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# Ecological Analysis of Climate Change on Soil Characteristics under Shifting Cultivation Practice in Tropical Moist Regions

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## ABSTRACT

This study delves into the multifaceted impact of climate change on soils subjected to shifting cultivation practices. Our findings reveal a complex interplay of both beneficial and adverse effects on the physical, chemical, and biological attributes of soils. Moreover, climate change exacerbates these detrimental impacts by inducing significant alterations in soil characteristics. Specifically, our study underscores that shifting cultivation practices, particularly those employing short fallow cycles, can pose a considerable threat to soil health when subjected to changing climatic conditions. In such scenarios, shifts in temperature and precipitation patterns have the potential to magnify the adverse consequences of shifting cultivation on soils, ultimately outweighing any positive influences. This study highlights the critical need for sustainable land management strategies, especially in the face of climate change, to preserve and enhance soil health and resilience in shifting cultivation regions.

**Keywords** Land use, Land cover change, Climate change, Soil dynamic, Tropical forest.

## INTRODUCTION

Earth ecosystems are facing rising pressure from two main anthropogenic processes including the direct process of land use and land cover change (LULCC) and the indirect process of climate change (Ostberg *et al.* 2015, Monsang *et al.* 2021, Upadhyay *et al.* 2021). LULCC has been identified as one of the key drivers responsible for changes in land surface and impacting biophysical, biogeochemical processes and ecosystem services (Prestele *et al.* 2017, Upadhyay *et al.* 2019, Manpoong and Tripathi 2019, Ozukum *et al*. 2019, Upadhyay and Tripathi 2019, Jopir and Upadhyay 2019). Abiding LULCCs have transformative effects on soil, water and atmosphere, which greatly influence the global environmental problems like soil health, quality and availability of fresh water, food security and biodiversity mainly due to rapid defor-

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estation for agriculture, industrial development and urbanization (Scanlon *et al.* 2007, Tripathi *et al.* 2012, Verburg *et al.* 2013, Newbold *et al.* 2015, Tripathi *et al.* 2016, Abdulkareem *et al.* 2019). Further, climate change and LULCC together determine hydrological processes such as evapotranspiration, interception and infiltration, and impact the water resources through spatial and temporal alterations in surface and subsurface flow patterns (Wang 2014, Zhang *et al.* 2016, Khoi and Suetsugi 2014, Marhaento *et al*. 2017a and b, Marhaento *et al.* 2018). LULCC and climate change have reciprocal effects on each other. LULCC control climate change through alterations in structure and functioning of ecosystems (Tripathi *et al.* 2008, Pachuau *et al.* 2014, Tripathi *et al.* 2016, Wapongnungsang *et al.* 2018, Ao *et al*. 2020, Ao *et al.* 2021) and related fluxes of energy (latent and sensible heat and radiative changes) and mass (water vapour, CO2 and trace gasses and particulates) (Dale 1997, Wilkenskjeld *et al.* 2013). Whereas, the impact of climate change on land use can be witnessed through changes in land management strategies to mitigate negative effects of climate change (Dale 1997).

Shifting cultivation also known as swidden or slash-and-burn or *Jhum* is one of the most ancient farming systems and widely practiced in the tropical moist areas of the world (Tripathi *et al.* 2017, Layek *et al.* 2018, Upadhyay *et al.* 2018). This land-use system forms the basis for land uses, livelihoods and customs in upland areas of the tropical forest-agriculture for centuries (van Vliet *et al.* 2012, Dressler *et al.* 2015, Mukul and Herbohn 2016) and involves approximately 14-34 million people alone from tropical Asia (Mertz *et al*. 2009). This practice of land use was sustainable in the past but now losing its credibility due to increasing population density and decreasing (< 3 years) fallow length (Grogan *et al.* 2012, Wapongnungsang *et al*. 2021). As per estimates, shifting cultivation is responsible for ~ 60% of total deforestation in tropical regions and acts as a major source of greenhouse gas emissions (Geist and Lambin 2002, Davidson *et al.* 2008). Globally, shifting cultivation covers an approximate area of 280 Mha (including currently cultivated and land abandoned as fallow of different years) with a major share in Africa, trailed by Americas and Asia (Heinimann *et al.* 2017). Although, shifting cultivation is considered unsustainable and harmful to the environment (Bruun *et al.* 2009, Ziegler *et al.* 2011, 2009, van Vliet *et al.* 2012), in many cases, alternative land-uses like promoting plantations of commercial crops like rubber and palm in different regions are found to be more negative than shifting cultivation (Vongvisouk *et al.* 2014, Dressler *et al.* 2015) as the later conserves the traditional biodiversity and culture of the region (Tripathi *et al.* 2017).

