PHYSICAL PROGRESS REPORT OF SCHEME

ESTIMATION OF ECONOMIC LOSSES IN REAL TERM PER HECTARE BASIS DUE TO FOREST FIRE IN UTTARAKHAND AND MADHYA PRADESH

(as on 31-3-2022)

Submitted by
Indian Council of Forestry Research and Education, Dehradun.

(Progress Report of the scheme "Estimation of economic losses in real term per hectare basis due to Forest Fire in Uttarakhand and Madhya Pradesh" funded by National Authority CAMPA)

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1. Introduction:

Based on the recommendations of the Parliamentary Standing Committee on Science & Technology, Environment & Forests to Uttarakhand (June 2016) Ministry of Environment, Forest & Climate Change (MoEF&CC), Govt. of India (GoI) vide letter no. F.No.7-2/2016-FPD dated 11th March, 2017 requested Indian Council of Forestry Research and Education (ICFRE), Dehradun to submit a proposal for undertaking the study on Estimation of economic losses in real term per hectare basis due to forest fire. Accordingly, ICFRE proposed a pilot study entitled "Estimation of economic losses in real term per hectare basis due to Forest Fire in Uttarakhand and Madhya Pradesh" for funding from National Authority CAMPA towards addressing the requirements **of estimation of total economic loss in real terms of monetary value on per hectare basis for the study states of Uttarakhand and Madhya Pradesh.** Through the study a framework / approach /methods /tools and techniques will be provided to estimate tangible and intangible losses due to forest fire on per hectare basis which may be used in other similar situations. **The pilot study being multidisciplinary in nature will be conducted by ICFRE through its institutes at Dehradun (Forest Research Institute) and Jabalpur (Tropical Forest Research Institute) in association with partner institutions mentioned below: -**

i. Forest Survey of India (FSI), Dehradun
ii. Wild life Institute (WII), Dehradun
iii. National Institute of Hydrology (NIH)
iv. G.B Pant National Institute of Himalayan Environment & Sustainable Development, Kosi-Katarmal, Almora, Uttarakhand (GBPIHESD)

The total outlay of scheme is Rs 378.840 lakhs. The scheme was sanctioned through Order No. 13-35/2019-CAMPA, dated 28th January, 2020 of National Authority Campa, MoEF& CC, New Delhi for recurring expenditure and vide Order No. 13-35/2019-CAMPA, dated 28th January, 2020 of National Authority Campa, MoEF&CC, New Delhi for Non-Recurring expenditure. As per approved scheme 50% of the funds (i.e. Rs. 18,942,000.00) were received vide sanction order No. 13-35/2019-NA dt. 28-01-2020. The scheme is for 24 months. As per the proposal, the date of initiation of the project will be from the date of finalization of polygons for the study by FSI. The scheme was extended for 06 months by MoEF&CC through letter No. 13-35/2019-NA dt. 22-11-2021.

2. Objectives of the Scheme are as under:

a) To quantify the forest loss in terms of total economic value i.e., monetary value on per hectare basis for the forest types in the States of Uttarakhand and Madhya Pradesh.

b) Burnt area assessment and severity classification due to forest fire for the respective states.

c) Economic loss assessment of terrestrial flora due to forest fire on per hectare basis for the respective states

d) Economic loss assessment of faunal diversity due to forest fire on per hectare basis for the respective states

e) Economic loss assessment of hydrological changes due to forest fire on per hectare basis for the respective states

f) Economic loss assessment of provisioning services and cultural value of forest produce loss due to forest fire on per hectare basis for specific forest types and extrapolated for the respective states.

3. Physical Progress of Scheme

3a: Coordination review meeting for execution of the project

i. Inception meeting of all the project partners (Forest Survey of India-Dehradun, Wild Life Institute-Dehradun, National Institute of Hydrology-Roorkee, GBPNIHESD Almora, ICFRE Dehradun, Forest Research Institute Dehradun and Tropical Forest Research Institute- Jabalpur) and Nodal Officers of State Forest Departments (Uttarakhand & Madhya Pradesh) was organised at ICFRE, Head Quarter, Dehradun on January 22, 2020 to discuss in detail the methodology and structure of the project for the smooth execution of it. It was discussed at length and all project partners agreed to conduct the study on the burnt polygons of forest areas burnt during fire season 2019 in different forest types as per the parameters identified in the approved project. Recruitment of staff was initiated by partners. Literature survey was under taken and consultation with experts was held in social distancing mode to decide methodology. Tender process for purchases was initiated by all the project partners in their respective institutes as per the project schedule.

ii. The 2nd Coordination meeting was held on 12th May 2020 after unlock 1.0 of COVID-19 to expedite the process of finalization of site of burnt area for the study. As discussed in 1st and 2nd coordination meeting, FSI submitted the Interim Report on findings of Burnt Scar Assessment of Uttarakhand on 9 June 2020. The minimum mappable unit for the study was 3 hectares. The burnt scars were classified into Severely Burnt, Moderately Burnt and Low Burnt severity classes based on the reflectance of a pixel of the satellite data. Based on the analysis of satellite data, a total of 4,897 fire polygons of different sizes with minimum area of 3 ha were identified in Uttarakhand. The 3rd coordination meeting was held on 29 June 2020. The received report on burnt scar polygons as shape files for fire season 2019 and also protocols to open the shape files was circulated amongst the partners of the project. The burnt scar polygon having minimum area of 3 hectare with following attributes have been provided in shape file, Format (.shp).

a) Polygon ID (ID. No)
b) Severity classes burnt-severe, moderate and low.
c) Burnt scar in hectares
d) Forest range information-boundaries of 18 relevant forest ranges in Uttarakhand
e) Forest cover/density classes from dense, moderately dense, open, scrub
f) Forest type group-1-total 9 forest types groups in Uttarakhand
g) Altitude zones ranging from 0-900 meters to above 3600 metres

h) Slope classes ranging from 0-3° to above 36°, Aspect classes-North, South, East, West

iii. In fourth coordination meeting held through video-conferencing (VC) on 24 September 2020, for reviewing progress and to discuss amongst project partners to decide a coherent methodology to work on the selected Burnt and Unburnt Polygons of Uttarakahnd and Madhya Pradesh required to conduct further studies as per the requirement of the approved project it was found that that based on the forest fire year 2019, details of 4897 polygons of Uttarakhand was received from Forest Survey of India, Dehradun. Out of these 4897 polygons identified, tentatively 164 selected Burnt Scar Polygons with minimum area of 3 ha belonging to different forest types, slope, aspect, severity of burnt areas etc were short listed. However, FSI Dehradun requested SFD Uttarakhand to validate 4897 polygons along with 164 shortlisted polygons. Uttarakahnd State Forest Department and FSI validated 289 polygons of Uttarakhand. The statistical expert from ICFRE identified 42 forest fire polygons (moderately burnt =32, low burnt =10) for the study in Uttarakhand which stands communicated to all the project partners. Also, the permission received from PCCF & HoFF Uttarakhand has also been communicated to all the PIs of the Project.

iv. FSI submitted information regarding Burnt Scar Polygons' for State of Madhya Pradesh to ICFRE. Total 17288 fire polygons of different sizes with minimum area of 3 ha have been listed in Madhya Pradesh. The burnt scar polygons belong to Severely Burnt, Moderately Burnt and Low Burnt classes. Out of 17288 fire polygons 178 polygons were finalized as per statistical requirements and keeping in view different parameters like forest types, slope, aspect etc. Madhya Pradesh State Forest Department and FSI validated 228 polygons. The statistical expert from ICFRE identified total 49 fire affected polygons (severe burnt = 5, moderately burnt =24, low burnt =20) for M.P. These details of polygons have been communicated to all the partners. Also, the permission received from PCCF & HoFF during 2nd week of December, 2020, has been forward to all the PIs of the project.

v. In fifth coordination meeting held through video conferencing (VC) on 21 May 2021, to review the progress so far made by all the Partner Institutes for last financial year ending 31st March, 2021 and submission of Utilization Certificates and cumulative physical progress reports (along with photographs and data) by all the Partner Institutes for last financial year i.e., 01st April, 2020 to 31st March, 2021. All project partners presented their work. The progress made by all the partners for duration 1/04/2020 to 31/03.2021 has been submitted to MoEF&CC. The progress made by all project partners for duration 01/04/2021 to 30/09/2021 is detailed below:

vi. In 6th (held on 24th September 2021) and 7th (held on 30th November 2021) coordination meeting it was decided to completed the remaining polygons studies by all the partner institutes.

3b. Progress made by Partner institutes:

❖ G.B. Pant National Institute of Himalayan Environment Institute (GBPNIHEI)

Objective: Economic loss assessment of provisioning services and cultural value of forest produce loss due to forest fire on per hectare basis for specific forest types and extrapolated for the respective states.

1. **Important steps for Estimation of economic losses were:**
   a) **Estimation of Loss of Timber Wood:** To calculate the timber volume of the burnt logs of each of the tree species due to forest fire (FF), length of the log (m) and diameter (cm) at three places (middle and at both ends of the log) were measured, and then calculated by quarter girth formula (cubic meter), and to determine the monetary value of the above fallen log of Pine its wood volume was multiplied by the timber rates (mean value of Grade III and Grade IV timber of Pine trees) as per the Forest Department. To determine the actual loss of timber wood the wood volume of unburnt trees was determined using species-specific regression equations for the trees of same girth and by deducting the wood volume of burnt and unburnt trees and then the monetary value of timber for this difference was determined.
   b) **Estimation of Loss of Fuel Wood:** Tree stumps, snags, branches, and twigs not having timber value ultimately end up as fuelwood either collected by the local people or by the forest Deptt. to be sold in wood depot. Such wood is sold by weight. The weight of branches/twigs was estimated using allometric equations (mean for branch and twigs) for each of the tree species separately. The rate of fuelwood has been computed based on stakeholders' consultations in Uttarakhand and Madhya Pradesh (i.e., Rs. 5.5/kg and Rs. 4.7/kg).
   c) **Estimation of Loss of Fodder:** Herb biomass was estimated in post rainy season by total harvest in 1x1m randomly placed quadrates (30 such quadrates in each polygon separately for both burnt and unburnt sites) and expressed in dry weight (assuming 25% of fresh weight; Misra, 1968). To estimate the monetary loss to fodder the rate of fodder determined during stakeholders' consultation was used (i.e., mean value in Rs. 5/kg dry weight).
   d) **Estimation of Loss of MAPs:** To estimate the loss of medicinal and aromatic plants (MAPs) in each polygon (both burnt and adjacent unburnt) thirty random quadrats of 1x1m (for herbs), twenty quadrats of 5x5 m (for shrubs) and ten quadrats of 10x10 m (for trees) were laid down to estimate density (ind./ha) of the MAPs and quantity (weight/ind.) of the useful and tradable plant parts (e.g., fruit, seed, leaves, root, flower or whole plant). The monetary value of MAPs was estimated by multiplying their density recorded during phyto-sociological survey (ind/ha), biomass of economic/tradable/useful plant part of the respective species (gm/plant) and the market rate/ Forest Department rates/ rates obtained during stakeholders' consultation meeting (Rs. /Kg.) of the respective species.

e) **Estimation of Loss of Wild Edibles:** The monetary value of wild edibles was estimated by multiplying density (ind./ha), yield of wild edibles per plant species (Kg/tree) and the market value (Rs. /Kg) of the wild edibles (eaten raw, cooked as vegetables, making pickle, juice etc.) using Forest Department/Forest Development Corporation rates and rates obtained during stakeholders' consultation, Bhesaj Sangh, Goraya and Ved (2017) etc. of the respective species.

f) **Estimation of Loss of Leaf Litter:** Leaf litter fall values are based on secondary data for these forests reported by Singh & Singh (1992) for U.K. and Pande et al. (2005) for M.P. The monetary value of leaf litter (used by the local people for animal bedding, FYM preparation, etc.) is based on stakeholder's consultations (i.e., Rs. 1/kg).

g) **Estimation of Loss of Tree Regeneration:** The number of saplings and seedlings were counted in each of the burnt polygons and adjacent unburnt forests by laying 10 quadrates each (10 x 10 m size) in post rainy season. Following Forest Deptt. rates (Rs. 25/- seedling/sapling we have estimated the loss to regeneration due to FF.

h) **Estimation of Loss of Stump/Stumpage:** For estimation of wood in the tree stumps left standing after FF (now only has fuelwood value to be used by local people) ten quadrats of 10m x 10m size were laid in the burnt polygons, the number of stumps were counted and their height and diameter were taken and weight of wood was determined using allometric equations published for each species. The monetary value of fuelwood was thus estimated by multiplying the wood weight with Rs. 5/kg.

i) **Estimation of Loss of Pine Resin:** To estimate the loss of resin in each polygon due to burning of Pine trees, the number of Pine trees fallen down (represented by burnt and charred logs), standing dead tree and stumps of Pine trees present in burnt polygons were counted and their length and girth was taken. Now, the number of Pine trees with > 40 cm girth were considered resin producing (4.35 Kg resin/tree/year) as per the norms of Forest Deptt. (2020-21). Thus, total resin production was estimated by multiplying the number of trees (> 40 cm girth with 4.35 kg resin production per tree and the rate of resin @ Rs. 45.7/kg) for the forests of Uttarakhand.

j) **Estimation of Loss of Tendu Leaves:** For estimation of loss of tendu leaves 10 quadrats of 10m x 10m size were laid in them number of saplings / trees (which produce marketable tendu leaves) were counted. The market rate of tendu patta (sold in bundles of 100 leaves each) as per Forest Department rates is Rs. 7.59/bundle. Thus, production of leaves from these trees (@3 bundles/tree) was taken as a loss due to forest fire. Now, taking that tree density (ind./ha) in unburnt and burnt polygons the difference in the number of trees we considered that these trees were burnt causing the loss of the production of tendu leaves.

k) **Estimation of Loss of Bamboo:** As per the ISFR, 2019 the forest area of bamboo in the reserve forest of M.P. is 20867 Km^2, with an estimated standing green weight of bamboo at 14088000 t (i.e., 6.75 t/ha). Gangopadhyay (2003) based on other studies has estimated its commercial production @ 1.23 t/ha and its market rates Rs. 6800/t which was used to estimate the loss to bamboo resources. In the burnt polygons of Uttarakhand bamboo was not found.

l) **Stakeholder's consultation for valuation of forest goods:** Stakeholders' consultation in the form of semi-structured/ open ended questionnaire surveys, focused group discussions, interactive meetings with forest Deptt. Officials, field staff and local people were held to collecting information on monetary loss due to forest fire on various forest resources in the vicinity of the selected FF polygons (35 consultative meetings in Uttarakhand and 31 in M.P.).

2. Result and discussion :

The 2016 summer (April-early June) witnessed a major forest fire (FF) in Uttarakhand (2069 FF incidents affecting 4423 ha forests), with an estimated loss of Rs. 4.62 million as per the Forest Department, Govt. of Uttarakhand. However, several other reports in media estimated this loss upto Rs. 50 billion. Due this FF, 6 people died, 31 people injured and 7 animals died (http://forest.uk.gov.in/contents/view). In the aftermath of this calamity the Parliamentary Standing Committee (PSC) on Science & Technology, Environment & Forests, Govt. of India visited Uttarakhand and H.P. in June 2016, and held consultations with a wide-range of stakeholders to discuss the reasons of FF, its control measures and assess the monetary loss due to FF. The PSC realized that hitherto the monetary loss values estimated by the Forest Department are too low, and in the absence of proper methodology and baseline data it was difficult to assess the actual monetary loss and compensation due to FF. Therefore, following the recommendations of PSC this pilot project was developed after intensive rounds of discussion among the partner organization and study funded by CAMPA, MoEF&CC, Govt. of India was undertaken with the major mandate of "Estimation of economic losses in real terms per hectare basis due to forest fire in Uttarakhand and Madhya Pradesh", involving leading organizations of the region viz., GBPNIHE, Almora; WII, FSI, FRI, and ICFRE, Dehradun and NIH, Roorkee for two years (w.e.f. January 2020). In this study GBPNIHE was given the components on quantification and valuation of loss of ecosystem services such as timber, fuelwood, fodder, wild edibles, NTFPs, medicinal and aromatic plants (MAPs), forest regeneration (seedlings+saplings), forest floor litter etc. due to forest fire.

