1. **Examining the Effects of Forest Fire on Terrestrial Ecosystem – A Comprehensive Review of Literature:**

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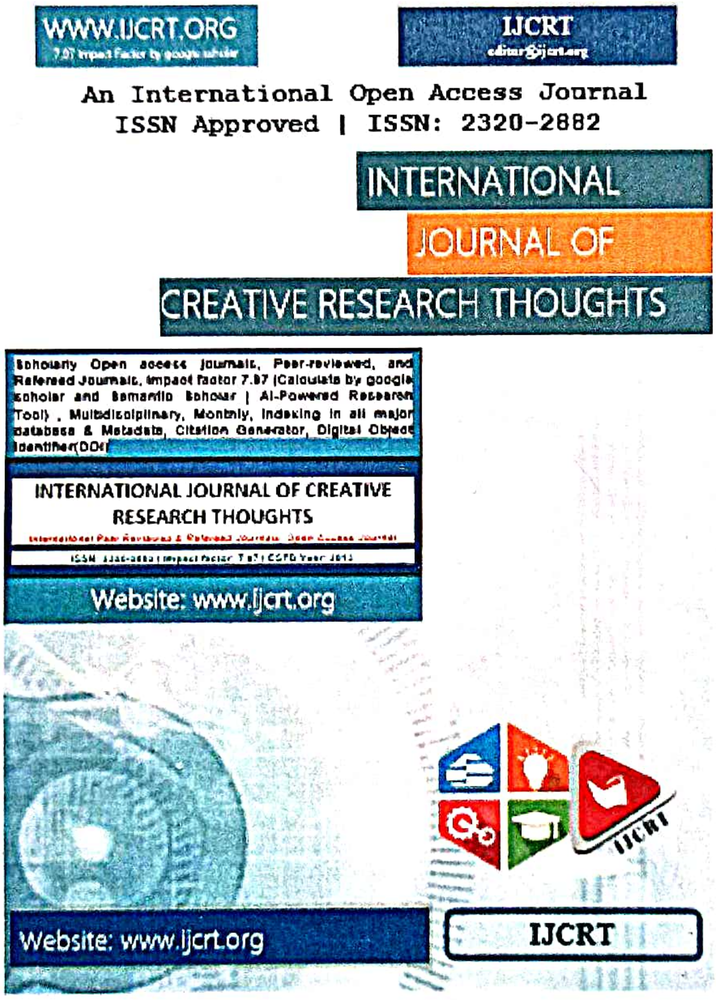

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Examining the Effects of Forest Fire on Terrestrial Ecosystem – A Comprehensive Review of Literature

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1.0 Abstract

Forest fire is very common in all the ecosystems and the forests of India are at risk of it due natural as well as anthropogenic interventions in these areas. Not all types of fires affect the forest ecosystems adversely; especially the larger ones have the potential to affect the ecosystems for a substantially longer period of time (in many cases the partial recovery also took more than a decade). In view of the above, this study was carried out to systematically assess the past research efforts in the focused area i.e. impact of forest fire on the forest ecosystem. For this study literature was collected from SCI journals and has been reviewed by following standard methodology. The review showed that more efforts are needed to control the large forest fires so that smaller fire incidences could allow the natural recovery processes to enhance biological diversity and sustainable development.

Keywords: *Forest fire, ecosystems, risk, biological diversity, sustainable development*

2.0 Introduction

Not just in India, but all over the world forest fire is very common to all the ecosystems. It affects both vegetation and soil. In certain instances it is also helpful in maintaining diversity and stability of ecosystems along with nutrient recycling. However, effect of forest fire and prescribed fire on forest soil is very complex as it (fire) affects soil organic matter, macro and micro-nutrients, and also the physical properties of soil like texture, colour, pH, Bulk Density as well as soil biota. Moreover, the incidences of forest fire are likely to increase in the future due to the climate warming. This also poses a serious challenge as there is very little understanding of the likely severity of such fire incidences. In addition to above, the uncertainty associated with the consequences of forest fire on the soil microbial communities would also have large scale complications thereby affecting the soil nutrient dynamics, which would pose a threat to the existing biodiversity. In view of the above, it was necessary to carry out a systematic study to understand the various efforts researchers have taken so far to gain knowledge of the implications of forest fires on the forest ecosystems.

3.0 Methodology

In the context of the aim and objectives of this study, a literature review was carried out to study the previous research efforts. For this review we considered following aspects, such as the research question posed in the previous studies; the theoretical background, methodology, findings, suggestions and recommendations, etc. moreover, the review was used to identify the research gaps and it (review) was used for synthesizing and gaining a new perspective of the issues concerning the litter decomposition under normal circumstances as well as during the **forest fire and its impact on microbial biomass present in the soil**. The discussion is presented in a chronological order, so that it also indicates the underlying pattern of evolution of thoughts and ideas in the focused domain. Similarly, to the extent possible, care was taken to reproduce the original terminology used by the authors, to preserve the originality of the views. The discussion is presented in the following section.