This paper aims to analyse the existing information on impact of shifting cultivation on soil and community attributes and to understand the multifaceted impact of climate change on soils characteristics subjected to shifting cultivation practices. For the purpose, a thorough literature review has been made on different aspects of shifting cultivation in a changing climate using broad databases (e.g., Web of Science, Science Direct). further, an in-depth analysis was done to analyse the impact of changing climate on soil characteristics and presented for developing future management strategies for shifting cultivation soils under changing climate scenario.

## Ecological impact of shifting cultivation on soil attributes

A large number of studies have been documented on shifting cultivation from different parts of the tropical world, investigating the physical, chemical and biological changes caused by any form of matter or energy resulting from activities under various components of shifting cultivation and the ecological interpretation of the results were presented for various community and soil attributes.

### *Shifting cultivation effects on plant and animal diversity*

The studies focused on early stages of fallow succession witnessed the minor effect of shifting cultivation on plant diversity (Raharimalala *et al.* 2010, d'Oliveira *et al.* 2011, Phongoudome *et al.* 2013), however, a significant effect of shifting cultivation on diversity indices compared to undisturbed forest has been observed by others (Castro-Luna *et al.* 2011, Do *et al.* 2011, De Wilde *et al.* 2012, Ding *et al.* 2012). The recovery of species composition and diversity depends upon intensity of previous land use, fallow age (Ding *et al.* 2012, Schmook 2010), local climate and biota. For example, full recovery of biodiversity of an old forest growth have been reported to require 60-80 years in certain areas of Africa and Southeast Asia (Do *et al.* 2011, McNicol *et al.* 2015). Similarly, forest structure has been reported to recover slowly which takes about 30 to 60 years depending on the climate, biota and parent material as compared to species diversity (Van Gemerden *et al.* 2003, Piotto *et al.* 2009), however, structure parameters like stand density recover at faster rate in young fallows (Phongoudome *et al.* 2013). A rapid recovery of biomass has been observed at the initial stage of fallow which slows down with fallow age (Wapongnungsang and Tripathi 2019). However, biomass accumulation for both above and below ground increases with increasing age of fallow (Raharimalala *et al*. 2012). The estimated rate of biomass recovery (above and below ground) at early successional stage (ca. 10 years) ranged between 7.5 and 15.0 Mg ha$^{-1}$ year$^{-1}$ (Kenzo *et al.* 2010) which attains about 50% biomass during a period of 25 years from last cultivation (Gehring *et al.* 2005). Many studies conducted on aspects of conservation biology reported negative consequences of shifting cultivation on different zoo taxa. Highly affected classes of zoo taxa include birds followed by insects, nematodes and reptiles (Mukul and Herbohn 2016).

