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Status of Regeneration in Burnt and Unburnt Sites of Chuliban Community Forest, Dhankuta

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Abstract

Several forest fires occur in forests of Nepal causing loss of life and property, that is visible, but the loss of forest's health has always been in shade. It is essential to determine the ecological health of fire-affected forests to save them from degradation. This study has assessed the status of soil properties (soil pH and moisture), regeneration and phytosociological parameters of burnt and unburnt sites in Chuliban Community Forest, Dhankuta. Burnt and unburnt sites were identified by site survey, and simple random sampling was adopted for forest and soil sampling. There was a significant difference between soil pH and moisture values in burnt and unburnt sites (p=0.029 for soil pH and p=0.002 for soil moisture). Both sites dominated by *Pinus roxburghii* showed fair regeneration as a whole, however the burnt site recorded no seedlings of *Pinus roxburghii* while the unburnt site recorded 208 seedlings of it. Soil moisture was positively correlated with number of seedlings (r=0.203, p=0.01) whereas the correlation of soil pH and number of seedlings was moderately positive (r=0.013, p=0.54). Burnt and unburnt sites had Shannon Diversity Index 3.12±0.18 and 0±0, and Simpson's Diversity Index 0.34±0.08 and 1±0 respectively. Though burnt site recorded higher diversity, the tree density was low as a result of chopping of dried and injured trees affected by forest fire. Overall, the results showed that soil properties, regeneration and phytosociological parameters were altered due to frequent forest fires in burnt site, and the site is in need of special attention and restoration programs.

Keywords: *Diversity, forest fire, seedling, soil properties*

Introduction

Forest fires have become an important environmental concern in today's world. It has been accepted as an alarming global environmental process that has been altered due to the influence of the biosphere and atmosphere (Bowman et al., 2009). Forest fires pose serious environmental and ecological challenges, and cause significant damage to human lives and properties (Russell et al., 2007). Due to the impact of uncontrolled burning of forest's undergrowth on natural regeneration, forest fires are considered to be the main cause of forest degradation (Matin et al., 2017).

In Nepal, the pre-monsoon season (March to May) appears to be a time of high temperatures that causes drought and forest fires (Matin et al., 2017). Every year, forest fires threaten to destroy the tropical, subtropical, and temperate forests of the Terai, Siwalik, and mid-hills, especially in the areas where *Shorea robusta* and *Pinus roxburghii* are widely distributed (Matin et al., 2017). The dramatic increase in forest fires over recent years in Nepal has caused significant negative effects on the country's forest ecology and environment, leading to the destruction of natural vegetation and severe harm to human settlements (Parajuli et al., 2020).

Fueled by the drought in dry seasons, several forest fires occur in Nepal's forest causing loss of lives and property (Matin et al., 2017), which often make news headlines, but there are limited studies carried out on the ecological impacts of forest fire in spite of its great significance in Nepal. Therefore, this study focused on ecological impact assessment of forest fire will provide a clear picture about the impacts of forest fire on regeneration and biodiversity of Chuliban Community Forest, and pave a new way for similar research in future.

The degradation of forest and absence/ lack of its natural regeneration has become a serious issue in many forests of the world including Nepal's forests (Shrestha, 2003; Vetaas, 2000). Considering this, the findings of this study assess the relation between number of seedlings and pH and moisture content of soil, and determined the regeneration pattern of burnt and unburnt areas of Chuliban Community Forest. Additionally, this study assesses phytosociological parameters of burnt and unburnt sites.

Materials and Methods

Study Area

The study was carried out in Chuliban Community Forest which lies in Dhankuta municipality, ward no. 7, Dhankuta district in the eastern mid hills of Nepal. Its altitude ranges from 1000 to 1250 m above mean sea level. The climate is warm and temperate. The average annual temperature and rainfall are 19.3ºC and 2603 mm respectively. The forest occupies an area of 14.69 hectares, and is divided into three blocks: Block 1, Block 2 and Block 3 as documented by Divison Forest Office, Dhankuta. 75% of the forest is dominated by *Pinus roxburghii*; Block 1 and Block 2 are composed of *Pinus roxburghii* forest with an area of 5 ha and 3.69 ha respectively whereas Block 3 comprises of mixed forest with an area of 6 ha. The major tree species found are *Pinus roxburghii*, *Schima wallichii, Castonopsis indica,* etc.