4.0 Discussion

In order to assess the influence of change in land use on microbial activity, Behera and Sahani (2003) conducted a systematic review and reported that soluble organic N and microbial N pools in terrestrial ecosystems have been less studied than those of inorganic N. Therefore, cross-system variation in their pool sizes and seasonal dynamics, both absolute and relative to inorganic N pools, needs to be quantified so that their ecological importance in different ecosystems can be evaluated. Zhu and Carreiro (2004) through their field based study reported that the extractable soil organic nitrogen and microbial biomass nitrogen dynamics are affected as a function of various seasons and further stated that the spring microbial biomass nitrogen increase could be an important retention mechanism for conserving soil inorganic N when plant N uptake may be low.

Pietikainen et al., (2000) has stated that the wildfires produce a charcoal layer, which has an adsorbing capacity resembling activated carbon. moreover, after the fire a new litter layer starts to accumulate on top of the charcoal layer, which liberates water-soluble compounds that percolate through the charcoal and the unburned humus layer. In view of this the author hypothesized that since charcoal has the capacity to adsorb organic compounds it may form a new habitat for microbes, which decompose the adsorbed compounds. Arunachalam and Arunachalam (2000) through his study of soil microbial biomass dynamics (in the humid subtropical broadleaved forest in north-east India) reported that canopy gaps had low soil moisture and low microbial biomass suggesting that belowground dynamics accompanied changes in light resources after canopy opening. Moreover, the study results indicate that fluctuation in microbial biomass related nutrient cycling processes in conjunction with the associated microclimate variation may affect the pattern of regeneration of tree seedlings in the gaps and hence be related with their size.

Michelsen et al., (2004) studied the seasonal changes and spatial distribution of soil total, dissolved organic C and microbial biomass C in relation to the fire frequency in dry vegetation types grassland, woodland and dry forest in Ethiopia. Based on the study results author reported that C release from burning organic matter may have strong implications for C and nutrient cycling in seasonally dry tropical ecosystems. In order to study the soil respiration and its spatial and temporal variation at boreal forest sites in central Canada, Singh et al., (2008) collected soil respiration, soil temperature, and organic layer thickness measurements from 100 points in a grid pattern and reported that soil respiration was positively related to the fine root biomass stated that variation in root biomass has a larger effect than differential forest floor organic layers on variation in soil respiration in young boreal post fire forests.

Kondapani et al., (2008) used a combination of remote sensing data and GIS techniques to determine the burnt areas and reported that temporal trends suggest increasingly short fire-return intervals in the landscape and further found that forest fires had significant adverse impacts on species diversity and regeneration in the tropical dry deciduous forests. However, Somashekar et al., (2008) monitored the burnt areas of Western Ghats (a biodiversity hot spot) using March 2000 and 2004 IRS LISS — III data and found that an area of 2.15 km^2 and 4.46 km^2 was affected by fire in 2000 and 2004 respectively. Author reports the reasons for these wild fires were repeated drought, followed by mass flowering and dying of bamboo, which accelerated the spread of fire from ground to canopy in areas with high bamboo density.

Meigs et al., (2009) quantified the short-term effects of low, moderate, and high-severity fire on carbon pools and fluxes in the Eastern Cascades of Oregon. The study results show that though soil C, soil respiration, and fine root net primary productivity were conserved across severity classes, net ecosystem production declined with increasing severity, driven by trends in aboveground net primary productivity. Based on the data related to effect of a severe wildfire 10 years after burning Sullivan et al., (2010) determined decadal-scale changes in soil gas fluxes following fire incident and found that there was less carbon available at the burned site for respiration by plants and microbes.

Verma and Jayakumar (2012) reviewed the effect of forest fire on various properties of soil, which are important in maintaining healthy ecosystem and based on this review reported that it (forest fire) affects soil organic matter, macro and micro-nutrients, physical properties of soil like texture, colour, pH, Bulk Density as well as soil biota. However, the impact of fire on forest soil depends on various factors such as intensity of fire, fuel load and soil moisture. Holden and Treseder (2013) conducted a review to test the hypothesis that soil microbial biomass would decline following forest disturbances, but that abiotic disturbances would elicit greater reductions in microbial biomass than biotic disturbances. Author found that changes in microbial abundance following disturbance were significantly positively correlated with changes in microbial respiration. Altogether, the study results suggest that abiotic forest disturbances may significantly decrease soil microbial abundance, with corresponding consequences for microbial respiration.

Jhariya et al., (2014) identified the fire prone areas (of Tropical Deciduous forests of Bhoramdeo Wildlife Sanctuary) on the basis of historical ground fire data in conjunction with satellite remote sensing data provided by NRSA, based on the frequency of forest fire damage. Author also investigated the biomass and carbon storage pattern of the same area and observed that forest fires are driving factor in shaping forest vegetation, biomass accumulation and carbon storage. Kittur et al., (2014) assessed the effect of four levels of historic wildland fire frequency (high, medium, low, and no-fire) on regeneration of seedlings in fire affected areas of moist deciduous forests of Chhattisgarh. Based on the study results, author reported that the major contributing components of fuel load included duff litter and small woody branches and twigs on the forest floor and repeated fires, however, slowly reduced stand stability.