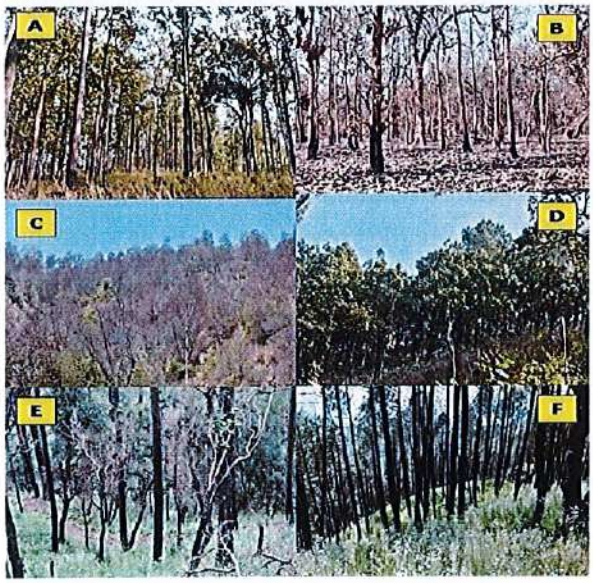


Fig. 1 Major Forest types in Uttarakhand: (A) Sal dominated forest; (B) Teak dominated burnt forest; (C) Teak dominated forest; (D) Sal Forest; (E) Mixed Forest burnt; (F) Pine dominated forest

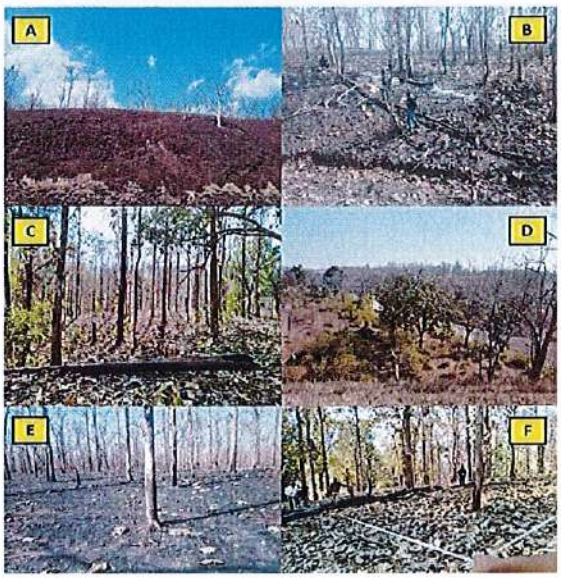


Fig 2 Major Forest types in Madhya Pradesh: (A) Khair Forest; (B) Measuring fallen log in Teak Forest; (C) Sal Forest; (D) Mixed broadleaf forest; (E) Sal Forest burnt; (F) Sampling in Teak Forest

To initiate this study ICFRE, Dehradun organized a few rounds of meetings (physical / virtual modes) at MoEF&CC, New Delhi / FRI, Dehradun, wherein the selection criteria of the study sites in Uttarakhand (U.K.) and Madhya Pradesh (M.P.) were determined so that the sites selected represent the typical physiographic (altitude, slope, aspect), vegetation (forest types and plant composition) and forest fire intensity (low, medium and severe) in Uttarakhand and Madhya Pradesh Forest Survey of India, Dehradun validated the FF affected sites of 2019 and provided a list of 289 FF affected polygons in U.K. and 228 FF affected polygons in M.P. The ICFRE, Dehradun further categorized the FF affected polygons using several criteria and provided a list of 42 FF polygons (out of 289 polygons of U.K.) and 49 FF polygons (out of 228 polygons of M.P.) for intensive study. The area of studied polygons ranged from 4.23 - 883.12 ha (U.K.) and 3.607 - 3108.53 ha (M.P) and altitudes from 230 - 2488 m asl in U.K. and 252 - 930 m asl in M.P. In the testing time of COVID-19 pandemic field work was conducted following SoP during 2020-21.

GBPNIHE visited and studied 39 polygons in Uttarakhand and 47 polygons in M.P. during pre-rainy season and 27 polygons in U.K. and 30 polygons in M.P. during post-rainy season in 2020-21. A total of 2860 study plots for trees, 5720 for shrubs and 8580 for herbs were laid out in burnt and unburnt sites of these identified polygons in the forests of Uttarakhand and M.P. To assess the monetary value of loss due to FF (fodder, fuel wood, NTFPs, MAPs, wild edibles, litterfall, and forest regeneration etc.) 35 meetings in Uttarakhand and 31 meetings in M.P. were organized among the villages nearby these studied polygons that involved 323 forest officials/field staff and 817 local people including women. To estimate the monetary loss before the existing rates of Forest Deptt. of both Uttarakhand and M.P. in addition to the loss revealed by the local people were considered.

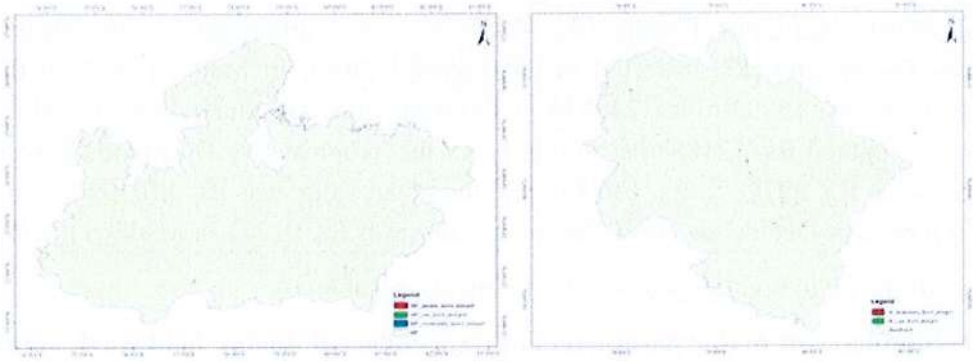


Fig 3 Map showing study area polygons in Uttarakhand (left) and Madhya Pradesh (right)

This study across the identified polygons revealed that in Uttarakhand, the timber loss due to FF ranged from 1.9-19.2 m^3/ha (mean= 5.86 m^3/ha) with an estimated mean price of Rs. 142994/ha as per the rates of Forest Deptt. Similarly, the mean value of loss of fuelwood was computed Rs. 21220/ha and ground fodder loss Rs. 2154/ha. in Uttarakhand and in M.P. the timber loss due to FF was computed ranging from 2.51-12.76 m^3/ha (mean= 6.51 m^3/ha) with an estimated market price of Rs. 96560/ha. Similarly, the fuelwood loss was computed Rs. 2005/ha and ground fodder loss Rs. 1542/ha. Mean loss of forest regeneration (seedlings and saplings burnt due to FF) was computed Rs. 10900/ha for Uttarakhand and Rs. 14579/ha for

M.P. Similarly, mean loss of MAPs was computed Rs. 1980/ha in Uttarakhand and Rs. 2655/ ha in M.P., and the loss of wild edibles in Uttarakhand Rs. 9091/ ha and Rs. 2856/ha in M.P. Forests of Uttarakhand were rich in flora, particularly MAPs (58 spp.) as compared to M.P. (41 spp.). However, in terms of tree species the forests of M.P. were richer (50 spp.) than the forests of Uttarakhand (63 spp.) but the number of shrub species were greater in Uttarakhand (45 spp.) than the forests of M.P. (31 spp.). The total loss (including all forest products) due to FF was computed Rs. 130387/ ha (Rs. 9696-352752/ha) in Uttarakhand and Rs. 114327 (Rs. 15892- 249614/ha) in the studied polygons.

According to slope of Uttarakhand forest sites the high loss was recorded in the polygons having >18 degree slope (Rs. 138980/ha), than the polygons of 0-18 degree (Rs. 102887/ha). In Madhya Pradesh forest the highest monetary loss is recorded in the polygons having 0-5-degree slope (Rs. 150350/ha), followed by the polygons of 11-36 degree (108566/ha), and lowest at 05–11-degree slope (101211/ha). According to altitude the highest loss was recorded in polygons having 1800-2200m altitude (Rs. 178473/ha), followed by 900-1800m altitude (Rs. 162963/ha), and minimum at 0-900 m altitude (Rs. 53527/ha). In M.P. the highest loss is recorded at polygons having 600-900m altitude (Rs. 118692/ha), followed by 0-300m altitude (Rs. 117982/ha), and minimum at 300-600m altitude (Rs. 113330/ha) in Uttarakhand forest. According to aspect the highest loss was recorded in the west aspect (Rs. 153285/ha), followed by north aspect (Rs. 136058/ha), south aspect (Rs. 122775/ha), and minimum at east aspect (Rs. 94597/ha) in Uttarakhand. In M.P. the highest loss is recorded in the east aspect (Rs. 123736/ha), followed by north aspect (Rs. 114659/ha), west aspect (Rs. 113745/ha), and minimum at south aspect (Rs. 106339/ha).

The highest loss is recorded in the Subtropical Pine Forest (Rs. 170392/ha), followed by Himalayan Moist Temperate Forests (Rs. 150243/ha), TOF/Plantation (Rs. 51671/ha), Tropical Moist Deciduous Forests (Rs. 40250/ha), and minimum in the Tropical Dry Deciduous Forest type (Rs. 9595/ha) in Uttarakhand forest. In Madhya Pradesh the value ranged between Rs. 15892 to Rs. 249614 in Tropical Moist Deciduous Forest, and the mean value was computed Rs. 121888/ha. Similarly, in the Tropical Dry Deciduous Forests value ranged between Rs. 29768 to Rs. 136006, and the mean value was Rs. 170392/ha. Similarly, in the Tropical Dry Deciduous Forest the mean value was Rs. 92271 in Madhya Pradesh.

Summary of the main highlights of results are given in Table-1.

Table-1: Summary of major parameters of data collected during field work across 2019 forest fire affected forests of Uttarakhand and Madhya Pradesh.

S. No.	Parameters	Uttarakhand	Madhya Pradesh
1.	Number of polygons of 2019 forest fire (FF) selected for study	42	49
2.	Number of polygons studied	39 (pre-monsoon) 27 (post-monsoon)	47 (pre-monsoon) 30 (post-monsoon)
3.	Area of polygon (ha)	4.23- 883.12	3.607-3108.53
4.	Altitudinal ranges of polygons (m asl)	230–2488	252-930
5.	Aspect of polygons	NE, SW, SE, and NW	NE, E, NW, SE, and SW
6.	Species richness in polygons- Trees	50	63

	Shrubs Herbs Wild edibles Medicinal and aromatic plants Total	45 67+10 (grass) 21 58 171	31 66+06 (grass) 19 41 166
7.	Tree saplings (ind./ha) Tree seedlings (ind./ha)	20 - 1150 50 - 1880	240 – 1610 130 - 1500
8.	Timber/ wood volume loss due to forest fire (m^3/ha) (mean)	1.9-19.2 (5.86)	2.51-12.76 (6.51)
9.	Monetary loss of timber (Rs. /ha) (range & mean)	30986 - 288570 (142994)	33314 – 230128 (96560)
10.	Quantity of fuel wood loss due to FF (t/ha) (range & mean)	0.21-10.15 (2.13)	0.08-1.22 (0.35)
11.	Monetary loss of fuel wood (Rs. /ha) (range & mean)	1232-58659 (21220)	418-5646 (2005)
12.	Quantity of ground fodder loss due to FF (t/ha) (range & mean)	0.60-1.78 (0.37)	0.13-0.79 (0.30)
13.	Monetary loss of ground fodder (Rs. /ha) (range & mean)	301-8937 (2154)	671-4003 (1542)
14.	Quantity of MAPs loss due to FF (kg/ha) (range & mean)	0.3-255.28 (29.87)	0.33-736.59 (80.41)
15.	Monetary loss of MAPs (Rs. /ha) (range & mean)	15-14426 (1980)	151-19138 (2655)
16.	Quantity of Wild edibles loss due to FF (kg/ha) (range & mean)	18-745 (302.74)	2-638 (100.5)
17.	Monetary loss of Wild edibles (Rs. /ha) (range & mean)	920-22324 (9091)	35-22985 (2856)
18.	Quantity of litterfall loss due to FF (t/ha) (range & mean)	3.2-3.4 (3.3)	3.3-3.3 (3.3)
19.	Monetary loss of Litterfall (Rs. /ha) (range & mean)	3250-3400 (3309)	3300-3350 (3328)
20.	Quantity of regeneration loss due to FF (ind/ha) (range & mean)	100-1480 (436)	90-4680 (583.19)
21.	Monetary loss of regeneration (Rs. /ha) (range & mean)	2500-37000 (10900)	2250-117000 (14579)
22.	Quantity of resin loss due to FF (kg/ha) (range & mean)	43.5-391.5 (149.14)	NA
23.	Monetary loss of resin (Rs. /ha) (range & mean)	2986-17875 (6809)	NA
24.	Quantity of tendu leaves loss due to FF (bundle/ha) (range & mean)	NA	180-900 (403)
25.	Monetary loss of tendu leaves (Rs. /ha) (range & mean)	NA	1366-6831 (3064)
26.	Quantity of bamboo loss due to FF (t/ha) (range & mean)	NA	1.23-1.23 (1.23)
27.	Monetary loss of bamboo (Rs. /ha) (range & mean)	NA	8365-8365 (8365)
28.	Stakeholder's meetings (Total participants)	35 (230 M; 136 F)	31 (316 M; 29 F)
29.	Total plot sampled in burnt and unburnt polygons- Herb Shrub	 3960 2640	 4620 3080

	Tree Total	1320 7920	1540 9240
30.	Total monetary loss due to FF (Rs./ha) (range & mean)	9595-352752 (130387)	15892-249614 (114327)

However, it may be pointed out that the monetary values GBPNIHE has computed for timber, fuelwood and fodder should be considered in view of certain limitations. As, all the burnt logs lying on forest floor do not have market value; all the ground herbage is not fodder, and all the trees and its branches/twigs are not used for fuel wood and do not bear fruits and other wild edibles. Also, in certain polygons positive effects of FF in terms of yield of MAPs/ NTFPs were recorded that needs further validation involving in-depth long-term studies. A major limitation of this work was that the study was initiated in June 2020 internationally under the Covid-Pandemic by this time the post-monsoon season of 2019 FF had already passed away. However, this is the pioneering comprehensive exercise in the states of U.K and M.P.

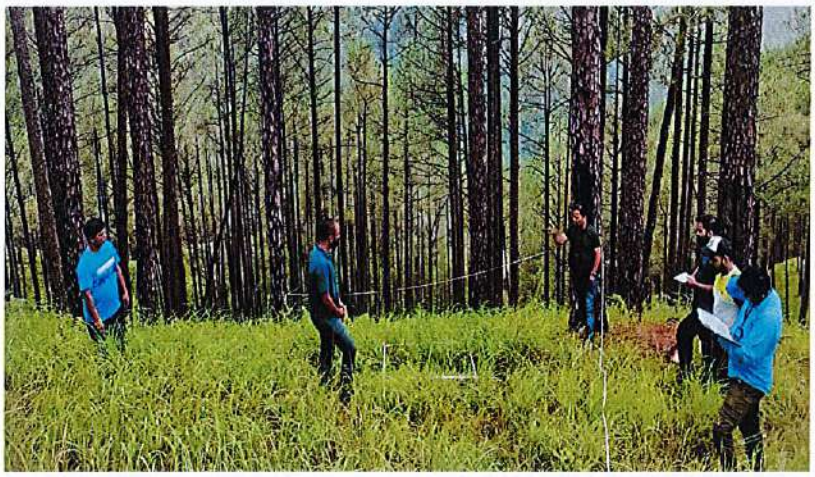


Fig.4 Demonstration of field techniques and survey methods for monetary loss evaluation (Polygon ID-2045)

Fig.5 Polygon survey before conducting intensive studies to estimate loss of forest wealth

❖ National Institute of Hydrology (NIH), Roorkee

Objective: Economic loss assessment of hydrological changes due to forest fire on per hectare basis for the respective states

Study Area

The study was proposed to be carried out in plots of 1 ha size in the states of Uttarakhand and Madhya Pradesh. Two neighbouring plots (one burnt and another un-burnt) of 1 ha size would be selected; one of these two plots in each of the finally selected burnt forest polygons i.e. 42 Nos. in Uttarakhand and 49 Nos. in Madhya Pradesh and one nearby unburnt plot in the similar forest type in the vicinity. The location and details of these sites have been given in Tables 2 and 3.