Site Identification Survey

In order to understand the circumstances and identify burnt and unburnt sites of the Chuliban Community Forest, a field visit was conducted in October, 2022. Signs of forest fire (burned, dead and dried trees and saplings) were observed. The field visit was accompanied by Mrs. Chandra Kumari Rai, President of Chuliban Community Forest Users Group and officials of Division Forest Office (DFO), Dhankuta. Thus, site identification was carried out by direct observation and expert consultation. GPS was used to record the coordinates of the sites. ArcGIS was used to generate the map of the study area (ArcGIS, 2011).

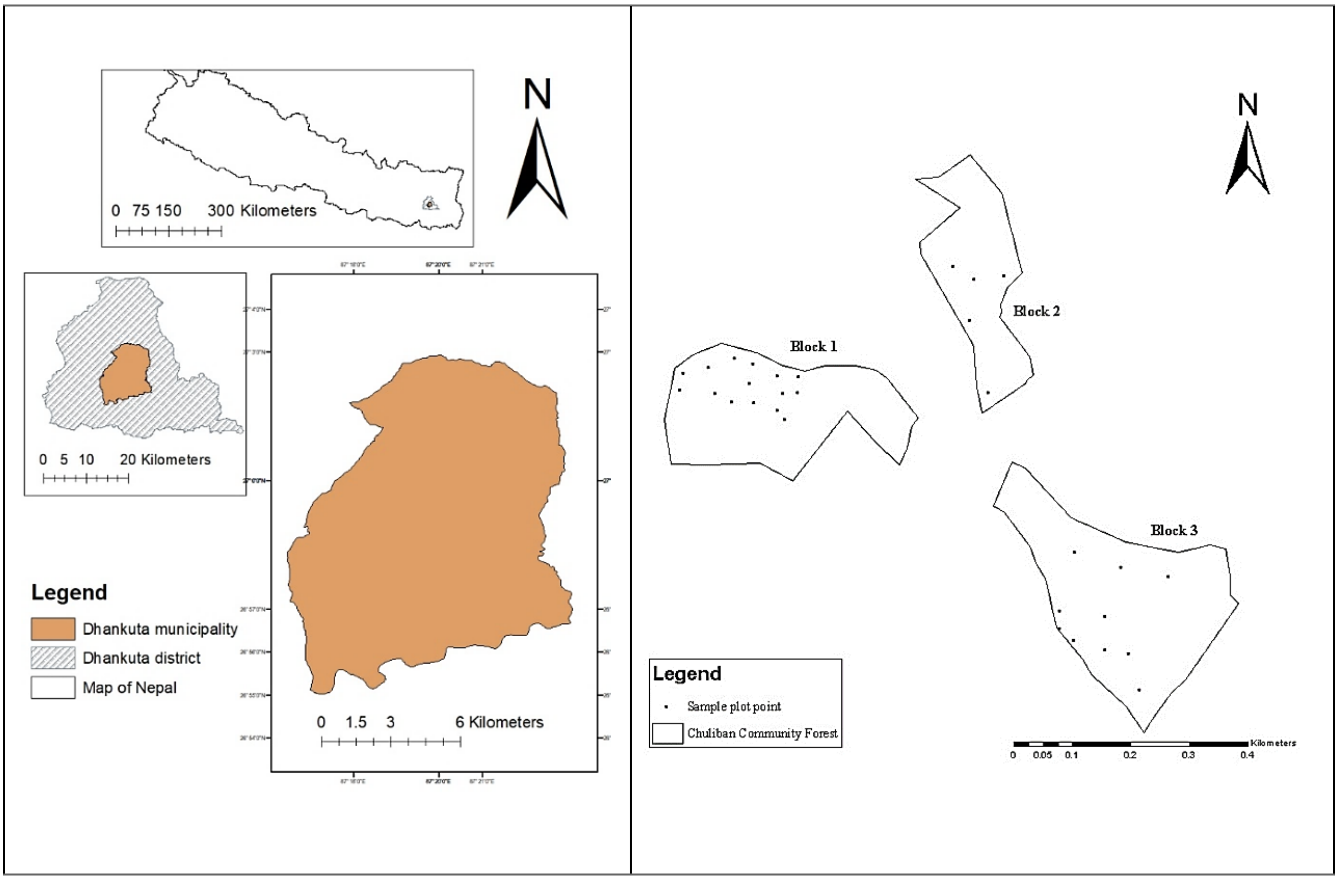

Figure 1: Map of study area (ArcGIS, 2011)