Chandra (2015) had stated that forest fire is very common in all the ecosystems and plays an important role in ecosystem dynamics, biodiversity, soil and microbes. Author further stated that the low intensity fire results in combustion of litter and soil organic matter, increases nutrients availability which supports regeneration of herbs and growth of post fire community. However, the higher intensity fire results into complete loss of soil organic matter and volatilization of nitrogen, phosphorus and potassium but very high temperature is required for complete burning of Mn, Mg, Cu and other micronutrients. Satish and Reddy (2015) aimed to integrate satellite derived forest burnt areas over a multi-decadal scale to understand fire frequencies in Silent Valley National Park, Kerala, India and found that overall, there is a declining trend of forest fires, which indicates management effectiveness in this area.

Using a combination of remote sensing and GIS technology Ajin et al., (2015) developed the Fire Risk Index model to prepare forest fire risk map of Nemmara Forest Division has classified the area into five risk zones: very high, high, moderate, low and very low. Maksimova et al., (2017) analyzed the state of microbial communities in gray-humus soils (Eutric Fluvic Arenosols (Ochric) of pine stands after forest fires of 2010 and found that it (fire) exert negative effects on the structure and metabolic activity of microbial communities in the postpyrogenic soils. The maximum content of the carbon of microbial biomass carbon and the maximum intensity of microbial respiration have been found in the subsurface and horizons two–three years the fire.

Singh et al., (2017) explored influence of wildfires on microbial biomass carbon, microbial respiration, and on representatives of hydrolytic (acid and alkaline phosphatase, β-glucosidase and dehydrogenase) and oxidative enzymes (phenol oxidase; Phenox and peroxidase; Perox) in tropical dry forest. The study results indicate that the role of oxidative enzymes in tropical dry forest is very critical for the ecosystems functioning and concluded that the wildfire resulted in a significant effect on soil microbial properties, and that these changes may exist for short-period, though it may lead to some critical changes in ecosystem functioning. Sharma et al., (2017) also supported the above mentioned observations and added that the forest fire also affect the soil nitrogen mineralizatioin and microbial biomass.

Verma and Jayakumar (2018) studied how repeated fires affect physical and chemical properties of soil in a tropical dry deciduous forest and alter soil fertility and health and found that specifically, NO_3^-N slightly decreased with high fire frequencies but NH_4^-N decreased significantly with increasing fire frequency. Dhiman (2018) studied the effect of fire on bacterial population and their enzymatic activity by comparing the soil samples of burnt and unburnt site. The study indicated Bacillus was dominant genera in both the samples but their abundance was higher 41% in burnt soil than unburnt soil i.e. 26%, while the enzymatic study revealed that bacteria showed 94% cellulase and 65% protease activity in burnt were as 86% cellulase and 43% protease activity in unburnt soil and concluded that fire affects not only the bacterial abundance but also their enzymatic properties.

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Verma et al., (2019) recently studied the recovery of soil properties after fire incident and reported that soil organic carbon was lower in burned plots than unburned plots. Total N, available P, and extractable K were lower 2-years and 5-years after the fire but are higher than unburned plot after 15-yearsa and reported that the response of soil properties varied with years after fire and soil depth. Sannigrahi (2020) assessed the impacts of forest fires on terrestrial ecosystem productivity in India during the period of 2003–2017 using spatiotemporal changes observed from satellite remote sensing data. The data showed that the spatial correlation between the burn indices and net primary productivity were mainly negative (−0.01 to −0.89) for the fire-prone states as compared to the other neighbouring regions. Authors stated that this approach has the potential to quantify the loss of ecosystem productivity due to forest fires.

5.0 Conclusions

Based on the review of existing literature, it is evident that there are certain studies that were carried out in the Indian context vis-à-vis impacts of the forest fires on the ecosystems. Among other studies that are carried out, the major focus of these studies was on the nutrient dynamics and microbial abundance in view of the forest fire incidences. Additionally, the review also showed that the remote sensing and GIS technology based data was majorly used to identify the extent of effect of the forest fire on spatial scale. Also the temporal data was used to identify the incidences of forest fires in a geographic area and its severity has been studied to classify these areas into various zones with respect to the risk of forest fires. Altogether, the literature shows that the forest fires have severe impact on the abiotic as well as biotic factors of the forest ecosystem, which may significantly affect the sustainability of these ecosystems, unless serious efforts are taken by the communities as well as the Governing bodies and departments. In developing countries, apart from natural forest fires, protected forests experience extensive anthropogenic disturbance due to mane induced fire, grazing, extraction of fuel wood and collection of non-wood forest products are also major issues that pose threat to these ecosystems. Moreover, the existing body of knowledge pertaining to the impact of forest fire incidences on various environmental compartments needs to be assessed and for this further focused studies are needed.

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