

**EFFECT OF FOREST FIRE ON SOIL PHYSICAL
CHARACTERISTICS**

M.Tech. (Agril. Engg.) Thesis

by

Kamal Prakash

**DEPARTMENT OF SOIL AND WATER ENGINEERING
SV COLLEGE OF AGRICULTURAL ENGINEERING AND
TECHNOLOGY AND RESEARCH STATION
FACULTY OF AGRICULTURAL ENGINEERING
INDIRA GANDHI KRISHI VISHWAVIDYALAYA
RAIPUR (C.G.)**

2022

**EFFECT OF FOREST FIRE ON SOIL PHYSICAL
CHARACTERISTICS**

Thesis

Submitted to the

Indira Gandhi Krishi Vishwavidyalaya, Raipur

by

Kamal Prakash

**IN PARTIAL FULFILMENT OF THE REQUIRMENTS
FOR THE DEGREE OF**

Master of Technology

in

Agricultural Engineering

(Soil and Water Engineering)

Roll No. 20200813

ID No. 20200813

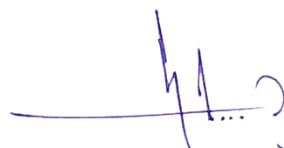
NOVEMBER, 2022

CERTIFICATE-I

This is to certify that the thesis entitled “**Effect of Forest Fire on Soil Physical Characteristics**” submitted in partial fulfilment of the requirement for the degree of the **Master of Technology in Agricultural Engineering** of Indira Gandhi Krishi Vishwavidyalaya, Raipur, is a recorded of the bonafide research work carried out by **Kamal Prakash** under our guidance and supervision. The subject of the thesis has been approved by the Student’s Advisory Committee and Director of Instructions.

No part of the thesis has been submitted for any other degree or diploma or certificate course. All the assistance and help received during the course of the investigation have been duly acknowledged.

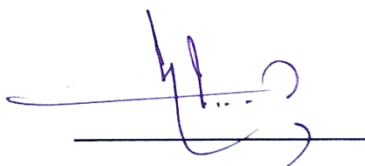

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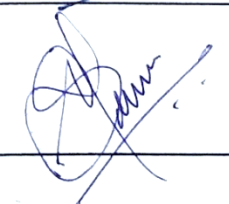
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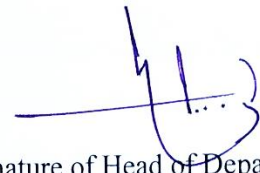


Member (Dr. M. K. Pradhan)



CERTIFICATE-II

This is to certify that the thesis entitled “**Effect of Forest Fire on Soil Physical Characteristics**” submitted by **Kamal Prakash** to the Indira Gandhi Krishi Vishwavidyalaya, Raipur, in partial fulfillment of the requirement for the degree of **Master of Technology in Agricultural Engineering** in the Department of **Soil and Water Engineering** has been approved by the external examiner and Student’s Advisory Committee after oral examination, under the chairmanship of Head of the Department/Dean (in case of out campii).




Signature of Head of Department/
Dean (in case of out campii)

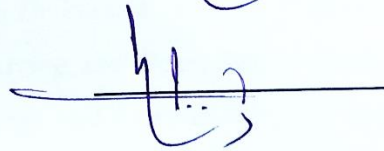
Date: 20/10/2022

(Name: Dr. V. K. Pandey)

Major Advisor



Faculty Dean



Approved/Not approved

Director of Instruction

ACKNOWLEDGEMENT

I am overwhelmed with pleasure and pride to express my feelings and a sense of indebtedness, in gesture of acknowledgment to different persons for their valuable guidance and wise direction during the course of my M.Tech thesis work.

I express my deep sense of thankfulness to Dr. Vinay K. Pandey, Major Advisor and Chairman of my advisory committee, Professor and Dean, SV College of Agricultural Engineering and Technology & Research Station, IGKV, Raipur,(C.G) for his helpful and inspiring guidance, persistent encouragements and meticulous effort during the study.