Sampling Techniques

Forest Sampling: Altogether 30 sampling plots each of 10*10 m in the burnt (15 plots) and unburnt sites (15 plots) of the Chuliban Community Forest were laid following simple random sampling technique in October, 2022. Seedlings, saplings and tree species within the sampling plots were counted and recorded. Tree species with DBH equal to or greater than 10 cm were considered as trees whereas DBH less than10 cm were considered as saplings and DBH less than 10 cm with height less than 30 cm were considered as seedlings (Rao et al., 1990).

Data was analyzed by using following formulas:

1. Important Value Index (IVI) = Relative Density + Relative Frequency+ Relative Basal Area (Curtice, 1959).
2. Diversity Indices:
   Shannon Diversity Index (H') = ∑ Pi ln (Pi) (Weaver and Shannon, 1963)
   Where,
   H' = Shannon Diversity Index, Pi = Proportion of the species (Pi = ni/N), N = Total importance value of plants, ni = Importance value of each species
   $Simpson's\ Diversity\ Index\ (D) = \sum \left(\frac{ni}{N}\right)^2$ (Simpson, 1949)
   Where,
   D= Simpson's Diversity Index, N= Total importance value of plants, ni= Importance value of each species
3. Regeneration Status (Shankar, 2001)
   - Good regeneration (GR): If number of seedlings > saplings > adults regeneration,
   - Fair regeneration (FR): If number of seedlings > or < saplings < adults,
   - Poor regeneration (PR): If the species occupy only at sapling life forms there are no seedlings (Number of saplings may be more, less or equal that of adults),
   - No regeneration (NR): If individuals of species are present only in adult form
   - New regeneration or not abundant (NA): If individuals of species have no adults only occupy in seedlings or saplings.

Soil sampling and laboratory analysis: Soil samples were collected from all the 30 sampling plots laid in burnt and unburnt sites. In each sampling plot, a composite soil sample was formed by mixing 4 soil samples collected each from 4 corners and one sample collected from the center of the sampling plot. The soil samples were collected from 15 cm depth. Altogether 30 soil samples were collected, air dried in shade, and stored in plastic bags until laboratory analysis (Kalu et al., 2015).

Soil pH was determined using 1:5 soil to distilled water ratio and then analyzed by using a digital pH meter in the Laboratory of GoldenGate International College, Kathmandu.

Soil moisture was determined by calculating the difference between the soil sample and the oven-dried soil sample, and calculation was done by using the following formula (Shukla et al., 2014):

$$Soil\ moisture\ (\%) = \frac{Weight\ of\ wet\ soil\ tare - Weight\ of\ dry\ soil\ tare}{Weight\ of\ soil\ tare - tare}$$

Data Analysis

Standard Deviation (SD) was calculated for phytosociological parameters. To analyze the variation between soil pH and soil moisture in burnt and unburnt sites, Analysis of Variance (ANOVA) was performed and Whisker box-plot was used. Scatter diagrams and Karl Pearson correlation were applied to analyze the relationship between the distribution of seedlings and parameters of the soil. Microsoft Excel (Microsoft Corporation, 2018) was used for all the statistical analyses.

Results and Discussion

Soil pH and soil moisture in burnt and unburnt site

The soil pH and moisture values were found to be significantly different in burnt and unburnt sites with ($F=5.28$, $p=0.029$) and ($F=10.83$, $p=0.002$) respectively.