## Shifting cultivation effects on soil attributes

### *Impact on physical characteristics*

Shifting cultivation impacts the physical characteristics of the soil (i.e., structure, texture, bulk density, porosity, temperature, water holding capacity and color (Bhuyan and Laskar 2020). Shifting cultivation impacts the soil texture through loss of organic material, grain size modification and alteration in the fine fraction of soil, which negatively affects surface runoff and soil erosion, and compacting of topsoil (Mataix-Solera *et al.* 2002, Dass *et al.* 2011, Ribeiro Filho *et al.* 2013). Similarly, it affects soil structure mainly in macroaggregates (> 0.250 mm) (Manpoong 2019) and their impact can be seen on capacity of soil to retain the water and absorb the nutrients (Cooper *et al.* 2020). Soil organic carbon (SOC) is an important component of soils and critically influence the soil structure. The burning of debris material results in combustion of SOC and negatively impacts the soil structure by negatively affecting the diversity of soil animals (Cerdà 1993, Arunrat *et al.* 2023). Although, the fire decreases the amount of organic matter in the soil but increases the amount of mineral carbon (black carbon) and carbonated matter with change in the proportion of macroaggregates (< 0.250 mm) (Santín and Doerr 2016, Berryman *et al.* 2020). It is also observed that soil moisture maintained by latent heat of vaporization controls the fire severity and decreases its impact on soil physical properties (Mataix-Solera *et al.* 2011). Further, the repeated exposure of soil during cultivation and fallow phases of intensive shifting cultivation results in increased surface runoff, erosion and decrease in water conductivity and rate of infiltration (Gafur *et al.* 2000). It hampers the ensuing recovery of soil and results in gradual degradation of soil.

### *Impact on chemical properties*

Shifting cultivation significantly influences various soil chemical properties (i.e., pH, cation exchange capacity, CEC, the kinetics of micro and macronutrients, soil organic matter, SOM and soil organic carbon, SOC) (Ribeiro Filho *et al.* 2015). In shifting cultivation, organic matter affects the nutrient cycling by regulating its dynamics, which in turn influences the CEC and soil pH, and exhibits a positive impact on soil fertility during the conversion phase and negative consequences under the cultivation phase (Arunrat *et al.* 2021). Unlike soil physical properties, chemical properties witness a synergistic effect due to the availability of stored macronutrients in the burned biomass and an increase in pH with the increase in basic cations (Ca, Mg, and K) (Saplalrinliana *et al.* 2016). However, varying results have been reported about the availability of P and K in the soil, and the status of their dynamics after burning is uncertain. Although an initial decrease has been recorded in the organic matter and volatility of macronutrients like N, C, and S, the soil fertility increased markedly (Bruun *et al.* 2009). Burning during the conversion phase also impacts levels of organic matter and SOC due to their low volatilization temperatures and ultimately the soil resilience and fertility (Arunrat *et al.* 2023).

The cultivation phase affects soil properties both positively and negatively. The exposure of soil at the beginning of the cultivation phase poses the problems of surface runoff, leaching, erosion, and loss of organic matter, which results in altered soil pH due to loss of bases, increased rate of decomposition leading to flow of carbon to the atmosphere, decreased CEC, a decline in macronutrients, and decreased soil fertility (Døckersmith *et al.* 1999, Eaton *et al.* 2009, Ovung *et al.* 2021). Growth and development of crop cultivars during the cultivation phase help in the upkeep of pH, decrease the loss of soil nutrients by providing soil cover, increase the availability of nutrients by addition of organic matter, and improve overall soil fertility (Singh *et al.* 2020). However, the inverse relationship of cultivation cycle numbers with the amounts of bases, the concentration of nutrients, and the amount of organic matter impacts the soil acidity, availability of soil nutrients, and soil fertility (Ovung *et al.* 2021, Singh *et al.* 2022).

However, the fallow component helps in reinstating the early growth conditions of the forest ecosystem through the processes related to ecological succession (Ovung *et al.* 2021). Soil exposure during the early fallow phase negatively impacts the soil pH due to loss of bases, but a fallow period of >10 years helps in recovery of soil pH through successional stages towards conditions before shifting cultivation cycle (Manpoong and Tripathi 2021). Further, shifting cultivation in early fallow phase and with short fallow cycle negatively impacts the amount of organic matter and SOC due to high decomposition rate and flow of carbon to atmosphere; low macronutrients availability and low CEC caused by low organic matter, and losses from surface runoff and leeching (Manpoong and Tripathi 2021). Nevertheless, longer fallow phases positively influence the dynamics of soil macronutrients by providing vegetation cover against surface losses of nutrients and increasing organic matter. Long fallow period supports improvement in CEC through increased availability of bases and helps in recovery of soil fertility (Ovung *et al*. 2021).