Table 2: Finally selected 42 Burnt plots in the forest areas of Uttarakhand

		Burnt Polygons		
SN	**Forest type**	**Severe**	**Moderate**	**Low**
1.	Group 3- Tropical Moist Deciduous Forests	Nil	4	2
2.	Group 5- Tropical Dry Deciduous Forests	Nil	Nil	2
3.	Group 9 -Subtropical Pine Forests	Nil	18	2
4.	Group 12- Himalayan Moist Temperate Forests	Nil	9	2
5.	Group- TOF/Plantation	Nil	1	2
	Total	**Nil**	**32**	**10**

Table 3: Finally selected 49 Burnt plots in the forest areas of Madhya Pradesh

SN	**Forest type**	**Burnt Polygons**		
		Severe	**Moderate**	**Low**
1.	Group 3- Tropical Moist Deciduous Forests	2	4	8
2.	Group 5- Tropical Dry Deciduous Forests	3	20	12
3.	Group 9 -Subtropical Pine Forests	Nil	Nil	Nil
4.	Group 12- Himalayan Moist TemperateForests	Nil	Nil	Nil
5.	Group- TOF/Plantation	Nil	Nil	Nil
	Total	**5**	**24**	**20**

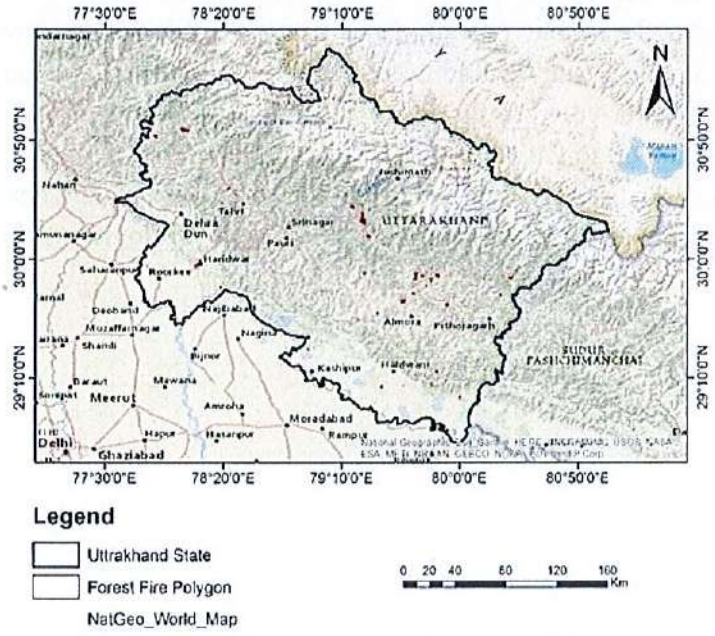


Fig. 6 Finally selected 42 Burnt plots in the forest areas of Uttarakhand

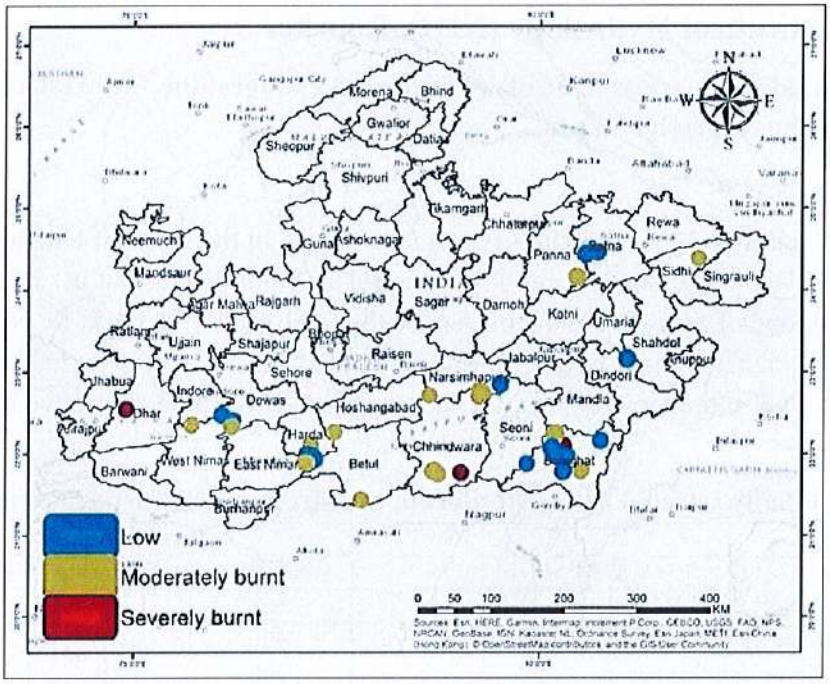


Fig. 7 Finally selected 49 Burnt plots in the forest areas of Madhya Pradesh

Methodology

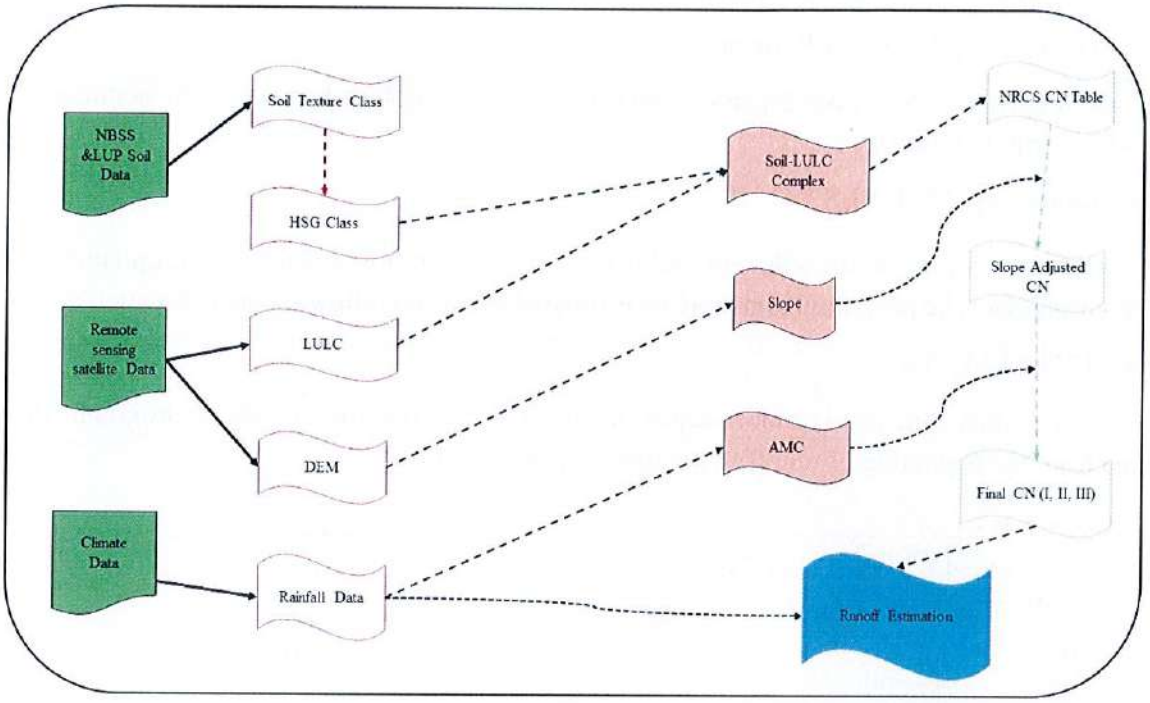
Estimation of changes in hydrological response due to forest fire

A paired-plot approach would be adopted in the study that involves use of two neighbouring plots (one burnt and another un-burnt) where precipitation inputs, pre-burnt vegetation characteristics,soil and geological conditions, and other variables are similar/ identical.

Field and Laboratory Investigations:

The burnt and un-burnt plots shall serve as treated and control plots for estimating the changes in hydrological variables. Extensive field and laboratory investigations would be carried out in experimental and control plots in all the forest types and in both the states. Double Ring Infiltrometer Tests and Guelph Permeameter Tests will be conducted to determine the infiltration capacity and hydraulic conductivity of the burnt and unburnt plots. The soil samples will be collected from the burnt and unburnt plots and analyzed in the laboratory for determination of soil texture, soil organic matter, soil porosity, soil-water retention characteristics, soil permeability etc. The field investigations would also be carried out for determination of vegetation cover characteristics and hydrologic condition of the cover.

Assessment of Hydrological Response: The gridded historical precipitation data, AET data and soil maps will be obtained from various sources. Direct runoff from the experimental plots will be estimated by SCS Curve Number (SCS-CN) Method.



The curve numbers for AMC-II condition are derived from NEH-4 tables and these curve numbersare used for estimation of runoff using the following equations:

$$Q = \frac{(P - 0.05S)^2}{P + 0.95S} \qquad S = \frac{25400}{CN} - 254$$

Further, these curve numbers are converted for AMC-I or AMC-III using the following equations:

Model	AMCI	AMC III
Sobhani (1975)	$CN_I = \frac{CN_{II}}{2.334 - 0.01334CN_{II}}$	$CN_{III} = \frac{CN_{II}}{0.4036 + 0.005964CN_{II}}$
Hawkins et al. (1985)	$CN_I = \frac{CN_{II}}{2.281 - 0.01281CN_{II}}$	$CN_{III} = \frac{CN_{II}}{0.427 + 0.00573CN_{II}}$
Chow et al. (1988)	$CN_I = \frac{4.2CN_{II}}{10 - 0.058CN_{II}}$	$CN_{III} = \frac{23CN_{II}}{10 + 0.13CN_{II}}$
Neitsch et al. (2002)	$CN_I = CN_{II} - \frac{20(100 - CN_{II})}{\{100 - CN_{II} + \exp[2.533 - 0.0636(100 - CN_{II})]\}}$	$CN_{III} = CN_{II}\exp\{0.00673(100 - CN_{II})\}$
Mishra et al. (2008)	$CN_I = CN_{II} - \frac{20(100 - CN_{II})}{2.274 - 0.012754CN_{II}}$	$CN_{III} = \frac{CN_{II}}{0.430 + 0.0057CN_{II}}$

Further, for assessing the hydrological response, Thornthwaite Water Balance Method will be used incorporating the precipitation data, AET data, SCS-CN estimated runoff and the hydrological parameters derived from the field and lab investigations. The difference in hydrological response of the two plots would be ascribed to the changes due to fire.

Assessment of Soil Erosion Patterns:

Modified Universal Soil Loss Equation (MUSLE) will be employed to assess the sediment yield patterns as follows:

$$S = 11.8 (Q^* qp)^{0.56} K^* LS * C * P$$

where, S is the single storm sediment yield (tons), Q is the runoff volume (m^3), qp isthe peak discharge. The peak discharge may be estimated using the following equation:

$$q_p = 0.278 * A * d / Tp$$

where, A is area (km^2); d is runoff depth (mm); Tp is the rise time of the hydrograph (h) (time from the beginning of runoff to the time of peak runoff.

$$t_{lag} = \frac{2.587 * L^{0.8}\left(\frac{1000}{CN} - 9\right)^{0.7}}{1900 * H^{0.5}} \quad [11.7]$$

where,

t_{lag} = Lag time [hr].

L = Hydraulic watershed length [m].

CN = Hydrologic area-weighted curve number.

H = Average watershed land slope [%].

$t_{lag} = 0.6\ t_c$

where,

t_c = Time of concentration [hr].

The hydraulic watershed length L can be approximated for small watersheds (<2000 ha) by the formula 11.8.

$$L = 110\ A^{0.6} \quad [11.8]$$

where,

A = watershed area [ha].

The main difference compared to the USLE is the replacement of the rainfall factor with a direct estimate of surface runoff and peak runoff rate. This method requires rainfall data, soil parameters, slope, vegetation cover, and land management practices. Due to forest fire, there will be change in soil erodibility and vegetation cover which will be reflected in the soil erosion patterns.

Estimation of Economic Losses due to change in hydrological response induced by forest fires

The study will evaluate economic loss based on the effect of forest fire on the hydrological behaviour of experimental plots through conducting primary surveys of selected sites under burnt and un-burnt categories specific to the study area. Capture the socio-economic and environmental loss due to change in hydrological behaviour caused by forest fire. The broad regulating and supporting ecosystem services of forest like water cycle and its related biophysical attributes like interception, infiltration, water holding, surface runoff, soil

erosion, sedimentation, river flow, downstream water quality and impact on aquatic lives will be focused and their impacts on ground and surface water causing loss or gain will be analyzed and estimated. The loss or gain will be analyzed in terms of use (direct and indirect) and non-use values using the methodology of TEEB India Initiative including the socio-economic and environmental losses/gains due to hydrological change.

Multi-stage random sampling technique will be adopted. The sample households will be chosen in the various selected distance ranges (to be specified depending on the experimental area of the forest). The semi-structured questionnaire will be used to collect the primary data. A survey will be conducted to test the questionnaire. Focused group discussions (FGDs) will also be conducted to get the qualitative data from the stakeholders. The questionnaire will cover broad aspects of socio-economic and demographic characteristics of the households and their access to environmental goods to investigate the various impacts and effects of wildfire on their lives, livelihood, occupation, assets, health, and different natural sources like water, food, soil/ agricultural land, homestead trees. To understand the differences in socioeconomic characteristics of stakeholders, several variables will be considered such as family-size and its composition; level of education; occupation; landholding pattern; livestock-ownership pattern; ownership of agricultural machinery and implements; exposure to watershed and wild fire and distance; access to infrastructure and natural resources; etc. In addition to use of statistical toolsand techniques, different GIS techniques shall be used. The analysis will be made by focusing on its impact on different systems and subsystems like land/soil/agriculture, forest, water, and their services. Different market and non-market valuation techniques will be applied to assess the monetary value of economic losses.

The field investigations (including double ring infiltrometer tests and Guelph Permeameter Tests and soil sample collection for texture, soil moisture retention, organic matter content etc.) at the burnt and unburnt plots have been completed for all the selected polygons. The laboratory investigations for the analysis of collected soil samples are also going on in parallel.

The required gridded precipitation data, Actual Evapotranspiration (AET) data, National Bureau of Soil Survey and Land Use Planning (NBSS&LUP) soil maps and Leaf Area Index for both the burnt and unburnt plots in both the states have been obtained. The development of various maps required for the assessment of change in hydrologic response as well as for assessment of soil erosion patterns have been completed.

One component of the study titled "Estimation of economic loss due to change in hydrologic variables caused by forest fires in Uttarakhand and Madhya Pradesh" was awarded to the Department of Humanities and Social Sciences, IIT Roorkee. They have made preliminary assessment based on their field surveys and the data provided by NIH on hydrological changes.

Assessment of change in infiltration characteristics

Infiltration tests using the double ring infiltrometer were conducted at selected burnt polygons in the forests of Uttarakhand and Madhya Pradesh as well as in the nearby unburnt

locations in the similar forest areas. The infiltration rates obtained in the field are shown in Tables 4 and 5.

For most of the sites, the infiltration rates at unburnt (control) sites have been found to be more than that at the burnt forest sites. The reason for the same may be attributed to the repulsive behaviour due to the ashes of the burnt vegetation getting accumulated over the soil surface and soil pores. The deposition of the ash as well as its downward movement in the subsequent monsoon season causes coagulation and formation of soil aggregates that generally acts as an impervious medium like a cement layer and thereby reducing the infiltration rate.