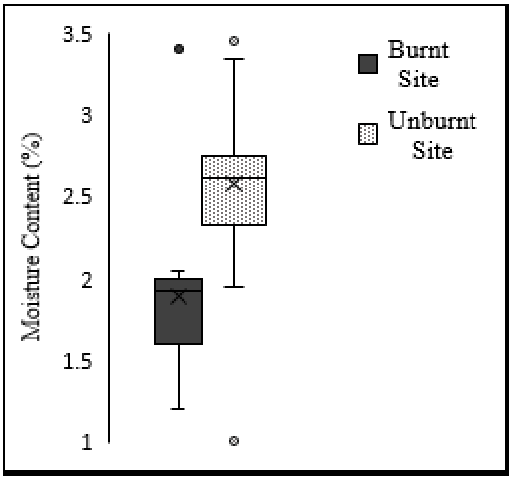

Figure 1: Box-plot showing soil pH in burnt and unburnt sites

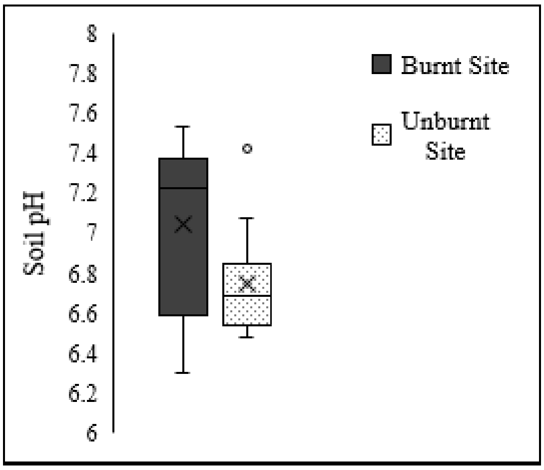

Figure 2: Box-plot showing soil moisture content in burnt and unburnt sites

Higher values of soil pH in the burnt site than unburnt site may be due to the presence of ash after burning (Molina et al., 2007). Study on soil pH conducted by Verma and Jayakumar (2012) had also found similar results in their study on impacts of forest fire on soil properties. The pH value of ash is higher, and the accumulation of ash in soil after forest fires resulted in the increase of soil pH (Schafer & Mack, 2010). According to Litton and Santelices (2003), burning destroys vegetation cover and causes more evaporation in the burnt site as a result of increase in temperature during hot seasons. This results in drier soil i.e. low moisture content in the burnt soil as compared to the unburnt soil. The lower value of soil moisture content in the burnt site in comparison to the unburnt site might be due to drying of soil as a result of forest fires in the burnt site. Destruction of vegetation cover and litter from the ground might have exposed the soil surface and increased the rate of evaporation resulting in comparatively lower moisture content in the plots of burnt site.

Status of regeneration in burnt and unburnt sites

In this study, in both burnt and unburnt sites, the number of seedlings was greater than the number of saplings, and the number of saplings was less than the number of trees. This distribution of population of trees, seedlings and saplings in burnt and unburnt sites indicated that the regeneration status of both sites was fair (Shankar, 2001).