### *Impact on soil biological properties*

Shifting cultivation significantly influences the soil biological properties including soil microfauna (20 to 200 µm in size; e.g., algae, bacteria, cyanobacteria, myxomycetes, actinomycetes, fungi, and yeasts), Mesofauna (0.1 to 2mm in size; arthropods, such as mites, collembola, and enchytraeids), macrofauna (larger than 2mm in size; e.g., pot-worms, millipedes, beetles, beetle larvae, myriapods, centipedes, slugs, snails, fly larvae, and spiders), and seed bank (Corsi *et al.* 2012). Usually, increase in soil temperature accelerate the process of decomposition and helps in building microbial biomass (Lalnunzira and Tripathi 2018, Singh and Tripathi 2020a, Singh *et al.* 2021, Singh *et al.* 2022). In shifting cultivation operations, the exposure of soil followed by an increase in its temperature and drying results in inhibition of the activity of soil microfauna. This situation aggravates with the use of fire in the burning of biomass and the increasing number of cultivation cycles, which impact the amount of biomass and diversity of microfauna and result in loss of soil fertility as a faction of decreased nutrient mineralization (Ovung *et al.* 2021). However, ecological succession under longer fallow period increases the activity, biomass and diversity of microbial fauna by addition of organic matter in the soil. Further, a similar effect of different shifting cultivation procedures (e.g., soil exposure, biomass burning and fallow period) has been observed on meso- and macrofauna (Manpoong and Tripathi 2021).

In the case of a soil seed bank, soil exposure facilitates the germination of seeds through phototropism and the establishment of their root system. But, burning of biomass and increasing numbers of cultivation cycles negatively affect the density and diversity of seeds mainly for herbaceous plant groups. The long fallow period after cultivation favors the density and diversity of seed banks through the process of ecological succession (Warrier and Kunhikannan 2022). It also helps in the germination of seed banks and the establishment of seedlings by improving the soil conditions (Warrier and Kunhikannan 2022).

## Climate change impact on soil parameters

Climate has an influence on soil attributes and health**.** Global change drivers like increasing atmospheric temperatures, rising levels of carbon dioxide ($CO_2$), changes in precipitation patterns, extreme climatic events (i.e., drought and flood) and deposition of atmospheric nitrogen (N) have deep impact on the physical, chemical and biological properties of soil (French *et al.* 2009, Porter *et al.* 2013). Global climate change drivers affect biological functioning of soil (Yin *et al.* 2020), biogeochemical cycles of elements like carbon, nitrogen and phosphorus (Delgado-Baquerizo *et al.* 2013, Yuan and Chen 2015), availability of plant nutrients (Yuan and Chen, 2015), structure and stability of soil against erosive forces (Robinson *et al.* 2019) and spread of plant disease (Cramer *et al.* 2018), and consequently the ecosystem functionality and productivity (Wapongnungsang *et al.* 2021). Temperature and rainfall have influence on magnitude of SOC pool and its rate of decomposition, which can negatively impact the global SOC pool and contribute to atmospheric $CO_2$ from prominent soil sinks (e.g., Cryosols, Histosols of boreal and arctic regions, and peat lands) under positive feedback (Martins *et al.* 2017, Zhang *et al.* 2020).