Table 4: Measured infiltration rates for burnt and unburnt forest plots of Uttarakhand

S. No.	Polygon ID	Fire Severity	NBSSLUP Soil Class	Measured Infiltration Rate (cm/hr)	
				Burnt Plot	Unburnt Plot
1	336	Moderately Burnt	Loamy skeletal	2.67	2.89
2	367	Moderately Burnt	Loamy	2.07	2.15
3	386	Low Burnt	Loamy	2.39	2.32
4	397	Moderately Burnt	Loamy	1.89	1.85
5	534	Moderately Burnt	Loamy	1.37	1.46
6	548	Moderately Burnt	Loamy	1.58	1.63
7	552	Moderately Burnt	Loamy	2.41	2.39
8	1008	Low Burnt	Loamy skeletal	2.53	2.56
9	1020	Low Burnt	Loamy	2.13	2.17
10	1238	Moderately Burnt	Loamy	2.21	2.26
11	1265	Moderately Burnt	Loamy skeletal	3.68	3.57
12	1293	Moderately Burnt	Loamy skeletal	3.18	3.24
13	1313	Moderately Burnt	Loamy skeletal	3.81	3.88
14	1388	Moderately Burnt	Loamy	1.56	1.62
15	1430	Moderately Burnt	Loamy	2.41	2.35
16	1518	Moderately Burnt	Loamy skeletal	2.28	2.46
17	1552	Low Burnt	Loamy	0.57	0.76
18	1783	Moderately Burnt	Loamy	1.29	1.36
19	1867	Moderately Burnt	Loamy	2.52	2.73
20	2041	Moderately Burnt	Loamy	2.07	2.19
21	2045	Moderately Burnt	Loamy	1.68	1.74
22	2090	Moderately Burnt	Loamy skeletal	3.65	3.46
23	2179	Moderately Burnt	Loamy	2.18	2.25
24	2201	Moderately Burnt	Loamy	2.34	2.39
25	2374	Moderately Burnt	Loamy	2.12	2.17
26	2655	Low Burnt	Sandy	4.29	4.04
27	3167	Moderately Burnt	Loamy	2.87	1.87
28	3300	Moderately Burnt	Loamy	2.63	2.65
29	3484	Moderately Burnt	Loamy	2.26	2.29
30	3625	Moderately Burnt	Loamy	1.83	1.92
31	3690	Moderately Burnt	Loamy	0.51	1.02
32	3700	Low Burnt	Loamy	2.73	2.96
33	3884	Moderately Burnt	Loamy	2.04	1.82
34	4002	Low Burnt	Loamy	1.64	1.72
35	4007	Low Burnt	Loamy	2.13	2.14
36	4204	Low Burnt	Loamy	2.34	2.48
37	4255	Low Burnt	Loamy	2.42	2.28
38	4344	Moderately Burnt	Loamy skeletal	3.87	3.82
39	4446	Moderately Burnt	Loamy	1.93	2.07
40	4452	Moderately Burnt	Loamy skeletal	3.56	3.58
41	4507	Moderately Burnt	Loamy	1.66	2.04

42	4603	Moderately Burnt	Loamy	2.47	2.56

Table 5: Measured infiltration rates for burnt and unburnt forest plots of Madhya Pradesh

S. No.	Polygon ID	Fire Severity	NBSSLUP Soil Class	Measured Infiltration Rate (cm/hr)	
				Burnt Plot	Unburnt Plot
1	1312	Low Burnt	Clayey	0.85	1.12
2	1316	Low Burnt	Clayey	0.72	
3	1357	Low Burnt	Clayey	1.07	1.13
4	1358	Low Burnt	Clayey	1.05	1.21
5	1443	Moderately Burnt	Loamy	1.8	2.4
6	4524	Moderately Burnt	Loamy	2.51	2.46
7	6534	Moderately Burnt	Loamy	2.23	2.18
8	6865	Moderately Burnt	Loamy	2.19	2.24
9	6993	Moderately Burnt	Clayey	1.16	1.28
10	7596	Severely Burnt	Clayey	1.09	1.17
11	9169	Moderately Burnt	Clayey	0.93	1.14
12	10013	Moderately Burnt	Loamy	2.28	2.35
13	10369	Low Burnt	Loamy	2.57	2.69
14	10701	Moderately Burnt	Clayey	1.34	1.56
15	10758	Moderately Burnt	Clayey	1.13	1.18
16	11001	Severely Burnt	Loamy	2.16	2.24
17	11473	Severely Burnt	Clayey	0.76	0.92
18	11530	Moderately Burnt	Clayey	1.03	1.12
19	11546	Low Burnt	Loamy	2.54	2.92
20	11563	Severely Burnt	Loamy	1.96	3.71
21	11576	Moderately Burnt	Clayey	0.73	0.87
22	11754	Low Burnt	Clayey	0.69	0.74
23	11791	Low Burnt	Loamy	1.82	1.94
24	11995	Low Burnt	Loamy	1.68	1.73
25	12459	Moderately Burnt	Clayey	0.61	0.78
26	12508	Severely Burnt	Clayey	0.74	0.71
27	12563	Moderately Burnt	Clayey	0.87	0.95
28	12628	Moderately Burnt	Clayey	1.03	1.17
29	14057	Moderately Burnt	Loamy	1.89	1.93
30	14676	Moderately Burnt	Clayey	1.12	1.26
31	14683	Moderately Burnt	Clayey	1.91	2.46
32	15203	Low Burnt	Loamy	1.74	1.83
33	15522	Low Burnt	Loamy	2.9	3.21
34	15762	Moderately Burnt	Loamy	5.13	6.92
35	16068	Low Burnt	Loamy	2.27	2.34
36	16181	Low Burnt	Loamy	2.19	2.26
37	16311	Moderately Burnt	Loamy	2.57	2.63
38	16455	Moderately Burnt	Loamy	2.96	3.12
39	16470	Moderately Burnt	Loamy	4.4	5.6
40	16529	Low Burnt	Loamy	1.85	5.7
41	16581	Low Burnt	Loamy	3.3	5.8
42	16622	Low Burnt	Loamy	2.19	2.26
43	16627	Low Burnt	Loamy	5.2	5.8
44	16645	Low Burnt	Loamy	1.81	1.83
45	16720	Low Burnt	Clayey	1.14	1.17
46	16722	Moderately Burnt	Clayey	0.83	0.89
47	16826	Moderately Burnt	Clayey	0.97	1.02
48	16846	Moderately Burnt	Loamy	1.92	2.03
49	16860	Low Burnt	Loamy	1.66	1.71

Soil Moisture Transmission Characteristics

The hydraulic conductivity and the permeability are two terms used for describing the soil moisture transmission characteristics. Field measurement of permeability was carried out using the Guelph Permeameter at selected burnt polygons in the forests of Uttarakhand and Madhya Pradesh as well as in the nearby unburnt locations in the similar forest areas. At few locations, where, the field conditions were not favourable to conduct the field measurements, undisturbed soil samples were collected and further analysed in the laboratory. The soil permeability rates obtained in the field and the laboratory are shown in Tables 6 and 7.

For most of the sites, the permeability rates at unburnt (control) sites have been found to be higher in comparison to that at the burnt forest sites. The reason for the same may be due to the accumulation of ashes of the burnt vegetation over the soil surface and soil pores. The deposition of the ash as well as its downward movement in the subsequent monsoon season causes coagulation and formation of soil aggregates that generally works as relatively impervious medium and thereby reduces the permeability.

Table 6: Measured permeability rates for burnt and unburnt forest plots of Uttarakhand

S. No.	Polygon ID	Fire Severity	NBSSLUP Soil Class	Measured Permeability (cm/hr)	
				Burnt Plot	Unburnt Plot
1	336	Moderately Burnt	Loamy skeletal	2.46	2.27
2	367	Moderately Burnt	Loamy	1.83	1.76
3	386	Low Burnt	Loamy	1.97	2.03
4	397	Moderately Burnt	Loamy	1.57	1.61
5	534	Moderately Burnt	Loamy	1.24	1.16
6	548	Moderately Burnt	Loamy	1.39	1.34
7	552	Moderately Burnt	Loamy	2.03	2.05
8	1008	Low Burnt	Loamy skeletal	2.30	1.48
9	1020	Low Burnt	Loamy	2.00	1.97
10	1238	Moderately Burnt	Loamy	1.92	1.88
11	1265	Moderately Burnt	Loamy skeletal	3.03	3.13
12	1293	Moderately Burnt	Loamy skeletal	2.75	2.70
13	1313	Moderately Burnt	Loamy skeletal	3.30	3.24
14	1388	Moderately Burnt	Loamy	1.38	1.33
15	1430	Moderately Burnt	Loamy	2.00	2.05
16	1518	Moderately Burnt	Loamy skeletal	2.09	1.94
17	1552	Low Burnt	Loamy	1.25	0.83
18	1783	Moderately Burnt	Loamy	1.16	1.10
19	1867	Moderately Burnt	Loamy	2.32	2.14
20	2041	Moderately Burnt	Loamy	1.86	1.76
21	2045	Moderately Burnt	Loamy	1.48	1.43
22	2090	Moderately Burnt	Loamy skeletal	2.94	3.10
23	2179	Moderately Burnt	Loamy	1.91	1.85
24	2201	Moderately Burnt	Loamy	2.03	1.99
25	2374	Moderately Burnt	Loamy	1.84	1.80
26	2655	Low Burnt	Sandy	1.75	3.53
27	3167	Moderately Burnt	Loamy	2.49	0.76
28	3300	Moderately Burnt	Loamy	2.25	2.24
29	3484	Moderately Burnt	Loamy	1.95	1.92
30	3625	Moderately Burnt	Loamy	1.63	1.56
31	3690	Moderately Burnt	Loamy	0.64	0.56
32	3700	Low Burnt	Loamy	0.41	0.01
33	3884	Moderately Burnt	Loamy	0.98	3.35

34	4002	Low Burnt	Loamy	1.46	1.39
35	4007	Low Burnt	Loamy	1.82	1.81
36	4204	Low Burnt	Loamy	2.11	1.99
37	4255	Low Burnt	Loamy	1.94	2.06
38	4344	Moderately Burnt	Loamy skeletal	3.25	3.29
39	4446	Moderately Burnt	Loamy	1.76	1.64
40	4452	Moderately Burnt	Loamy skeletal	3.04	3.03
41	4507	Moderately Burnt	Loamy	1.73	1.41
42	4603	Moderately Burnt	Loamy	2.18	2.10

Table 7: Measured permeability rates for burnt and unburnt forest plots of Madhya Pradesh

S. No.	Polygon ID	Fire Severity	NBSSLUP Soil Class	Measured Permeability (cm/hr)	
				Burnt Plot	Unburnt Plot
1	1312	Low Burnt	Clayey	0.7055	0.9296
2	1316	Low Burnt	Clayey	0.5976	0.6308
3	1357	Low Burnt	Clayey	0.8881	0.9379
4	1358	Low Burnt	Clayey	0.8715	1.0043
5	1443	Moderately Burnt	Loamy	1.494	1.992
6	4524	Moderately Burnt	Loamy	2.0833	2.0418
7	6534	Moderately Burnt	Loamy	1.8509	1.8094
8	6865	Moderately Burnt	Loamy	1.8177	1.8592
9	6993	Moderately Burnt	Clayey	0.9628	1.0624
10	7596	Severely Burnt	Clayey	0.9047	0.9711
11	9169	Moderately Burnt	Clayey	0.7719	0.9462
12	10013	Moderately Burnt	Loamy	1.8924	1.9505
13	10369	Low Burnt	Loamy	2.1331	2.2327
14	10701	Moderately Burnt	Clayey	1.1122	1.2948
15	10758	Moderately Burnt	Clayey	0.9379	0.9794
16	11001	Severely Burnt	Loamy	1.065	1.8592
17	11473	Severely Burnt	Clayey	0.6308	0.7636
18	11530	Moderately Burnt	Clayey	0.8549	0.9296
19	11546	Low Burnt	Loamy	2.1082	2.4236
20	11563	Severely Burnt	Loamy	1.6268	3.0793
21	11576	Moderately Burnt	Clayey	0.6059	0.7221
22	11754	Low Burnt	Clayey	0.5727	0.6142
23	11791	Low Burnt	Loamy	1.5106	1.6102
24	11995	Low Burnt	Loamy	1.3944	1.4359
25	12459	Moderately Burnt	Clayey	0.5063	0.6474
26	12508	Severely Burnt	Clayey	0.6142	0.5893
27	12563	Moderately Burnt	Clayey	0.7221	0.7885
28	12628	Moderately Burnt	Clayey	0.8549	0.9711
29	14057	Moderately Burnt	Loamy	1.5687	1.6019
30	14676	Moderately Burnt	Clayey	0.9296	1.0458
31	14683	Moderately Burnt	Clayey	0.93	1.14
32	15203	Low Burnt	Loamy	1.4442	1.5189
33	15522	Low Burnt	Loamy	2.407	2.6643
34	15762	Moderately Burnt	Loamy	4.2579	5.7436
35	16068	Low Burnt	Loamy	1.8841	1.9422
36	16181	Low Burnt	Loamy	1.8177	1.8758
37	16311	Moderately Burnt	Loamy	2.1331	2.1829
38	16455	Moderately Burnt	Loamy	0.68	0.538
39	16470	Moderately Burnt	Loamy	0.607	0.23
40	16529	Low Burnt	Loamy	0.342	0.98
41	16581	Low Burnt	Loamy	0.292	0.144
42	16622	Low Burnt	Loamy	1.8177	1.8758
43	16627	Low Burnt	Loamy	0.294	0.38

44	16645	Low Burnt	Loamy	1.5023	1.5189
45	16720	Low Burnt	Clayey	0.9462	0.9711
46	16722	Moderately Burnt	Clayey	0.6889	0.7387
47	16826	Moderately Burnt	Clayey	0.8051	0.8466
48	16846	Moderately Burnt	Loamy	1.5936	1.6849
49	16860	Low Burnt	Loamy	0.49	0.37

Estimation of Changes in Runoff and Sediment Yield

The changes in runoff, water balance and sediment yield due to forest fire for all the selected burnt and unburnt polygons were estimated using the well established SCS-CN Methodology, Thornthwaite Method and MUSLE, respectively. These assessments were made using the satellite data of rainfall and ET; and field and laboratory experiments. The representative results obtained for one polygon each from Uttarakhand and Madhya Pradesh is shown below in Tables 8 and 9.