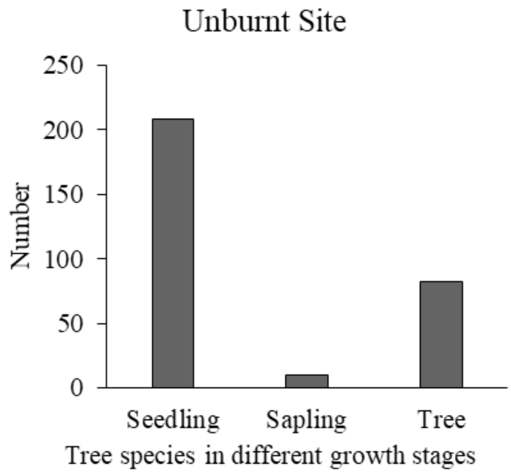

Figure 3: Bar diagram showing tree species in unburnt site

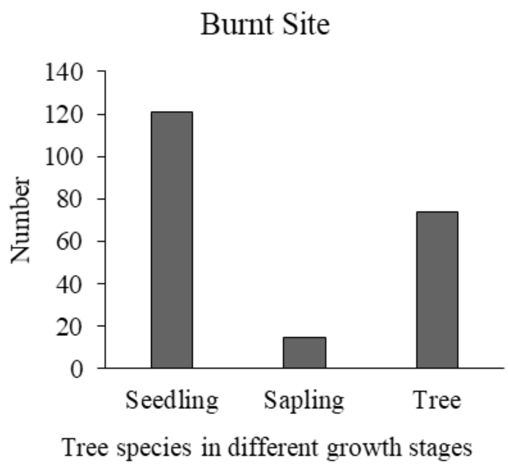

Figure 4: Bar diagram showing tree species in burnt site

The study conducted by Nauni (2008) in *Pinus roxburghii* forests in Himanchal Pradesh, India found the greater density of seedlings of trees in the occasional fire affected areas than the control areas, and the density of sapling was found more for control areas. In contrast to the study, seedlings were less in the burnt site of this study area. As mentioned by DFO, burnt sites had a history of severe forest fires every year, and it was not occasional. The frequent fires might have contributed to the lesser number of seedlings in the burnt site. Although the latest fire in the site in 2021 had killed many seedlings, the CFUG of the forest had planted useful tree species like *Schima wallichii, Cinnamomum tamala*, *Zanthoxylum piperitum*, *Phyllanthus emblica*, etc. in burnt site at the time of the forest sampling. Thus, seedlings were planted more in burnt sites (less natural regenerated) than in unburnt sites (naturally regenerated seedlings).

Species wise regeneration in burnt and unburnt sites

The burnt site was composed of mixed tree species dominated by *Pinus roxburghii*. Out of 16 tree species found in the burnt site, only 5 tree species had all three stages: seedlings, saplings and tree. No seedlings of *Pinus roxburghii* were recorded in the burnt site in spite of its dominance.

The unburnt site was composed of *Pinus roxburghii* forest with no other species of trees present in any of the three stages: seedlings, saplings and trees. Total 208 seedlings of *Pinus roxburghii* were recorded at the site.

Pinus roxburghii being the dominant species in the burnt site recorded zero seedlings in the site. The regeneration status of *Pinus roxburghii* in the burnt site was poor whereas in the unburnt site, it showed fair regeneration with 208 seedlings of it alone. Studies have shown that frequent fire incidences affect regeneration of *Pinus roxburghii*. *Pinus roxburghii* in spite of having fire-resistance capacity can be negatively affected by different intensities of forest fire (Aryal et al., 2016). A study conducted by Sharma and Ahmed (2014) on regeneration of *Pinus roxburghii* in Ponda watershed of Rajouri Forest Range, Jammu and Kashmir, India found that the regeneration of *Pinus roxburghii* in the areas with negligible fire incidences was good whereas it was poor in the areas prone to fire and grazing. In the burnt site of this study area, frequent forest fire incidences with different intensities might be the reason behind the burning of seedlings and zero seedlings count. The burnt site experienced forest fires every year due to human negligence and misuse of fire. The latest fire that occurred in the site was in 2021, and the site had a history of frequent fires

Table 1: Regeneration status of tree species in burnt site

Local Name	Scientific Name	Seedlings number	Saplings number	Trees number	Regeneration Status
Dalle Katus	*Castanopsis indica*	13	4	10	Fair
Chilaune	*Schima wallichii*	37	1	2	Fair
Salla	*Pinus roxburghii*	0	1	41	Poor
Kag Bhalayo	*Rhussuccedanea*	0	1	1	Poor
Bach	*Anogeissus latifolia*	16	1	3	Fair
Sach	*Terminalia tomentosa*	8	2	5	Fair
Mauwa	*Engelhardia spicata*	18	2	7	Fair
Khaneu	*Ficus semicordata*	0	1	2	Poor
Pipri rukh	*Ficus amplissima*	0	1	1	Poor
Jamuna	*Syzygium jambos*	0	1	1	Poor
Angeri	*Lyonia ovalifolia*	0	1	1	Poor
Musure Kattus	*Castanopsis tribuloides*	11	0	0	New
Timur	*Zanthoxylum piperitum*	3	0	0	New
Tes patta	*Cinnamomum tamala*	2	0	0	New
Aamala	*Phyllanthus emblica*	8	0	0	New
Katmero	*Litsea polyantha*	5	0	0	New

Table 2: Regeneration status of tree species in unburnt site

Local Name	Scientific Name	Seedlings number	Saplings number	Trees number	Regeneration Status
Salla	*Pinus roxburghii*	208	10	82	Fair

in previous years. This might have affected the regeneration of *Pinus roxburghii*, and resulted in low number of saplings and zero seedlings of it in spite of having dominance in the burnt site.

Different species of trees like *Schima wallichii* were planted in the burnt site by CFUG of the community forest in order to regenerate the forest after frequent forest fires. Out of 121 seedlings recorded in the burnt site, 42 seedlings were found to be naturally regenerated while 79 seedlings were planted and not naturally regenerated. Majority of trees and saplings recorded in the burnt site were dry, injured and had signs of burning in their stems. This indicated that forest fires had negatively affected the trees in all stages: seedlings, saplings and trees, and the regeneration of many tree species in the burnt sites.