### *Climate change effect on soil architecture*

Soil architecture determines the physical properties of soil such as porosity (more importantly pore size distribution and pore continuity) and bulk density. The size affects functional role of pores in soil ecology, and their proportion in different pore size affects the soil ecological processes. For example, proportion of macropores (>75 mm) play key role in regulation of water and gases, and the proportion of smaller pores (<30-0.2 mm) impacts the storage of water in the soil (Kay 1990). Soil hydraulic properties like soil moisture characteristics and permeability are largely affected by distribution of pore sizes and their continuity through functions of soil water content–potential and hydraulic conductivity–water content (Durner and Fluhler 2006). Climate change is projected to alter soil structure through extreme temperatures and changes in the frequency and intensity of precipitation episodes. Extreme events such as drought, rainfall, and fire may start a variety of processes (e.g., slaking, dispersion, mechanical disturbance, and compaction) that eventually undermine the structural integrity of the soil in hotter, drier places (Mondal 2021). Further, it can have an indirect effect on soil structure through possible effect on soil biota. Earthworms and termites, also known as the "soil engineers," may profoundly affect soil structure and physical qualities, including hydraulic conductivity (Cheik *et al.* 2018). They selectively consume mineral and organic particles, expelling them as faeces pellets and organo-mineral aggregates, undergoing digestive processes that alter the colloidal characteristics of organic matter, and constructing durable galleries, burrows, and chambers. Future climate change, marked by reduced soil stability due to altered soil biota in combination to more intense rainstorms, will likely lead surface soil degradation, forming seals or crusts. This negatively impacts of soil water entry and water use efficiency (WUE), particularly under conventional systems like shifting cultivation. Soil seals and crusts decrease infiltration rates and can trigger erosion by increasing runoff (Parihar *et al.* 2019). Erosion is expected to rise under climate change scenarios, even in areas with reduced precipitation. This, combined with deteriorating soil structure, threatens topsoil loss, reduced WUE, lower crop yields, and increased erosion, creating a destructive cycle of land degradation (Chan *et al*. 2010).

### *Climate change effect on soil biology*

Elevated temperature (eT) was observed to have impact on soil biological processes like decomposition and respiration. The decomposition rates found to be increasing with higher temperatures, though substantial warming (4-8°C) is needed for significant effects (Robinson 2009). The warming effects can vary depending on factors like soil substratum characteristics and plant functional types. It has been observed that root rhizosphere respiration is less affected by a temperature increase of 3°C than bulk soil respiration. Further, the belowground respiration can increase significantly during colder periods with low plant productivity.

A limited number of studies have explored the impact of eT on soil biological communities. Soil fauna biomass and diversity are expected to increase with global warming, along with alterations in life history features (Couˆteaux and Bolger 2000). Microbial communities are more adaptable to eT, and their responses depend on historical temperature exposure (Waldrop and Firestone 2006). Bacterial communities adapt to their mean annual soil temperature, and their temperature sensitivity increases with higher mean annual temperatures (Rinnan *et al.* 2009). Laboratory experiments also showed adaptive responses in fungal and bacterial communities across a wide temperature range (5-50°C), particularly above the optimum for microbial growth (around 30°C) (Barcenas-Moreno *et al.* 2009). These adaptations are linked to changes in community structure, microbial biomass, enzyme activities, and microbial respiration, although substrate availability plays a significant role in elevated temperature responses (Andrews *et al.* 2000). However, soil organic matter quality plays a crucial role in determining response of microbial communities to global warming

***Climate change effects on soil fertility in ecosystems***

Soil pH varies spatially and temporally (Gottlein *et al.* 1999, Gregory and Hinsinger 1999), with daily and seasonal fluctuations of up to one pH unit. In seasons with low to moderate rainfall, salt accumulation lowers soil pH by pushing $H^+$ ions in the soil solution, while wet seasons dilute salts, leading to an increase in soil pH (Rengel 2002). These short-term changes differ from long-term acidification caused by increased rainfall leaching basic cations over decades (Tang and Rengel 2003). Soil acidification can result from increased biomass production caused by rising temperatures and elevated $CO_2$ levels. Plant material contains excess cations that balance organic molecule charges by releasing $H^+$ ions into the soil. When this material decomposes *in-situ,* it returns alkalinity to the soil, neutralizing acidity. However, in managed ecosystems like shifting cultivation, biomass removal as harvest leaves non-neutralized soil acidity, creating unbalanced carbon and nitrogen cycles. Climate change has also been recognized as a potential driver of alterations in forest species composition (Kotroczo *et al.* 2008), resulting in decreased total leaf litter production. This shift could have repercussions on the structure and functionality of microbial communities. Intriguingly, a mere 2°C rise in average soil temperature has been linked to a 22% increase in soil respiration. It is worth noting that this impact can be even more pronounced in modified land use systems, such as shifting cultivation (Lungmuana *et al.* 2017).