Table 8: Hydrological Changes due to forest fire in Uttarakhand (Polygon ID 336)

		Unburnt				Burnt			
Month	Rainfall, mm	Runoff, mm	Sediment Yield, Tonnes/ha	ET, mm	Change in Storage, mm	Runoff, mm	Sediment Yield, Tonnes/ha	ET, mm	Change in Storage, mm
Jun	79.49	0.00	0.00	85.67	-6.18	0.06	0.00	84.38	-4.95
Jul	327.20	48.56	0.92	86.79	191.85	122.24	6.01	85.49	119.47
Aug	233.80	23.89	0.45	102.46	107.45	63.81	3.01	100.92	69.07
Sep	247.22	47.25	0.97	96.42	103.56	101.01	5.37	94.97	51.24
Oct	11.05	0.00	0.00	78.73	-67.68	0.00	0.00	77.55	-66.50
Nov	24.14	0.00	0.00	55.60	-31.46	0.00	0.00	54.77	-30.63
Dec	41.43	0.00	0.00	42.08	-0.65	0.33	0.01	41.45	-0.35
Jan	112.89	0.00	0.00	37.43	75.46	10.34	0.42	36.87	65.68
Feb	28.54	0.00	0.00	51.25	-22.71	1.17	0.04	50.48	-23.12
Mar	150.54	2.49	0.04	84.78	63.26	17.52	0.72	83.51	49.51
Apr	52.13	0.00	0.00	101.88	-49.75	0.14	0.00	100.35	-48.36
May	83.88	0.00	0.00	115.14	-31.26	0.64	0.02	113.41	-30.17
Annual	**1392.30**	**122.20**	**2.37**	**938.23**	**331.88**	**317.27**	**15.60**	**924.16**	**150.88**
Monsoon	**887.71**	**119.70**	**2.34**	**371.34**	**396.67**	**287.13**	**14.38**	**365.77**	**234.82**
Non-Monsoon	**504.59**	**2.49**	**0.04**	**566.89**	**-64.79**	**30.14**	**1.22**	**558.39**	**-83.94**

Table 9: Hydrological Changes due to forest fire in M.P. (Polygon ID 1312)

Month	Rainfall, mm	Unburnt				Burnt			
		Runoff, mm	Sediment Yield, Tonnes/ha	ET, mm	Change in Storage, mm	Runoff, mm	Sediment Yield, Tonnes/ha	ET, mm	Change in Storage, mm
Jun	107.49	0.00	0.00	53.52	53.97	1.74	0.06	52.72	53.04
Jul	409.27	91.89	2.90	97.16	220.21	174.73	10.89	95.70	138.83
Aug	724.32	303.55	9.56	100.06	320.71	444.63	28.85	98.56	181.12
Sep	433.65	113.95	3.25	97.68	222.02	204.38	12.23	96.21	133.06
Oct	30.28	0.00	0.00	104.53	-74.25	0.11	0.00	102.96	-72.80
Nov	8.17	0.00	0.00	82.48	-74.31	0.00	0.00	81.24	-73.07
Dec	3.45	0.00	0.00	53.83	-50.38	0.00	0.00	53.02	-49.57
Jan	38.47	0.02	0.00	57.79	-19.34	7.02	0.38	56.92	-25.47
Feb	40.59	0.09	0.00	61.74	-21.24	7.85	0.43	60.81	-28.08
Mar	39.98	0.00	0.00	62.91	-22.93	1.67	0.07	61.97	-23.66

Apr	15.10	0.00	0.00	47.51	-32.41	0.00	0.00	46.80	-31.70
May	22.04	0.00	0.00	41.22	-19.18	0.06	0.00	40.60	-18.62
Annual	**1872.82**	**509.51**	**15.72**	**860.43**	**502.88**	**842.20**	**52.92**	**847.52**	**183.09**
Monsoon	**1674.73**	**509.40**	**15.71**	**348.42**	**816.91**	**825.48**	**52.03**	**343.19**	**506.06**
Non-Monsoon	**198.09**	**0.11**	**0.00**	**512.01**	**-314.03**	**16.72**	**0.88**	**504.33**	**-322.97**

Estimation of Economic Losses due to changes on Hydrological Variables Induced by Forest Fires

NIH apply the replacement cost method to estimate the net monetary losses of hydrological changes due to forest fire. Four hydrological variables—water runoff change, sedimentation change, Evapotranspiration (ET) change, and water storage change are considered. Details of the estimation process are shown in the methodology section. First of all, polygon-wise changes in the status of the major hydrological variables are found (pre and post-fire) following the NIH data on these four variables. We observe that the expected impact of forest fire matches with the data given. The runoff increased after the forest fires in all the 48 polygons, except polygon 16581, which comes under the low burnt category. Likewise, sedimentation also increases in all polygons, except the polygon 1358, which falls in the low burnt category. Evapotranspiration and water storage are expected to decrease after the forest fire.

Estimation of Monetary Losses in Madhya Pradesh

The summary statistics given in Table 10 show that the monetary value of losses per hectare of the brunt areas varies significantly across polygons as the standard deviation (S.D.) is very high. The losses are estimated separately for low, moderate, and severe brunt polygons. In our sample, out of 49 polygons, 20 polygons are under the low brunt category, and 24 polygons are under the moderate brunt category. Severe brunt polygons are only 5. In the case of the low brunt category of polygons, the value of S.D. is relatively high (2107.50), which indicates that the per hectare losses in the hydrological outcome indicators vary significantly. The outliers affect the mean value but not the median value. The mean value of losses is Rs. 957.20 per hectare, while the median value is Rs.219.94, which seems to be a more realistic estimate due to the high magnitude of S.D.

In the case of a moderate brunt polygon, the magnitude of SD (1966.40) is higher than the mean value (1403.39). It implies that losses due to forest fire vary substantially across polygons. There are some polygons where losses are substantial, and in some others, it is negligible. In such skewed data of monetary losses, the mean value may not be the true estimate of losses. Therefore, the median value (Rs.608.12) may be considered.

There are only five polygons under the severe brunt category. The magnitude of S.D. (584.06) is the lowest in the monetary losses among all the three categories. Moreover, we find not much difference in the mean and median values, though the median value is higher (Rs.958.01) than the mean value (Rs.887.40).

Table 10: Changes in Hydrological Indicators and Estimated Monetary Losses in Madhya Pradesh

Intensity of Fire	Statistics	Run_ off_change (mm)	Sedi_change Tonne/ha	ET_change (mm)	Storage change (mm)	Monetary Losses (Rs./ha)
Low	Mean	228.23	15.57	-5.95	-285.31	957.20
	Median	291.66	17.26	-5.87	-286.06	219.94
	S.D.	284.15	9.94	0.15	30.15	2107.50
	Count	20	20	20	20	20
Moderate	Mean	288.17	13.23	-5.94	-277.91	1403.39
	Median	288.65	12.36	-5.87	-283.39	608.12
	S.D	49.33	8.89	0.26	56.23	1986.40
	Count	24	24	24	24	24
Severe	Mean	260.37	7.80	-5.77	-254.78	887.40
	Median	268.92	6.45	-5.87	-263.26	958.01
	S.D	31.24	3.00	0.23	31.10	584.06
	Count	5	5	5	5	5
Overall	Mean	260.87	13.63	-5.93	-278.57	1168.62
	Median	284.50	12.10	-5.87	-279.01	421.35
	S.D.	184.46	9.11	0.22	45.10	1931.75
	count	49	49	49	49	49

Overall there are 49 polygons of the state whose monetary losses are estimated. The estimate shows that the value of S.D. is much higher (1931.75) than the mean value (1168.62), implying a high variation in the losses across polygons. The median value is Rs.421.35, which seems to be a better estimate of the measurement of central tendency than the mean value.

A perusal of Table 10 (above) reveals that considering the median value as average, the per hectare monetary losses in the hydrological outcome indicators due to forest fire increase with the increase in the intensity of brunt areas. It is only Rs.219.94 per hectare in low, Rs.608.12 is moderate, and Rs.958.01 in severe brunt polygons. Taking all polygons together, per hectare average losses comes out to Rs.421.35 when the median is considered and Rs.1168.62 if the arithmetic mean is taken into consideration.

Estimation of Monetary Losses in Uttarakhand

The summary statistics given in Table 11 show that the monetary value of losses per hectare of the brunt areas varies significantly across polygons, as is indicated by the magnitude of standard deviation (S.D.). In our sample, we have only two categories of polygons—low brunt and moderate brunt. We do not have any polygon under the severe brunt category. The losses are estimated separately for low and moderate brunt polygons. In our sample, out of 42 polygons, 10 polygons are under the low brunt category, and 32 polygons are under the moderate brunt category. Thus, most of the Polygons are under the moderate brunt category.

In the case of the low brunt category of polygons, the value of S.D. is much higher (8731.15) than the mean value (Rs. 4894.05). It implies that losses due to forest fire vary substantially across polygons. There are some polygons where losses are substantial, and in some others, it is negligible. In such skewed data of monetary losses, the mean value may not be the true estimate of losses. The outliers affect the mean value but not the median value. The median

value under the low brunt category is Rs.178.23, which seems to be a more realistic estimate due to the high magnitude of S.D.

Table 11: Changes in Hydrological Indicators and Estimated Monetary Losses in Uttarakhand

Intensity of Fire	Statistics	Run_ off_change (mm)	Sedi_change Tonne/ha	ET_change (mm)	Storage change (mm)	Monetary Losses (Rs./ha)
Low	Mean	184.99	18.74	-5.87	-164.13	4894.05
	Median	190.82	18.10	-5.87	-180.93	178.23
	S.D.	67.29	20.18	0.00	77.61	8731.15
	Count	10.00	10.00	10.00	10.00	10.00
Moderate	Mean	168.37	-50.56	-5.87	-162.84	2851.61
	Median	170.99	7.71	-5.87	-165.41	1170.97
	S.D	37.89	327.68	0.00	37.87	3392.72
	Count	32	32	32	32	32
Overall	Mean	172.33	-34.06	-5.87	-163.15	3337.90
	Median	175.16	8.73	-5.87	-168.32	1043.40
	S.D.	46.16	286.65	0.00	49.06	5119.80
	count	42	42	42	42	42

In the case of moderate burnt polygons, the magnitude of SD (3392.72) is relatively lower than that in the low brunt polygons. The mean value is 2851.61, and the median is Rs.1170.97. Since the median is not affected by minimum and maximum values, it is considered a better estimate than the mean.

Fig. 8 Field investigations at Rajaji National Park

❖ Wild life Institute (WII), Dehradun

Objective: Economic loss assessment of faunal diversity due to forest fire on per hectare basis for the respective states.

A major study area includes both Uttarakhand and Madhya Pradesh, however, as a preliminary approach, Binsar Wildlife Sanctuary in Uttarakhad was chosen to carry out the first field survey. The Binsar Wildlife Sanctuary is situated at the top of Jhandi Dhar hills, about 33 km north of Almora district in Uttarakhand state, northern India, between 29° 30' to 29° 43' N and 79° 41' to 79° 47' E, spreading over an area of 45.6 km2 . The mean monthly temperatures range from 2.2° C to 15.5° C during winter and from 17.2° C to 26.6° C during summer. Average rainfall was approximately 1,200 mm (Sharma et al., 1999). Throughout the sanctuary, the terrain is hilly and characterized by deep ravines, crevices and elevated ridges. The forested area starts at an elevation of 1,600 m and rises to about 2,400 m. Lower altitude areas in the sanctuary are used for livestock grazing and agriculture. The forested hilltops and slopes in the sanctuary are covered by chir pine (*Pinus roxburghii*), ban oak (*Quercus leucotrichophora*), and rhododendron (*Rhododendron arboreum*) as pure or mixed stands. The forest covers are classified into open, moderately dense and very dense forests. Pure pine forests are present between 1,600 and 1,900 m, while mixed forests of pine and oak are distributed over 1,900 to 2,100 m.

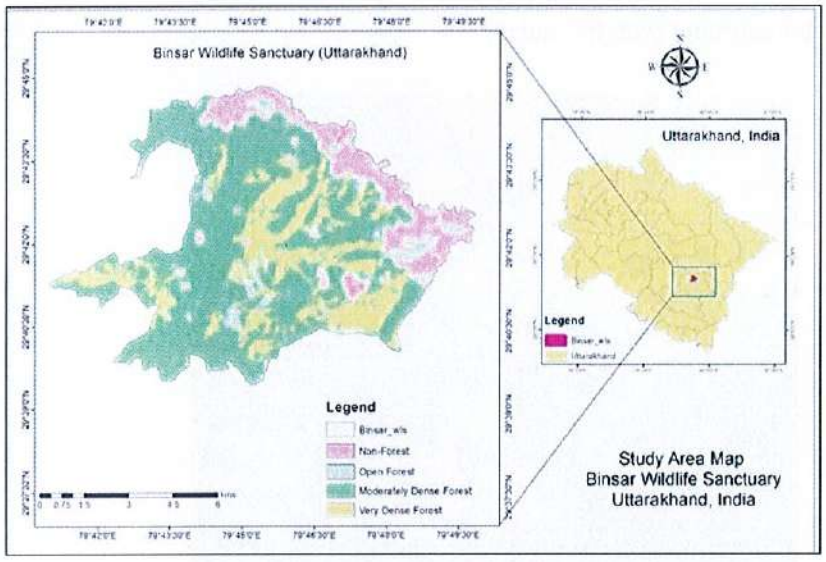


Fig 9 Study Landscape, FSI Generated Map derived from LISS III, 2019

The pure oak and mixed oak forests (*Quercus leucotrichophora* and *Quercus floribunda*) are present between 2,100 and 2,400 m. Other dominant tree species include *Lyonia ovalifolia, Quercus leucotrichophora, Rhododendron arboreum, Myrica esculenta* and *Alnus nepalensis* (Majila et al., 2005, Majila and Kala 2010, Kala and Majila 2013, Kala 2013). Common leopards are major wild predators in the sanctuary. Other predators include jungle cats (*Felis chaus*) and leopard cats (*Prionailurus bengalensis*). Major ungulate species include gorals (*Nemorhaedus goral*), barking deer (*Muntiacus muntijak*), serows (*Capricornis sumatrensis*), and wild pig (*Sus scrofa*). Other mammal species in the sanctuary are common langurs (*Presbytus entellus*), rhesus macaques (Macaca mulatta), Himalayan black bears (*Selenarctos*

thibetanus), and jackals (*Canis aureus*). The sanctuary also harbors diverse birds, including black francolins (*Francolinus francolinus*), koklass pheasants (*Pucrasia macrolopha*), kaleej pheasants (*Lophura leucomelana*), hill partridges (*Arborophilla torqueola*), great barbets (*Megalaima virens*), hawk eagles (*Spizaetus nipalensis*), Himalayan griffons (*Gyps himalayensis*), lammergeyers (*Gypaetus barbatus*), and yellow-billed magpies (*Cissa flavirostris*; Khan et al.,2000, Majila and Kala 2010). Farming and animal husbandry are the main economic activities of the people living in and around the sanctuary. Livestock provide the basis for livelihoods and are used for ploughing and composting crop fields. A variety of products important for socioeconomic and cultural advancement are also produced.

Fig 10 Camera trapping for mammals A. Goral: IUCN Status: - Near Threatened; B. Leopard: IUCN Status: - Vulnerable; C. Porcupine: IUCN Status: - Least Concern & D. WildBoar: IUCN Status: - Least Concern

It is being observed that, within the herbivorous species class, Goral had lost a maximum high potential zone of 2.36 km2 , followed by porcupine of about 0.446 km2 and lowest by barking deer accounting to 0.265 km2 . The loss in their very low habitat zones accounts to be more for barking deer i.e., 4.45 km2 , slightly less for goral which is 3.48 km2 and minimum for porcupine of 1.50 km2 . The total potential losses in their medium habitat 99 | P a g e zones are 8.24 km2 and 8.09 km2 for goral and barking deer respectively. The medium habitat area loss is highest in case of porcupine accounting to be 10.27 km2 . In the low habitat zone, goral lost a total of 7.26 km2 , barking deer lost a higher area of 8.55 km2 and porcupine's area degraded maximum upto 9.13 km2 due to forest fire. In case of the bird species, maximum area was degraded in very low habitat zone, which is 8.25 km2 and considerably a meager land of 0.53 km2 was degraded because of wildfires in Binsar Wildlife Sanctuary. Considering the high habitat potential zone of the higher order species of carnivore and omnivore, leopard lost an area of 1.55 km2 and its prey wild pig lost a meager area of 0.0432 km2 . Similarly, in medium habitat zone, leopard's loss was comparatively more and lost an area of 8.39 km2 , whereas wild pig lost an area of 4.97 km2 . For low and

very low potential habitat zones, wild pig's loss was higher than that of leopard, given 9.66 km2 and 6.68 km2 (for boar) and 8.06 km2 and 3.35 km2 (for leopard), respectively.

Table 12: Potential habitat area lost due to forest fire for specific species

Species	Leopard	Goral	Porcupine	Barking deer	Wild pig	Galliformes
Habitat Zones	Area lost(Sq km)	Area lost (Sq km)	Area lost(Sq km)	Area lost(Sq km)	Area lost (Sq km)	Area lost(Sq km)
High	1.5543	2.3679	0.4464	0.2655	0.0432	0.5337
Medium	8.3934	8.2476	10.2744	8.0946	4.9779	4.4685
Low	8.0649	7.2684	9.1377	8.5599	9.6687	8.1153
Very Low	3.3543	3.483	1.5084	4.4514	6.6816	8.2539

Table 13: Potential habitat zones degraded area in forest types

Habitat Zones	Sub-Tropical Pine Forest (Sq km)	Himalayan Temperate Forest (Sq km)	DryDeciduous Forest (Sq km)	Total(Sq km)
High Potential	3.4501	0.3644	0.00163	3.81622
Medium Potential	13.7282	3.0082	0.06661	16.8031
Low Potential	16.7511	2.9341	0.07252	19.7577
Very Low Potential	10.7686	0.5634	0.06882	11.4009

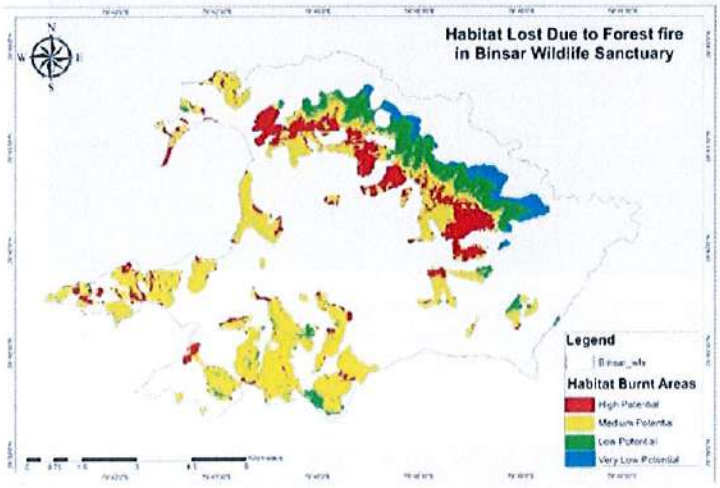


Fig 11 Total habitat burnt area in Binsar WLS B.

