1982) Nitrogen total 1. In : Methods of soil analysis. Part 2. Chemical and Microbiological Properties, pp 595—624.

Cairns M (2007) Management of fallows based on *Austoeupatorium inulaefolium* by Minangakabau farmers in Sumatra, Indonesia. In: Voices from the Forest: Integrating Indigenous Knowledge into Sustainable Upland Farm ing. Resources for the Future, Washington, DC, pp 153—184.

Certini G (2005) Effects of fire on properties of forest soils: A review. Oecologia 143 : 1—10. doi:10.1007/s00442-004-1788-8

Cornwell WK (2008) Plant species traits are the predominant control on litter decomposition rates within biomes worldwide. Ecol Lett 11 : 1065—1071.

Das A (2012) Natural resource conservation through indigenous farming systems : Wisdom alive in North East India 11 : 505—513.

Filho AAR (2018) Dynamics of the soil fertility in quilombola shifting cultivation communities of the Atlantic Rain Forest, Brazil. Boletim do Museu Paraense Emílio Goeldi Ciências Naturais 13 : 79—106.

Gessner MO, Swan CM, Dang CK, McKie BG, Bardgett RD, Wall DH, Hättenschwiler S (2010) Diversity meets decomposition. Trends Ecol Evol 25 : 372—380.

Heinimann A (2017) A global view of shifting cultivation: Recent, current and future extent. PLOS ONE 12:e0184479 doi:10.1371/journal.pone.0184479

Inter Ministerial Task Force (2008) Draft Report of the Inter-Ministerial National Task Force on Rehabilitation of Shifting Cultivation Areas, Ministry of Environment and Forest, Government of India. New Delhi, 20th September 2008.

Jackson ML (2005) Soil chemical analysis: Advanced course. UW-Madison Libraries Parallel Press.

Lawrence D, Foster D (2002) Changes in forest biomass, litter dynamics and soils following shifting cultivation in southern. Mexico: An overview. Interciencia 27 : 400—408.

Mishra G, Marzaioli R, Giri K, Borah R, Dutta A, Jayaraj R (2017) Soil quality assessment under shifting cultivation and forests in North Eastern Himalaya of India. Arch Agron Soil Sci 63 : 1355—1368.

Osman KS, Jashimuddin M, Haque SS, Miah S (2013) Effect of shifting cultivation on soil physical and chemical properties in Bandarban hill district, Bangladesh. J For Res 24 : 791—795.

Prasad R (1998) A practical manual for soil fertility. Division of Agronomy, Indian Agricultural Research Institute. ICAR Agronomy National Professor Unit, New Delhi, pp 50.

Ramakrishnan P (2007) Indigenous Fallow Management Based on *Flemingia vestita* in North East India. In: Voices from the Forest: Integrating Indigenous Knowledge Into Sustainable Upland Farming, pp 237.

Rathore S, Karunakaran K, Prakash B (2010) Alder-based farming system a traditional farming practices in Nagaland for amelioration of *Jhum* land. Indian J Tradit Know 9 : 677—680.

Rossi JP (2010) Decreasing fallow duration in tropical slash and burn agriculture alters soil macro-invertebrate diversity:A case study in Southern French Guiana. Agric Ecosyst Environ 135 : 148—154.

Saha R, Chaudhary R, Somasundaram J (2012) Soil health management under hill agro-ecosystem of North East India. Appl Environ Soil Sci, pp 2012.

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. J Ind Soc Soil Sci 64 : 402—413.

Sariyildiz T, Anderson JM (2005) Variation in the chemical composition of green leaves and leaf litters from three deciduous tree species growing on different soil types. For Ecol Manage 210 : 303—319. doi:https://doi.org/10.1016/j.foreco.2005.02.043

Sarkar D, Meitei CB, Baishya LK, Das A, Ghosh S, Chongloi KL, Rajkhowa D (2015) Potential of fallow chronosequence in shifting cultivation to conserve soil organic carbon in North East India. Catena 135 : 321—327.

Selmants PC, Hart SC, Boyle SI, Stark JM (2005) Red alder (*Alnus rubra*) alters community-level soil microbial function in conifer forests of the pacific North West, USA. Soil Biol Biochem 37 : 1860—1868.

Sharma E (1993) Nutrient dynamics in Himalayan alder plantations. Ann Bot 72 : 329—336.

Sharma E, Ambasht R (1987) Litterfall, decomposition and nutrient release in an age sequence of *Alnus nepalensis* plantation stands in the Eastern Himalaya. J Ecol, pp 997—1010.

Sharma R, Sharma E, Purohit A (1994) Dry matter production and nutrient cycling in agro-forestry systems of cardamom grown under Alnus and natural forest. Agro-for Syst 27 : 293—306.

Thakuria D, Sharma U (2014) Shifting cultivation, coexistence of forest and agriculture. NAAS News 14 : 4—8.

Tomar JMS, Das A, Arunachalam A (2013) Crop response and soil fertility as influenced by green leaves of indigenous agro-forestry tree species in a lowland rice system in North East India. Agro-for Syst 87:193—201. doi:101007/s10457-012-9535-3.