I extend my deep sense of gratitude and earnest appreciation to Dr. Pradeep Kumar, Co-Major Advisor, Scientist-D, Environmental Hydrology Division, National Institute of Hydrology, Roorkee, Uttarakhand for his helpful and admiring guidance, effective discussions, persistent encouragements and meticulous effort during the study. Despite his busy academic schedule and other preoccupations, he has patiently guided me throughout the period of my research work and thesis preparation.

I am very much grateful to members of my advisory committee including Dr. Jitendra Sinha, Dr. Anurag Singh Tomar, Dr. M.K. Pradhan for their advice and encouragement throughout the course of investigation.

I like to express my sincere thanks to Dr. Vinay K. Pandey, Professor and Head, Department of Soil and Water Engineering, and Dean, Swami Vivekanand College of Agricultural Engineering Technology And Research Station, Faculty of Agriculture Engineering, IGKV, Raipur(C.G) for his support and guidance throughout the research work.

I express my special thanks and gratefulness to Mr. S.L. Shrivastava, C.S. Chowhan, N.K. Lakhera, R.K. Goyal, and Dinesh Kumar for their immense help during field visits, data collection and laboratory analysis.

I avail this pleasant opportunity to express my sincere thanks to all of my Seniors, Dr. Jhalesh Kumar Sahu, Dr. Vijeta Singh, Er. Deepa Sahu, Er. Sekhar Saini, Er. Shams Quamar, and Dr. Shweta Yadav for their love, contribution, and timely help during the study and research work

I also express my thanks to my friends and seniors namely Er. Sangeeta Korram, Er. Nistha Sharnagat, Er Akanksha Maravi, Dr. Kiran Sharkhel, Miss Anoushka Amuj, Miss Shubha Dixit, Miss Vaishali Saini, Miss Anju Sahu, Miss Sukrita Kanwar, Miss Pratibha Dhiwar, Er. Kuldeep Kumar Kashyap, Er. Achal Singh Patel, Mr. Aditya Goyal, Mr. Vikash Kumar Yadav, Er. Shubham Kindo, Er. Shubham Bhensle, Er. Gaurav Mourya, for their love, contribution, help and encouragement during my research tenure.

Also, I express special thanks to all those who helped directly or indirectly during this study. My literacy power is too less to express my gratitude to Dr. Girish Chandel, Hon'ble Vice-Chancellor, Dr. S. S. Sengar, Director of Instructions and Dr.V.K. Tripathi, Directorate of research service, Raipur for their administrative and technical help which facilitated my research work.

I am thankful to all the technical and clerical staff members and other staff members of Department of Soil and Water Engineering, SVCAET&RS ,Faculty of Agriculture Engineering, IGKV, Raipur(C.G) for their kind support and help during the entire study.

I would like to convey my cordial thanks to all those unmentioned persons who helped me directly and indirectly t for successful completion of my research work.

Words cannot express my indebtedness to my Mother Gouri Bai, Father Har Prasad, Brother Amar Prakash Patel and all other family members, whose emotional support helped this thesis a successful pursuit.

Last but not the least ,I wish from my core of heart to the almighty for his blessings.

Place : IGKV Raipur

Date : 20/10/2022

Kp Patel
(Kamal Prakash)

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LIST OF NOTATIONS / SYMBOL

| Notations/Symbols | Description |
|-------------------|---------------------|
| m | Metre |
| cm | Centimetre |
| cm/hr | Centimeter per hour |
| cm ² | Square centimeter |
| cm ³ | Cubic centimeter |
| Ha | Hectare |
| Mm | Millimetre |
| Km | Kilometer |
| km ² | Kilometer square |
| m ² | Square metre |
| ° | Degree |
| ' | Minute |
| " | Second |
| No. | Number |
| % | Percent |
| + | Plus |
| - | Minus |
| × | Multiply |

| | |
|----|-------------------|
| °C | Degree centigrade |
| < | Less than |
| > | Greater than |
| H | Hour |