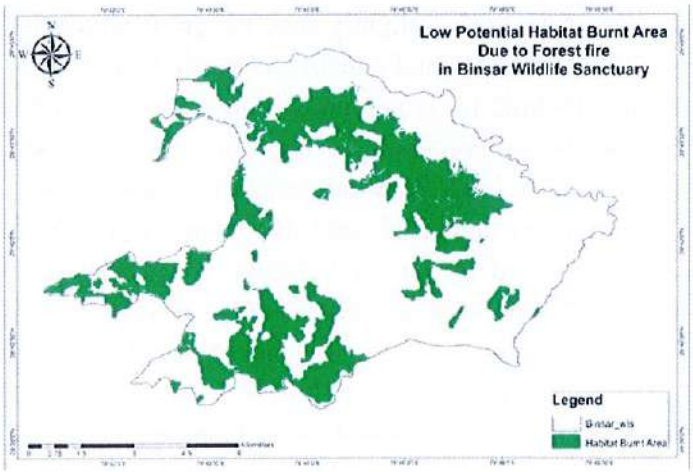


Fig 12 Total low potential habitat burnt area

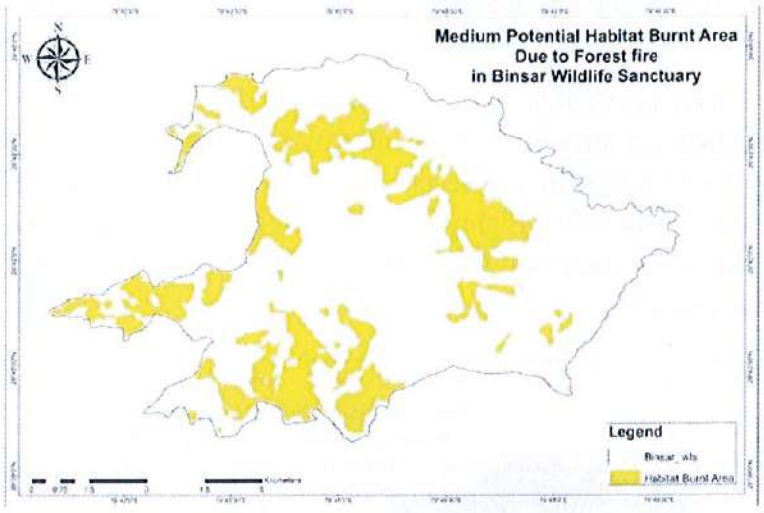


Fig 13 Total medium potential habitat burnt area

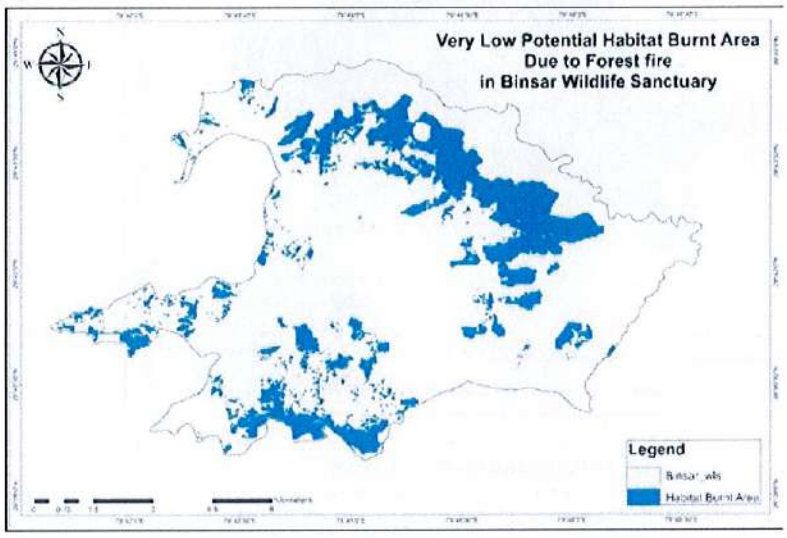


Fig 14 Total very low potential habitat burnt area

In term of forest type, Sub-tropical pine forest was degraded the most than any other type of forest followed by the Himalayan Temperate Forest and Dry deciduous forest. Similarly, for the habitat zones also same pattern was observed. For, high potential zone maximum area was degraded in Sub-tropical forest (3.4501 km^2) and then Himalayan temperate forest (0.3644 km^2) and minimum in the dry deciduous forest 0.00163 km^2 . In the medium potential zones 13.7282 km^2 , 3.0082 km^2 and 0.06661 km^2 of area was degraded for the Sub-tropical, Himalayan temperate and Dry deciduous forest respectively. The loss in the low habitat zones accounts to be more for Sub tropical forest i.e., 16.7511 km^2 , slightly less for Himalayan temperate which is 2.9341 km^2 and minimum for Dry deciduous forest of 0.07252 km^2 . In the very low habitat zone, Sub tropical forest lost a total of 10.7686 km^2 , Himalayan temperate forest lost a lower area of 0.5634 km2 and Dry Deciduous Forest area degraded maximum upto 0.06882 km^2 due to forest fire. For overall total habitat area lost due to forest fire, most of the area was from low potential zone (19.7577km^2) and followed by the medium potential zone (16.8031 km^2). Very low potential zone (11.4009 km^2) was slightly

less degraded as compared to low and medium potential zones. Lowest degraded area was observed in the high potential zones i.e., 3.81622 km^2 .

Incorporating the field data, an absolute value of Rs 8987641.52/- (Eighty-nine lakhs eighty-seven thousand six hundred and forty-one rupees and fifty-two paise) is estimated to be ward off for wildlife losses due to forest fire per hectare annually and using the density approach, an absolute figure of Rs 8780144.35/- (Eighty-seven lakhs eighty thousand one hundred and forty-four rupees and thirty-five paise only) is estimated to be ward off for wildlife losses due to forest fire per hectare annually.

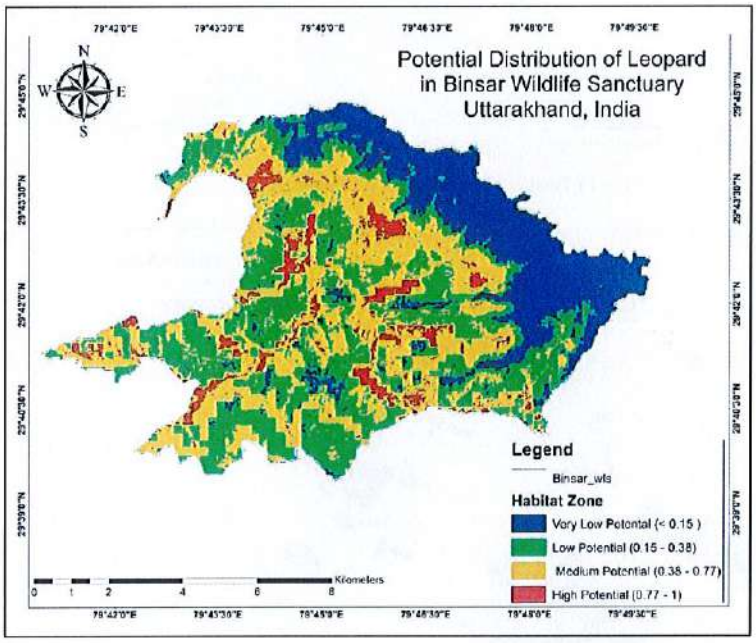


Fig. 15 Habitat Distribution of Leopard

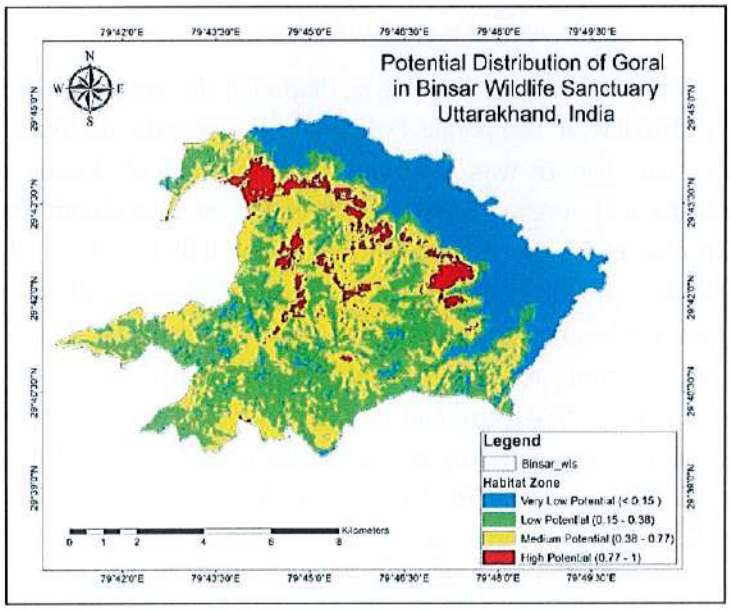


Fig. 16 Habitat Distribution of Goral

❖ Forest Research Institute (FRI), Dehradun

Objective: Economic loss assessment of terrestrial flora due to forest fire on per hectare basis for the respective states

Reconnaissance survey and finalization of study sites, sample size, methodology and modality for collection of baseline data: For phytosociological survey laid out plots size 10M × 10M, 5M × 5 M and 1M × 1M for Trees, Shrubs and herbs layers respectively. Collected dead twigs, litter, and diameter for Tree Carbon pool while entire plant for shrubs and Herbs have been harvested. Collected soils samples from different burnt and unburnt polygons areas for bulk density and carbon pool.

Baseline data generation/survey/ Vegetation structure, density Lab analysis:

- Field survey (have been conducted to collect vegetation and carbon pool data from 40 **burnt and unburnt polygons** in post and pre-monsoon season from different Forest Types of Uttarakhand viz. Himalayan Moist Temperate Forests and Subtropical Pine Forests, Tropical Moist Deciduous Forest, Tropical Dry Deciduous Forest.
- Vegetation data of post monsoon season of all 42 burnt and unburnt polygon have been collected and vegetation data of pre-monsoon season of 2 burnt and unburnt polygon are in under progress.
- The phytosociological data of 42 sites have been analysed which includes different diversity indices (Importance Value Index (IVI), Shannon-Wiener index (H") and Buza and Gibson"s evenness index). Rest of two sites will be calculated after pre-monsoon data recorded from field **(Annexure- I).**
- Rare, endangered and threatened category species (RET) have been prepared referring to the Red Data Book of Botanical Survey of India, IUCN Red data list as well other published records.
- The preparation of listing of Cryptogamic flora (Bryophytes and Lichens have also been prepared for all sites.
- The list of invasive species are also prepared for all sites.
- Lab analysis: For 5 Carbon pool dead twigs, litter were collected, and diameter for Tree were measured while for shrub and herb entire plant have been harvested. Collected soils samples from different burnt and unburnt polygons areas for bulk density and organic carbon. The lab investigations are completed and analysis part in under progress for all 5 C-pool.

Pre-monsoon

Post -monsoon

Fig 17 Poly 2045-Burnt (Sub Tropical Pine Forests) MB

Boswellia serrata *Buchanania lanzan* *Aegle marmelos* *Myrica esculenta*

Roscoea purpurea *Bergenia ciliata* *Celastrus paniculatus*

Fig 18 Some medicinal Economic important plant species

❖ Tropical Forest Research Institute (TFRI), Jabalpur

Objective: Economic loss assessment of terrestrial flora due to forest fire on per hectare basis for the respective states

Status of Survey Sites: Primary baseline data on Terrestrial floral diversity was collected through extensive field surveys in the study area during pre-monsoon and post-monsoon season using stratified sampling with GPS locations. The quadrate nested method was used for vegetation sampling for trees, shrubs, and Herbs. The phyto-sociological data for trees and shrubs were collected from random quadrates of 10 m ×10 m and 5 m × 5 m size. Random quadrats of 1 m × 1 m size were laid for the study of herbaceous flora. Status of the field survey sites for carbon stock assessment in 5 carbon pools as stated below Table 14.

Table 14: Status of survey sites

Season	Burnt	Unburnt
Pre-Monsoon	49	49
Post-Monsoon	49	49
Total	98	98

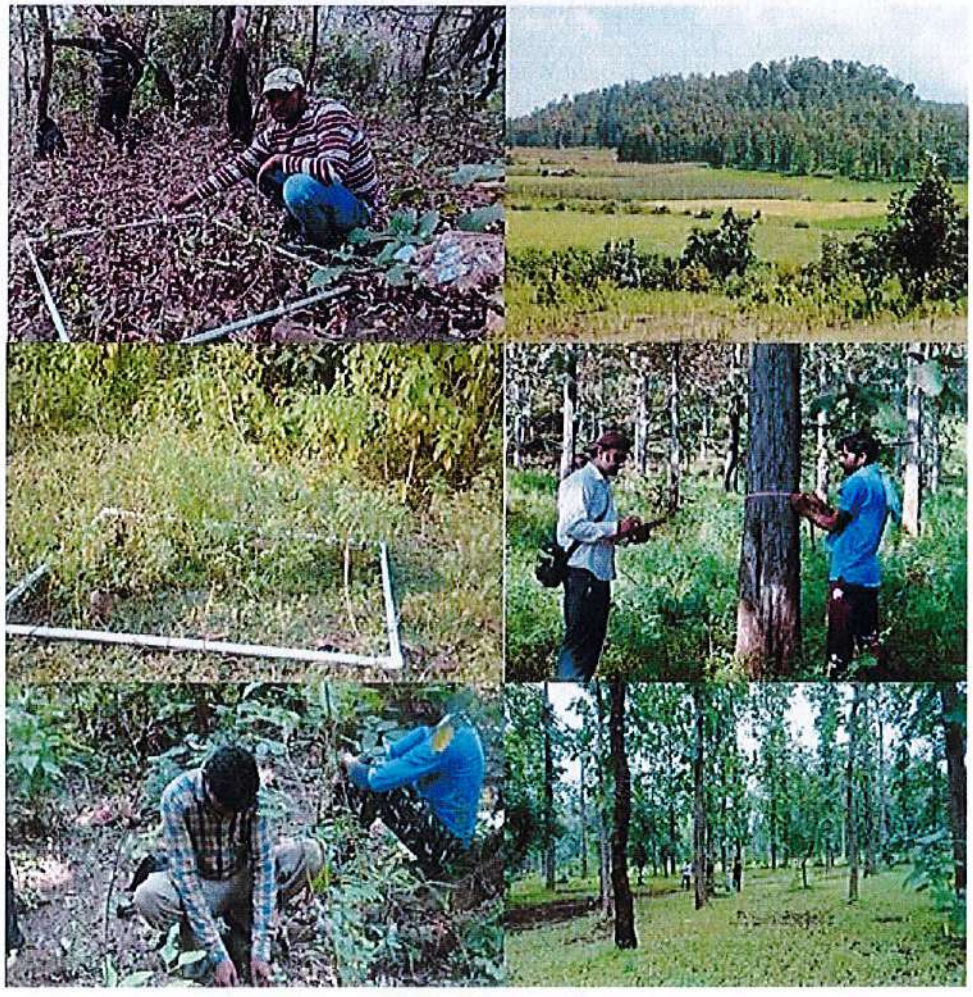


Fig. 19 Survey of sites

Vegetation Survey and Sample Collection (Litter, Deadwood, Herb, and Shrub):

Samples of Litter, Dead Wood, Herb, and Shrub for all 49 polygon ids were collected in the pre-monsoon season by site visit and processed under the laboratory for moisture content analysis. Each site consists of two areas such as fire and control for which we have collected 5 random samples from each area. Batch-wise, litter, dead wood, herb, and shrub samples were kept in an oven and after every three days weighing have been done until constant weight is attained. Status of sample collection for carbon stock assessment is showed in the below table 15 and also status of vegetation survey for calculation of biodiversity indices is showed in table 16. Moisture content analysis of all samples is completed and calculation of carbon stock is under processed.