Soil organic carbon (SOC) stocks are influenced by the balance between carbon inputs and outputs (Lalnunzira and Tripathi 2018). Inputs primarily come from plant biomass, manure, and microbial biomass, while outputs are mainly in the form of $CO_2$ emissions, with minor contributions from leaching and runoff of dissolved and particulate organic carbon (POC), and in hydromorphic environments, $CH_4$ emissions. Climate change influences both the inputs and outputs of soil organic carbon. SOC decomposition depends on temperature and adheres to the Arrhenius equation, where temperature dictates the reaction rate constant (Arrhenius 1889). The temperature sensitivity of SOC decomposition is also explained through $Q_{10}$ functions, showing how reaction rates change with temperature (Davidson and Janssens 2006). The more recalcitrant SOC pool is less reactive to temperature than the labile carbon pool in the soil that exhibit slower turnover rate (Gruber *et al.* 2004, Jones *et al.* 2005, Manpoong *et al.* 2020, Hauchhum and Tripathi 2019). Further, substrate availability during SOC degradation, shifts due to factors like spatial variation, inaccessibility, and chemical resistance, affecting temperature sensitivity (Singh *et al.* 2022). Since, rising temperatures can limit substrate supply and, consequently, SOC decomposition and affect the carbon cycle. However, varying temperature sensitivity among SOC pools is mainly due to differences in substrate supply, which depends on number of soil attributes (e.g., substrate quality, aggregation, water availability, nutrients, particularly nitrogen, N). The reliable estimates of these processes will be crucial in changing climate scenarios which regulate substrate supply to enzyme sites in soil. Further, the soil C stocks is also affected by factors like forest fires and their intensity, precipitation, $CO_2$ fertilization, N deposition, and soil management practices, which can help in estimating changes in soil C stocks due to climate change (Tripathi *et al.* 2008, Tripathi *et al.* 2012, Ao *et al.* 2023).

Further, the intricate relationship between temperature fluctuations and N deposition can result in unforeseen consequences for carbon sequestration and soil $N_2O$ emissions due to complex interactions (Singh and Tripathi 2000). The projected doubling of atmospheric $CO_2$ levels by 2100 (Forster *et al.* 2007) from the current ambient level is anticipated to further alter the N cycle in terrestrial ecosystems, which will pose challenges for effective management of terrestrial ecosystems (Gruber and Galloway 2008) under N deposition scenario (Tripathi and Singh 2001). The warming trend typically enhances N mineralization and nitrification but is subject to influence by soil moisture levels, adding to the complexity of the situation (Groffman *et al.* 2009). A comprehensive grasp of the dynamics involving soil solution inorganic nitrogen ($NH_4^+ + NO_3^-$) is vital for efficient fertilizer management. Temperature variations can impact these concentrations, affecting plant uptake and the potential for leaching losses (Verburg 2005). An analysis suggests that striving to significantly enhance global $CO_2$ sequestration through increased N deposition may not yield substantial benefits (Reay *et al.* 2008). While increased N emissions could potentially lead to extra C sequestration in forests, the resulting $N_2O$ emissions might offset these advantages.

### Soil characteristics under shifting cultivation in a changing climate scenario

Shifting agriculture exerts significant effects on the physical attributes of the soil by strongly altering the intricate relations of biological and physical processes (Wapongnungsang *et al.* 2020, Wapongnungsang *et al.* 2021). One noteworthy alteration is the adjustment of soil texture, primarily resulting from material loss and changes in grain sizes, especially in the fine soil particle fraction (Wapongnungsang and Tripathi 2019). Importantly, these modifications to soil structure may be further intensified by the consequences of climate change, which are expected to exert a substantial impact on soil characteristics due to extreme temperatures and shifts in precipitation patterns (Tripathi *et al.* 2017, Wapongnungsang *et al.* 2020).