Relation between soil pH and soil moisture with number of seedlings

The number of seedlings was statistically insignificant ($r=0.013$, $p=0.54$) with pH values of soil samples but statistically significant ($r=0.203$, $p=0.01$) with soil moisture.

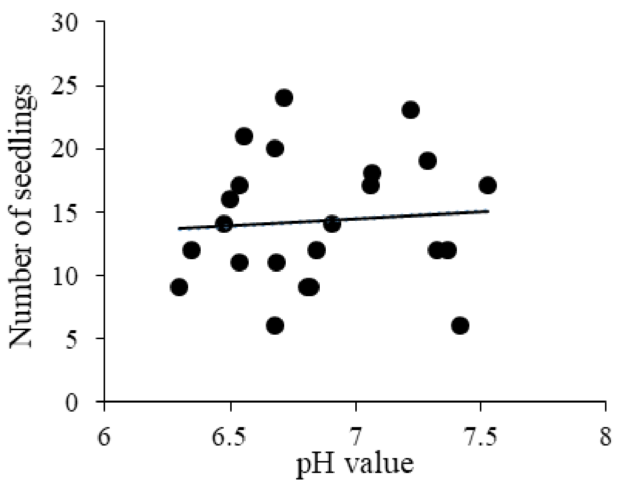

Figure 5: Scatter plot diagram showing relationship between soil pH and number of seedlings

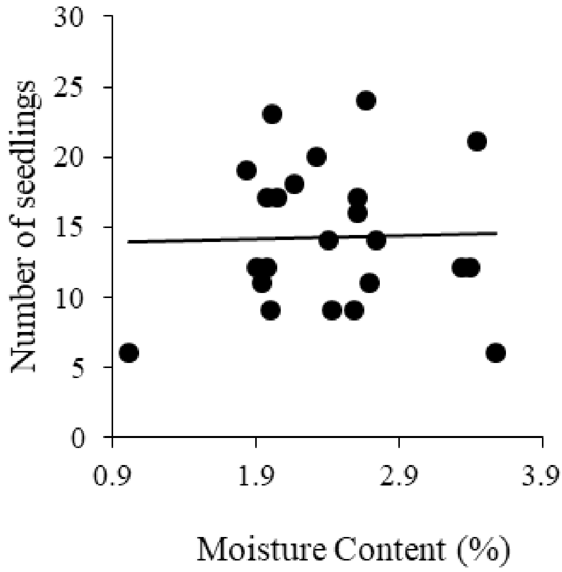

Figure 6: Scatter plot diagram showing relationship between soil moisture and number of seedlings

Soil moisture content is taken as an important factor in regeneration. As the promotion of photosynthesis by the presence of the high levels of moisture affects all the physiological processes of species (Bhattarai & Vetaas, 2003), it favours the growth of a large number of seedlings. In the study conducted by Ghimire and Lekhak (2007) on regeneration, the sampling plots with high moisture content had comparatively higher number of seedlings than other plots with low moisture content. Similar to the study, the sampling plots of the unburnt site of this study area recorded the highest number of seedlings as those plots had comparatively higher moisture content than the plots in the burnt site. Frequent forest fires in the burnt site might have burned the vegetation cover and dried the soil increasing the soil exposure to the sun i.e. evaporation rate, and as a result, the moisture content of many sampling plots of the burnt site was low. The low moisture content in the burnt sites might have affected the germination of seedlings and its development. This might have resulted in a lower number of seedlings in the burnt site as compared to the unburnt site.