Table 15: Status of vegetation survey

	Burnt				Unburnt			
Status of Vegetation survey (no. of polygon ids)	Tree	Climber	Herb	Shrub	Tree	Climber	Herb	Shrub
Pre-monsoon	49	49	49	49	49	49	49	49
Post-monsoon	-	-	49	-	-	-	49	-
Total	49	49	98	49	49	49	98	49

Table 16: Status of sample Collection for Carbon stock assessment

	Burnt				Unburnt			
Status of Sample collection (no. of polygon ids)	Litter	Dead Wood	Herb	Shrub	Litter	Dead Wood	Herb	Shrub
Pre-monsoon	49	49	49	49	49	49	49	49
Post-monsoon	-	-	-	-	-	-	-	-
Total	49	49	49	49	49	49	49	49

Soil samples analysis for Soil Carbon Assessment (Bulk Density & % Organic Carbon): Soil samples collected in pre-monsoon season from both burnt and unburnt sites were brought to the TFRI laboratory for soil carbon analysis. All samples were first dried by keeping in an oven until dry and constant weight achieved and calculated bulk density; second, the sample is put through a sieve to obtain well uniform particle size later on organic carbon was determined using the Walkley-Black method.

A total of 98 (49 sites × 2 classes (Burnt and Unburnt/control)) samples have been collected and analysed for the bulk density and % organic carbon (Table 17). The result of the analysed soil samples showed in table **(Annexure-II).** Based on the result obtained, it was observed that most of the samples show high carbon content as per the standard rating chart. Percent organic carbon of samples observed within the range of 0.05%-2.7%. Analysis for Soil carbon is under process.

Table: 17 Status of soil samples collected for Bulk Density and % Organic Carbon for Soil Carbon assessment

	Burnt		Unburnt	
Status of Soil sample collection (no. of polygon ids)	Bulk Density	Organic Carbon	Bulk Density	Organic Carbon
Pre-monsoon	49	49	49	49
Post-monsoon	-	-	-	-
Total	49	49	49	49

Identification of plants: During the field survey, the number of plants of different species in each quadrate was identified and counted while unidentified plants were collected and brought to TFRI. Identification and nomenclature of plants have been done by using regional and state floras and also some of the plants identified by using online websites such as *Flowers of India*, *India Biodiversity Portal*, *Kew Herbarium*. For accepted names, *the plant list* and Plants of the World Online websites were checked regularly.

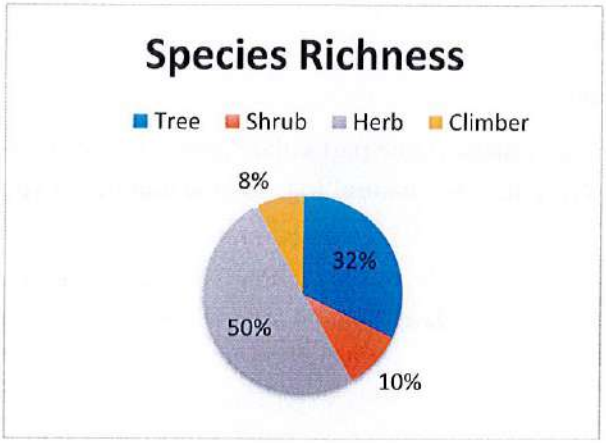


Fig 20 Habit-wise Species Diversity

After correct identification, plant data is entered into an excel sheet and unique species are extracted. As far now a total of 282 unique plant species are observed, out of which 91, 22, 27, and 142 are Trees, Climbers, Shrubs, and Herbs respectively **(Table : Annexure- III).**

Methodology

Quantitative Analysis of Phyto-sociological data: Calculation of biodiversity indices for Burnt Area and Unburnt/Control plot (1 ha size). The phyto-sociological data for trees (10 m × 10 m), shrubs (5 m × 5 m) and herbs (1 m × 1 m) have been collected from random quadrates. Methodology adopted for calculation of biodiversity indices such as IVI, Shannon-Wiener index (H), Importance Value Index (IVI), Simpson Index (D), Buza and Gibson's Evenness (E).

Important Value Index (IVI):

IVI = *Relative density* +*Relative frequency* + *Relative dominance*

Where,

$$\text{Density} = \frac{Number\ of\ species}{Total\ area\ Sampled}$$

$$\text{Frequency} = \frac{Individul\ number\ of\ species}{Total\ number\ of\ species}$$

$$\text{Dominance} = \frac{Total\ basal\ area\ of\ an\ individual\ species}{Total\ area\ sampled}$$

$$\text{Relative density} = \frac{Density\ of\ a\ Species}{Total\ Density\ of\ all\ Species} * 100$$

$$\text{Relative frequency} = \frac{Frequency\ of\ a\ Species}{Total\ frequency\ of\ all\ species} * 100$$

$$\text{Relative dominance} = \frac{Dominance\ of\ a\ Species}{Total\ dominance\ of\ all\ species} * 100$$

Shannon-Wiener diversity index (H):

$$H = -\sum_{i=1}^{s} p_i \ln p_i$$

Where,

H - Shannon diversity index;

Σ is the sum of the calculations

p is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N), ln is the natural log, s is the number of species

Simpson Index (D):

$$D = \frac{1}{\sum_{i=1}^{s} {p_i}^2}$$

Where,

Σ is sum of the calculations,

p is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N),

s is the number of species

Buza and Gibson's Evenness Index (E):

$$\mathbf{E} = \frac{H}{S} = \frac{-\sum_{i=1}^{s} p_i \ln p_i}{S}$$

Where,

H is Shannon-Wiener index,

S is Species Numbers

Carbon Stock Assessment for 5 C pool: Carbon stock of 5 C pools i.e., above ground biomass (AGB), below ground biomass (BGB), Litter, Dead wood, and Soil is calculated by methodology. Primary data for carbon stock estimation is obtained by field visits. For estimation C stock of ABG, allometric equations will be used for different forest trees while carbon pool in BGB and soil will be estimated by Monolith method and organic carbon analysis of soil in the laboratory and measuring dry bulk density. Further, carbon stock for each polygon id will be derived using biomass values based on phyto-sociological data.

Table 18: Status of vegetation survey

	Burnt				Unburnt			
Status of Vegetation survey (no. of polygon ids)	Tree	Climber	Herb	Shrub	Tree	Climber	Herb	Shrub
Pre-monsoon	49	49	49	49	49	49	49	49
Post-monsoon	-	-	49	-	-	-	49	-
Total	49	49	98	49	49	49	98	49

Table 19: Status of sample Collection for Carbon stock assessment

	Burnt				Unburnt			
Status of Sample collection (no. of polygon ids)	Litter	Dead Wood	Herb	Shrub	Litter	Dead Wood	Herb	Shrub
Pre-monsoon	49	49	49	49	49	49	49	49
Post-monsoon	-	-	-	-	-	-	-	-
Total	49	49	49	49	49	49	49	49

Annexure -I

Sample analysis

Phyto-sociological data of Burn and Unburnt Polygon

Polygon ID: 2045, **Location:** Binsar Wildlife Sanctuary Division: Dhaulchina Beat (Binsar North). **Forest Type**: Sub Tropical Pine Forests, **Fire Severity Class**: Moderately Burnt

Tree layer in Burnt site:

Species name	Relative Density	Relative Frequency	Relative Dominance	IVI
Pinus roxburghii	87.10	62.5	94.70	244.29
Lyonia ovalifolia	4.84	12.5	0.82	18.15
Rhododendron arboreum	3.23	12.5	0.29	16.02
Myrica esculenta	4.84	12.5	4.20	21.54
IVI				**300**
Shannon-Wiener index (Diversity)				**0.52**
Buzas-Gibson Index (Evenness)				**0.42**

Tree layer in Unburnt site:

Species name	Relative Density	Relative Frequency	Relative Dominance	IVI
Pinus roxburghii	64.86	35.71	74.89	175.47
Myrica esculenta	16.22	28.57	12.97	57.76
Lyonia ovalifolia	10.81	21.43	5.00	37.23
Alnus nepalensis	8.11	14.29	7.14	29.53
IVI				**300**
Shannon-Wiener index (Diversity)				**1.02**
Buzas-Gibson Index				**0.69**

Shrub Layer in Burnt Site:

Species name	Relative Density	Relative Frequency	Relative Dominance	IVI
Rubus ellipticus	38.98	37.50	25.16	101.64
Glochiodon velutinum	50.85	37.50	68.94	157.28
Berberis asiatica	5.08	12.50	1.91	19.50
Myrica esculenta (Sapling)	5.08	12.50	3.99	21.58
IVI				300
Shannon-Wiener index (Diversity)				**1.01**
Buzas -Gibson Index(Evenness)				**0.689**

Shrub Layer in Unburnt Site:

Species name	Relative Density	Relative Frequency	Relative Dominance	IVI
Colobrokeia oppositifolia	43.51	25.00	37.08	105.58
Rubus ellipticus	18.83	25.00	9.55	53.38
Glochiodon velutinum	25.32	31.25	15.45	72.02
Lyonia ovalifolia (sapling)	5.19	6.25	9.88	21.33
Berberis asiatica	3.90	6.25	5.34	15.49
Myrica esculenta (Sapling)	3.25	6.25	22.70	32.20
IVI				**300**
Shannon-Wiener index (Diversity)				**1.42**

Buzas -Gibson Index(Evenness)				0.687

Herb Layer in Burnt Site:

Species name	Relative Density	Relative Frequency	Relative Dominance	IVI
Pouzolzia zeylanica	2.47	2.26	2.191	6.92
Micromeria biflora	4.94	3.01	2.658	10.60
Setaria glauca	3.46	3.76	2.643	9.86
Oxalis corniculata	7.41	7.52	1.846	16.77
Leptodermis lanceolata	1.73	2.26	2.717	6.70
Cassia pumila	2.96	3.01	4.060	10.03
Selliguea oxyloba	2.47	3.01	5.548	11.02
Asplenium sp.	2.96	4.51	5.457	12.93
Fern	1.98	2.26	2.599	6.83
Murdannia divergens	1.48	2.26	1.692	5.43
Taraxacum officinale	0.49	0.75	0.525	1.77
Galium aparine	1.98	1.50	1.151	4.63
Salvia cana	2.96	3.01	2.136	8.11
Eupatorium adenophorum	4.94	3.76	9.007	17.70
Flemengia strobilifera	3.21	2.26	8.235	13.70
Desmodium heterophyllum	3.46	4.51	1.469	9.44
Desmodium microphyllum	6.42	4.51	2.078	13.01
Pteris sp.	2.96	3.01	6.151	12.12
Aleuritopteris sp.	2.22	2.26	1.348	5.83
Artemesia spp.	2.22	2.26	4.660	9.14
Lespedeza spp.	2.96	3.76	4.492	11.21
Morina longifolia	0.49	0.75	1.656	2.90
Flemengia macrophylla	2.72	2.26	6.408	11.38
Aleuritopteris sp.	1.73	1.50	1.081	4.31
Erigeron emodi	3.70	3.76	0.995	8.46
Kyllinga spp.	1.48	1.50	0.401	3.39
DSC_0194	2.22	2.26	0.631	5.11
Cynoglossum sp.	2.47	2.26	5.247	9.97
Bergenia ciliata	1.98	2.26	0.538	4.77
Drosera peltata	0.74	0.75	0.367	1.86
Pimpinella diversifolia	0.25	0.75	0.262	1.26
Crotalaria albida	0.74	0.75	0.200	1.69
Senecio nudicaulis	0.49	0.75	0.377	1.62
Scrophularia edgeworthii	0.49	0.75	0.374	1.62
Justicia sp.	2.47	3.01	0.809	6.29
Ageratum conizoides	1.98	1.50	1.374	4.85
Galansoga sp.	0.49	0.75	0.131	1.38
Arundinella sp.	5.68	5.26	3.373	14.32
Chrysopogon fulvus	3.21	3.01	1.006	7.22
IVI				**300.00**
Shannon-Weiner Index				**3.48**
Buzas-Gibson Index				**0.81**

Herb Layer Unburnt Site:

Species name	Relative Density	Relative Frequency	Relative Dominance	IVI
Oxalis corniculata	22.87	10.10	6.26	39.23
Cassia pumila	4.68	6.06	6.30	17.05
Selliguea oxyloba	3.86	5.05	8.12	17.03
Fern	2.48	3.03	4.60	10.11
Fern	3.31	4.04	5.26	12.60
Murdannia divergens	2.75	5.05	3.99	11.80
Arundinella sp.	7.71	5.05	3.49	16.25
Chrysopogon fulvus	2.48	2.02	1.44	5.94
Galium aparine	1.65	3.03	0.99	5.68
Salvia sp.	4.41	5.05	4.51	13.97
Eupatorium adenophorum	3.86	3.03	8.00	14.88
Flemengia strobilifera	2.75	4.04	6.41	13.20
Aleuritopteris sp.	3.31	5.05	0.91	9.27
Cyperus spp.	1.65	3.03	3.75	8.44
Artemesia sp.	1.93	4.04	3.85	9.82
Lespedeza sp.	4.96	6.06	8.65	19.67
Flemengia macrophylla	2.48	4.04	5.13	11.65
Bergenia ciliata	1.65	2.02	0.43	4.11
Drosera peltata	0.55	1.01	0.24	1.81

Annexure- II

Soil Sample Analysis for Bulk density and Organic Carbon

Sr. No.	Polygon ID	Control/Fire	Dry weight of soil (gm)	Volume (cm3)	Bulk Density(gm/cm3)	% Organic Carbon
1	1312	Control	313	240	1.3042	0.81
2	1312	Fire	258	240	1.0750	0.85
3	1316	Control	358	240	1.4917	0.72
4	1316	Fire	321	240	1.3375	0.91
5	1357	Control	350	240	1.4583	0.34
6	1357	Fire	284	240	1.1833	1.55
7	1358	Control	306	240	1.2750	1.06
8	1358	Fire	330	240	1.3750	0.73
9	1443	Control	324	240	1.3500	0.44
10	1443	Fire	333	240	1.3875	0.59
11	4524	Control	249	220	1.1318	0.97
12	4524	Fire	177	220	0.8045	0.66
13	6534	Control	296.4	240	1.2350	1.63
14	6534	Fire	259	240	1.0792	1.27
15	6865	Control	300	240	1.2500	1.51
16	6865	Fire	272	240	1.1333	1
17	6993	Control	252	220	1.1455	2.54
18	6993	Fire	338	220	1.5364	1.83
19	7596	Control	418	240	1.7417	1.24
20	7596	Fire	396	240	1.6500	0.59
21	9169	Control	342.3	240	1.4263	1.16
22	9169	Fire	330.8	240	1.3783	0.95
23	10013	Control	247	220	1.1227	0.96
24	10013	Fire	323	220	1.4682	0.44
25	10369	Control	234	220	1.0636	0.8
26	10369	Fire	280	220	1.2727	0.46
27	10701	Control	299	220	1.3591	0.05
28	10701	Fire	296	220	1.3455	1.22
29	10758	Control	205	220	0.9318	0.94
30	10758	Fire	236	220	1.0727	1.25
31	11001	Control	330	220	1.5000	1.75
32	11001	Fire	338	220	1.5364	1.13
33	11473	Control	294	220	1.3364	0.23
34	11473	Fire	292	220	1.3273	0.09
35	11530	Control	313	220	1.4227	0.65
36	11530	Fire	277	220	1.2591	0.97
37	11546	Control	322	220	1.4636	0.73