Soil macrofauna play a crucial role in influencing soil structure and physical characteristics. Their creation of durable galleries, burrows, and chambers within the soil matrix significantly impacts hydraulic conductivity and soil stability, enhancing the resilience of soil aggregate structure (Bottinelli *et al.* 2015). However, engaging in shifting cultivation practices may expose soil, subsequently leading to elevated temperatures and increased dryness. This, in turn, can have a detrimental effect on the activity of soil microfauna, inhibiting their normal functioning. This situation is compounded by climate change, which has the potential to modify the development and functioning of these crucial organisms by impacting their physiological processes through changes in soil temperature and moisture conditions (Mondal 2021). The reduced activity and limited development of these organisms may result in adverse consequences on soil health that include heightened surface runoff and erosion and compaction of topsoil. These alterations collectively lead to the deterioration of soil quality and diminish its capacity to efficiently retain water and nutrients. Moreover, the use of fire in biomass combustion and the heightened frequency of cropping cycles due reduced fallow length might exacerbate the problem, affecting both the quantity of biomass and the variety of microfauna. Consequently, a decline in nutrient mineralization might lead to a reduction in soil fertility (Sofo *et al.* 2020).

Soil organic carbon (SOC) stocks play a crucial role in maintaining soil health, subject to the impact of the balance between carbon inputs and outputs. Inputs primarily come from sources such as plant biomass, manure, and microbial biomass (Monsang *et al.* 2023). On the other hand, the primary outputs consist mostly of carbon dioxide ($CO_2$) emissions, accompanied by minimal contributions of dissolved and particulate organic carbon from the leaching and runoff losses (Chaplot *et al.* 2019). Further, methane ($CH_4$) emissions also contribute to the dynamics of hydromorphic settings. In the context of shifting agriculture, especially during the initial fallow phase and with brief fallow cycles, there is an adverse impact on the quantity of organic matter and soil organic carbon (Nath *et al.* 2016). The primary cause of this phenomenon can be attributed to the rapid pace of decomposition and the subsequent release of carbon into the Earth's atmosphere. Moreover, it should be noted that there is a likeliness of reduced accessibility of macronutrients with a decrease in cation exchange capacity (CEC) due to low organic matter levels (Ovung *et al.* 2021). The issue is exacerbated by additional losses of soil carbon and nutrients through surface runoff and leaching. These issues may be further intensified by increased temperatures, as they impact soil biological activities such as breakdown and respiration. Consequently, this might result in a decrease in soil carbon stores when short fallow periods are used (Tripathi *et al.* 2017).

Soil pH and cation exchange capacity (CEC) are additional significant factors to consider concerning soil affected by shifting agriculture (Tripathi *et al.* 2017). The impact of organic matter dynamics in the context of shifting agriculture may have implications for nutrient cycle processes, ultimately resulting in alterations to soil pH levels. The soil pH may be raised by the presence of burnt biomass due to an increase in basic cations, including calcium (Ca), magnesium (Mg), and potassium (K). Nevertheless, climate change has the potential to have adverse impacts on soil pH, primarily due to changes in precipitation patterns and the subsequent leaching of basic cations (Rengel 2002).

Temperature and moisture play crucial roles in influencing soil microbial populations and their activity, which in turn significantly affects nutrient cycling and carbon storage mechanisms (Momin *et al.* 2021, Singh and Tripathi 2020b). In the context of shifting agriculture characterized by short fallow cycles, temperature may have a dual impact on microorganisms. On one side of the argument, higher temperatures have the potential to have a beneficial influence on the development and activity of organisms, resulting in heightened rates of respiration and decomposition (Singh and Tripathi 2020b). Nevertheless, in situations characterized by diminished moisture levels and restricted substrate availability, these impacts may become detrimental to the overall health and well-being of the soil.

## CONCLUSION

In conclusion, the practice of shifting cultivation has a significant impact on the physical and chemical properties of soil, which may adversely affect soil fertility and overall soil health. Such alterations when combined with the challenges presented by climate change (like extreme temperatures and fluctuations in precipitation), might further intensify adverse effects on soil properties. This will adversely affect the crop productivity and yield, and pose a problem of food security for the local populations dependent on shifting agriculture. Hence, understanding these relationships is crucial for the implementation of sustainable land management strategies to promote food security options to tribal populations by conserving soil resources under changing environmental conditions.

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