Table 3: Phytosociological parameters in burnt and unburnt sites

Phytosociological Parameter	Burnt Site (±SD)	Unburnt Site (±SD)
Shannon Diversity Index	3.12±0.18	0
Species Richness	16	1
Simpson's Diversity Index	0.34±0.08	1±0
Tree Density (number/hectare)	493	547

Phytosociological parameters in the burnt and unburnt sites

Forest fire has a significant impact on how the ecosystem and plant variety are shaped (Joern & Laws, 2013). The composition of forest in burnt and unburnt sites of this study area was different. There was variation in the diversity and evenness index values in the sites. The unburnt site had only one tree species i.e. *Pinus roxburghii* whereas the burnt site recorded 16 tree species. In contrast to the study conducted by Bhatta et al. (2022) which reported the lower value of Shannon Diversity Index in burnt site than unburnt site, the study calculated the higher value of Shannon Diversity Index in burnt site than unburnt site. Although burnt site recorded the highest value Shannon Diversity Index, the tree density of the site was lower than the unburnt site. This indicated that the burnt site had less number of trees as compared to the unburnt site. Forest fire had injured, burned and dried many trees of Chuliban Community Forest. The severely fire-affected trees were fell down by the CFUG of the community forest. Thus, felling of those trees in the burnt site might have reduced the tree density of the site.

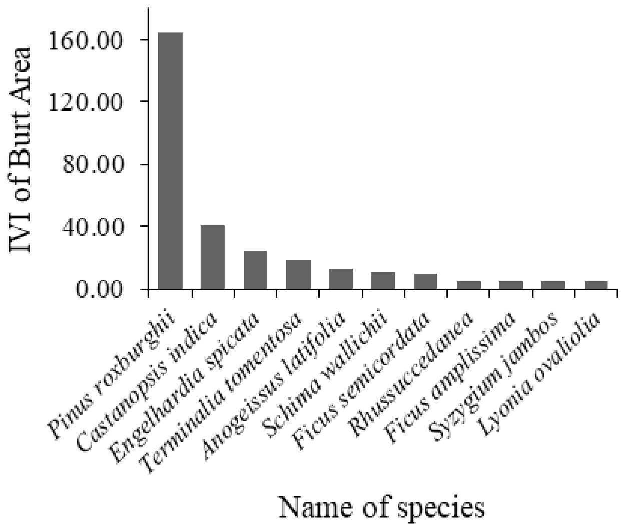

Figure 8: Bar diagram showing IVI of tree species in burnt site

Pinus roxburghii had the highest IVI values in both burnt and unburnt sites. Other species in the burnt site had significantly lower IVI values than *Pinus roxburghii*. Literature suggests that some plants are fire-adaptive (Narendran, 2001). In spite of frequent forest fires, fire adaptive plants dominated the forest community and slowly replaced other species as reported in the study conducted by Narendran (2001) in Madhumalai Sanctuary in India. *Pinus roxburghii* is a fire adaptive plant (Hoecker, 2021). The highest IVI value of *Pinus roxburghii* in the burnt site (Figure 8) might be due to its fire adaptive capacity than other species present in the site. Although the regeneration status of *Pinus roxburghii* in the burnt site was found poor during this study, its IVI value suggests that it had adapted in the history of forest fires more than other tree species. Low IVI values of some tree species recorded in the burnt site might be due to the lack of fire adaptive capacity and poor regeneration. The IVI value of *Pinus roxburghii* was 300 in the unburnt site due to the absence of other tree species in the site.

Conclusion

There was change in soil pH and moisture due to forest fire in the burnt site of Chuliban Community Forest, Dhankuta. The burning of forest increased soil pH and decreased soil moisture. There was a significant effect of moisture content on the number of seedlings in burnt and unburnt sites. The number of seedlings in the burnt site was found to be less as soil moisture content reduced due to burning and drying of soil. However, there was no relationship between soil pH and number of seedlings.

The overall regeneration status of the burnt and unburnt site was fair. However, more seedlings were planted by CFUG after fire in 2021 as a restoration strategy in burnt sites. In contrast, there was more natural regeneration in the unburnt site. In spite of the highest IVI value of *Pinus roxburghii* in both burnt and unburnt sites, there were no seedlings of it in the burnt site. This indicated poor regeneration of *Pinus roxburghii* as a result of frequent forest fires in the burnt site.

CFUG fell down severely burnt trees in the burnt site affecting other trees. This reduced tree density in the burnt site despite its higher diversity values than in the unburnt site. Likewise, the seedlings recorded in the burnt site were planted and not naturally regenerated. This suggested that frequent forest fires in the burnt site had adversely affected the soil parameters, forest composition and regeneration while the unburnt site recorded no such significant variation. Hence, the burnt site of the study area was found to be adversely affected by frequent forest fires, and there was a need for active programs to combat this loss.

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