38	11546	Fire	306	220	1.3909	1.39
39	11563	Control	246	220	1.1182	0.64
40	11563	Fire	350	220	1.5909	0.75
41	11576	Control	248	220	1.1273	0.52
42	11576	Fire	248	220	1.1273	0.93
43	11754	Control	299	220	1.3591	0.5
44	11754	Fire	317	220	1.4409	0.61
45	11791	Control	280	220	1.2727	0.69
46	11791	Fire	350	220	1.5909	0.79
47	11995	Control	374	220	1.7000	0.43
48	11995	Fire	390	220	1.7727	0.58
49	12459	Control	380	220	1.7273	0.88
50	12459	Fire	362	220	1.6455	1.75
51	12508	Control	345.7	220	1.5714	0.95
52	12508	Fire	432.7	220	1.9668	0.49
53	12563	Control	349.5	220	1.5886	1.85
54	12563	Fire	419.3	220	1.9059	0.44
55	12628	Control	407.6	220	1.8527	0.96
56	12628	Fire	315.3	220	1.4332	0.74
57	14057	Control	358	220	1.6273	2
58	14057	Fire	330	220	1.5000	0.81
59	14676	Control	310	240	1.2917	0.34
60	14676	Fire	336	240	1.4000	0.76
61	14683	Control	329	240	1.3708	0.34
62	14683	Fire	317	240	1.3208	0.81
63	15203	Control	250	220	1.1364	0.62
64	15203	Fire	236	220	1.0727	0.54
65	15522	Control	245	240	1.0208	1.56
66	15522	Fire	253	240	1.0542	0.95
67	15762	Control	262	240	1.0917	1.77
68	15762	Fire	255	240	1.0625	2.42
69	16068	Control	355	240	1.4792	0.76
70	16068	Fire	266	240	1.1083	1.25
71	16181	Control	335	240	1.3958	1.69
72	16181	Fire	324	240	1.3500	0.69
73	16311	Control	323	240	1.3458	2.31
74	16311	Fire	365	240	1.5208	0.31
75	16455	Control	239	220	1.0864	2.03
76	16455	Fire	298	220	1.3545	1.69
77	16470	Control	301	220	1.3682	0.6
78	16470	Fire	220	220	1.0000	1.58

79	16529	Control	394	220	1.7909	1.95
80	16529	Fire	414	220	1.8818	0.65
81	16581	Control	325	220	1.4773	0.9
82	16581	Fire	360	220	1.6364	0.44
83	16622	Control	287	220	1.3045	0.34
84	16622	Fire	328	220	1.4909	0.4
85	16627	Control	336	220	1.5273	0.67
86	16627	Fire	273	220	1.2409	2.7
87	16645	Control	278	220	1.2636	0.53
88	16645	Fire	274	220	1.2455	0.09
89	16720	Control	291	220	1.3227	0.31
90	16720	Fire	300	220	1.3636	0.42
91	16722	Control	298	220	1.3545	0.06
92	16722	Fire	295	220	1.3409	0.25
93	16826	Control	334	220	1.5182	1.11
94	16826	Fire	331	220	1.5045	1.08
95	16846	Control	349	220	1.5864	0.65
96	16846	Fire	295	220	1.3409	1.3
97	16860	Control	350	220	1.5909	1.12
98	16860	Fire	400	220	1.8182	1.41

Annexure- III

Unique Species List

Sr. no.	Botanical Name	Habit
1	*Acacia catechu*	Tree
2	*Acacia chundra*	Tree
3	*Acacia lanceolata*	Tree
4	*Acacia leucophloea*	Tree
5	*Acacia nilotica*	Tree
6	*Acalypha malabarica*	Herb
7	*Achyranthes aspera*	Herb
8	*Achyranthes sp.*	Herb
9	*Acmella ciliata*	Herb
10	*Acmella paniculata*	Herb
11	*Adina cordifolia*	Tree
12	*Aegle marmelos*	Tree
13	*Ageratum conyzoides*	Herb
14	*Ailanthus excelsa*	Tree
15	*Albizia amara*	Tree
16	*Albizia lebbeck*	Tree
17	*Albizia odoratissima*	Tree
18	*Alternanthera sessilis*	Herb
19	*Alysicarpus bupleurifolius*	Herb
20	*Alysicarpus ovalifolius*	Herb
21	*Alysicarpus vaginalis*	Herb
22	*Andrographis echioides*	Herb
23	*Andrographis paniculata*	Herb
24	*Anisomeles indica*	Herb
25	*Anogeissus latifolia*	Tree
26	*Argemone mexicana*	Herb
27	*Argyreia nervosa*	Climber
28	*Aristida sp.*	Herb
29	*Arundinella pumila*	Herb
30	*Asparagus racemosus*	Climber
31	*Azadirachta indica*	Tree
32	*Azanza lampas*	Shrub
33	*Balanites aegyptiaca*	Tree
34	*Bamboo*	Tree
35	*Bambusa arundinacea*	Tree
36	*Barleria cristata*	Herb
37	*Barleria montana*	Herb
38	*Barleria prionitis*	Herb
39	*Bauhinia malabarica*	Tree
40	*Bauhinia purpurea*	Tree
41	*Bauhinia racemosa*	Tree
42	*Bauhinia vahlii*	Climber
43	*Bauhinia variegata*	Tree

44	*Bidens biternata*	Herb
45	*Biophytum sensitivum*	Herb
46	*Blumea glomerata*	Herb
47	*Blumea lacera*	Herb
48	*Blumea sp.*	Herb
49	*Bombax ceiba*	Tree
50	*Boswellia serrata*	Tree
51	*Bridelia retusa*	Tree
52	*Buchanania cochinchinensis*	Tree
53	*Butea monosperma*	Tree
54	*Butea superba*	Climber
55	*Byttneria herbacea*	Herb
56	*Cajanus scarabaeoides*	Climber
57	*Calotropis gigantea*	Shrub
58	*Canscora alata*	Herb
59	*Canscora diffusa*	Herb
60	*Cardiospermum halicacabum*	Climber
61	*Careya arborea*	Tree
62	*Carissa bispinosa*	Shrub
63	*Carissa carandas*	Shrub
64	*Carissa spinarum*	Shrub
65	*Casearia graveolens*	Tree
66	*Casearia tomentosa*	Tree
67	*Cassia fistula*	Tree
68	*Cassine glauca*	Tree
69	*Catunaregam spinosa*	Tree
70	*Celastrus paniculatus*	Climber
71	*Celosia argentea*	Herb
72	*Centella asiatica*	Herb
73	*Chamaecrista mimosoides*	Herb
74	*Chloris barbata*	Herb
75	*Chloroxylon swietenia*	Tree
76	*Chromolaena odorata*	Shrub
77	*Cissampelos pareira*	Climber
78	*Cleistanthus collinus*	Tree
79	*Cocculus hirsutus*	Climber
80	*Cochlospermum religiosum*	Tree
81	*Colebrookea oppositifolia*	Shrub
82	*Commelina benghalensis*	Herb
83	*Convolvulus prostratus*	Herb
84	*Corchorus aestuans*	Herb
85	*Corchorus olitorius*	Herb
86	*Crotalaria albida*	Herb
87	*Crotalaria calycina*	Herb
88	*Crotalaria sp.*	Herb
89	*Cryptolepis buchananii*	Climber
90	*Curculigo orchioides*	Herb

91	*Curcuma aromatica*	Herb
92	*Curcuma pseudomontana*	Herb
93	*Cyanthillium cinereum*	Herb
94	*Cyathocline purpurea*	Herb
95	*Cyclea peltata*	Climber
96	*Cymbopogon coloratus*	Herb
97	*Cynoglossum lanceolatum*	Herb
98	*Cyperus rotundus*	Herb
99	*Cyperus sp.*	Herb
100	*Dalbergia lanceolaria*	Tree
101	*Dalbergia latifolia*	Tree
102	*Dalbergia sissoo*	Tree
103	*Dendrocalamus strictus*	Herb
104	*Desmodium dichotomum*	Herb
105	*Desmodium gangeticum*	Herb
106	*Desmodium heterocarpon*	Herb
107	*Desmodium laxiflorum*	Herb
108	*Desmodium oojeinense*	Tree
109	*Desmodium sp.*	Herb
110	*Desmodium triflorum*	Herb
111	*Dicliptera paniculata*	Herb
112	*Digitaria ciliaris*	Herb
113	*Dioscorea bulbifera*	Climber
114	*Diospyros melanoxylon*	Tree
115	*Diospyros montana*	Tree
116	*Diplocyclos palmatus*	Climber
117	*Ehretia laevis*	Tree
118	*Elephantopus scaber*	Herb
119	*Emilia sonchifolia*	Herb
120	*Eragrostis tenella*	Herb
121	*Eranthemum roseum*	Herb
122	*Euphorbia hirta*	Herb
123	*Euphorbia indica*	Herb
124	*Euphorbia parviflora*	Herb
125	*Evolvulus alsinoides*	Herb
126	*Evolvulus nummularius*	Climber
127	*Ficus arnottiana*	Tree
128	*Ficus benghalensis*	Tree
129	*Ficus racemosa*	Tree
130	*Flacourtia indica*	Tree
131	*Flemingia nana*	Herb
132	*Flemingia strobilifera*	Shrub
133	*Gardenia gummifera*	Tree
134	*Gardenia latifolia*	Tree
135	*Gardenia resinifera*	Tree
136	*Garuga pinnata*	Tree
137	*Globba marantina*	Herb

138	*Gmelina arborea*	Tree
139	*Grass sp.*	Herb
140	*Grewia asiatica*	Tree
141	*Grewia flavescens*	Shrub
142	*Grewia hirsuta*	Shrub
143	*Grewia orbiculata*	Shrub
144	*Grewia tiliifolia*	Tree
145	*Gymnosporia senegalensis*	Shrub
146	*Hardwickia binata*	Tree
147	*Helicteres isora*	Shrub
148	*Hemidesmus indicus*	Climber
149	*Hemigraphis latebrosa*	Herb
150	*Heteropogon contortus*	Herb
151	*Hibiscus hirtus*	Herb
152	*Hibiscus lobatus*	Herb
153	*Holarrhena pubescens*	Tree
154	*Holoptelea integrifolia*	Tree
155	*Hyptis suaveolens*	Herb
156	*Ichnocarpus frutescens*	Climber
157	*Indigofera cordifolia*	Herb
158	*Indigofera linnaei*	Herb
159	*Indigofera trita*	Herb
160	*Ipomoea hederifolia*	Climber
161	*Ixora parviflora*	Shrub
162	*Ixora pavetta*	Tree
163	*Justicia procumbens*	Herb
164	*Justicia quinqueangularis*	Herb
165	*Justicia sp.*	Herb
166	*Knoxia sumatrensis*	Herb
167	*Kydia calycina*	Tree
168	*Lagascea mollis*	Herb
169	*Lagerstroemia parviflora*	Tree
170	*Lannea coromandelica*	Tree
171	*Lantana camara*	Shrub
172	*Laportea interrupta*	Herb
173	*Lavandula bipinnata*	Herb
174	*Leea asiatica*	Herb
175	*Lepidagathis cristata*	Herb
176	*Leucas sp.*	Herb
177	*Lindernia ciliata*	Herb
178	*Lindernia sp.*	Herb
179	*Lindernia viscosa*	Herb
180	*Madhuca longifolia*	Tree
181	*Malvastrum coromandelianum*	Herb
182	*Manilkara hexandra*	Tree
183	*Mecardonia procumbens*	Herb
184	*Melastoma malabathricum*	Shrub

185	*Melochia corchorifolia*	Herb
186	*Miliusa tomentosa*	Tree
187	*Mitragyna parvifolia*	Tree
188	*Morinda tinctoria*	Tree
189	*Murdannia simplex*	Herb
190	*Nelsonia canescens*	Herb
191	*Nyctanthes arbor-tristis*	Tree
192	*Oldenlandia corymbosa*	Herb
193	*Oldenlandia ovatifolia*	Herb
194	*Oldenlandia sp.*	Herb
195	*Oplismenus burmannii*	Herb
196	*Oroxylum indicum*	Tree
197	*Oxalis corniculata*	Herb
198	*Parthenium hysterophorus*	Herb
199	*Paspalidium flavidum*	Herb
200	*Phoenix acaulis*	Shrub
201	*Phoenix sylvestris*	Tree
202	*Phyllanthus emblica*	Tree
203	*Phyllanthus fraternus*	Herb
204	*Phyllanthus niruri*	Herb
205	*Phyllanthus reticulatus*	Shrub
206	*Phyllanthus sp.*	Herb
207	*Phyllanthus tenellus*	Herb
208	*Phyllanthus urinaria*	Herb
209	*Phyllanthus virgatus*	Herb
210	*Phyllodium pulchellum*	Herb
211	*Pimpinella tomentosa*	Herb
212	*Platostoma hispidum*	Herb
213	*Plumbago zeylanica*	Herb
214	*Poa cilianesis*	Herb
215	*Pogostemon benghalensis*	Herb
216	*Pterocarpus marsupium*	Tree
217	*Randia uliginosa*	Tree
218	*Ruellia prostrata*	Herb
219	*Ruellia tuberosa*	Herb
220	*Rumex dentatus*	Herb
221	*Rumex sp.*	Herb
222	*Rungia pectinata*	Herb
223	*Rungia repens*	Herb
224	*Rungia sp.*	Herb
225	*Schleichera oleosa*	Tree
226	*Schrebera swietenioides*	Tree
227	*Scoparia dulcis*	Herb
228	*Semecarpus anacardium*	Tree
229	*Senna tora*	Shrub
230	*Sesamum indicum*	Herb
231	*Setaria pumila*	Herb

232	*Shorea robusta*	Tree
233	*Sida acuta*	Herb
234	*Sida cordata*	Herb
235	*Sida cordifolia*	Herb
236	*Sida rhombifolia*	Herb
237	*Smilax zeylanica*	Climber
238	*Smithia sp.*	Herb
239	*Solanum violaceum*	Shrub
240	*Soymida febrifuga*	Tree
241	*Spatholobus parviflorus*	Climber
242	*Spermacoce articularis*	Herb
243	*spermacoce exilis*	Herb
244	*Spermacoce hispida*	Herb
245	*Spermacoce verticillata*	Herb
246	*Spigelia anthelmia*	Herb
247	*Sterculia urens*	Tree
248	*Stereospermum chelonoides*	Tree
249	*Synedrella nodiflora*	Herb
250	*Syzygium aromaticum*	Tree
251	*Syzygium cumini*	Tree
252	*Tectona grandis*	Tree
253	*Tephrosia purpurea*	Herb
254	*Terminalia arjuna*	Tree
255	*Terminalia bellirica*	Tree
256	*Terminalia chebula*	Tree
257	*Terminalia tomentosa*	Tree
258	*Themeda triandra*	Herb
259	*Trachyspermum roxburghianum*	Herb
260	*Trichodesma indicum*	Herb
261	*Tricholepis glaberrima*	Herb
262	*Tridax procumbens*	Herb
263	*Triumfetta pentandra*	Herb
264	*Triumfetta rhomboidea*	Shrub
265	*Urena lobata*	Shrub
266	*Ventilago denticulata*	Climber
267	*Ventilago madraspatana*	Climber
268	*Vicoa indica*	Herb
269	*Vigna vexillata*	Climber
270	*Vitex negundo*	Tree
271	*Waltheria indica*	Shrub
272	*Woodfordia fruticosa*	Shrub
273	*Wrightia arborea*	Tree
274	*Wrightia tinctoria*	Tree
275	*Xanthium strumarium*	Herb
276	*Ziziphus jujuba*	Tree
277	*Ziziphus mauritiana*	Tree
278	*Ziziphus nummularia*	Shrub

279	*Ziziphus oenoplia*	Shrub
280	*Ziziphus rugosa*	Tree
281	*Ziziphus sp.*	Shrub
282	*Ziziphus xylopyrus*	Tree