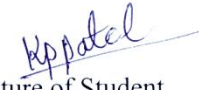
LIST OF ABBREVIATIONS

| Abbreviation | Full forms |
|--------------|-------------------------------------------|
| ICAR | India Council of Agricultural Research |
| Argil. | Agricultural |
| Avg | Average |
| C.G. | Chhattisgarh |
| Agril. Engg. | Agricultural Engineering |
| Depl. | Depletion |
| Engg. | Engineering |
| et al. | Et Alia (and others) |
| etc. | Etcetera (so on) |
| GEN | General |
| GIS | Geographic Information System |
| GOI | Government of India |
| Govt. | Government |
| i.e. | id est (that is) |
| IGKV | Indira Gandhi Krishi Vishwavidyalaya |
| IMD | India Meteorological Department |
| IWMP | Integrated Watershed Management Programme |
| M.Tech. | Master of Technology |
| Max | Maximum |
| NIH | National Institute of Hydrology |
| RF | Rainfall |

THESIS ABSTRACT

- a) Title of the Thesis : Effect of forest fire on soil physical characteristics.
- b) Full Name of Student : Kamal Prakash
- c) Major Subject : Soil and Water Engineering
- d) Name and Address of the Major Advisor : Dr. Vinay K. Pandey
Professor, Head (SWE) & Dean
SV College of Agricultural Engineering and
Technology & Research Station, Raipur (C.G.)
- e) Degree to be Awarded : Master of Technology
Agricultural Engineering
(Soil and Water Engineering)


Signature of Major Advisor


Signature of Student

Date:- 20/10/2022


Signature of Head of the Department

ABSTRACT

Forests play an important role in human life; they provide food, timber, and a variety of other items. Forests play a very important role in the hydrological cycle as well. Forest vegetation helps with rainfall, decreasing the velocity of raindrops, decreasing runoff and sediment output, and increasing infiltration rate. Trees are a natural groundwater recharge technique that also acts as a bio drainage system. Forests also provide shelter and protection to animals and other living things. India is an agricultural country, and much of its population lives in villages that are

surrounded by forest. Therefore, they depend on forest vegetation for their daily necessities like wood, resin, and other products.

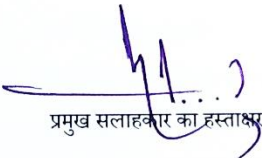
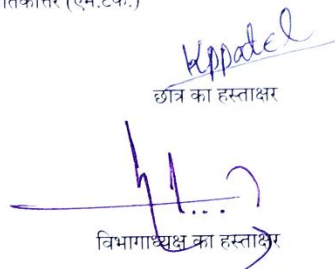
Forest fires are a major issue in every country. The causes of the forest fire were both natural and man-made. When a fire occurs in a forest, it destroys plants, animals, and other living things. After a forest fire, the soil's physical and chemical properties change. In India forest fires are most common in the Himalayan region. Forest fires were mostly affected in Uttarakhand and Himachal Pradesh. In these states, 90% of fires were caused by man, while 10% were caused by nature. The present study was therefore carried out to increase knowledge of the importance of fire effect on soil physical characteristics.

Forest fires are a major issue in every country. The causes of the forest fire were both natural and man-made. When a fire occurs in a forest, it destroys plants, animals, and other living things. After a forest fire, the soil's physical and chemical properties change. In India, forest fires are most common in the Himalayan region. Uttarakhand and Himachal Pradesh had the largest number of forest fires. In these states, 90% of fires were caused by man, while 10% were caused by nature. The present study was therefore carried out to increase knowledge of the importance of fire impacts on soil physical characteristics. This study's approach involved the use of two neighbouring plots (one burnt and one unburnt) of 15 forest sites in Uttarakhand with similar or equal rainfall inputs, pre-burnt plant characteristics, soil and geological formations, and other factors. To examine changes in soil qualities, burnt and unburned plots were employed as treatment and control plots (soil moisture holding capacity, infiltration rate, and permeability). Field and laboratory experiments were carried out using experiment plots. Double ring infiltrometer and Guelph permeameter tests were carried out in the field to measure the infiltration rate and permeability of the burned and unburnt areas. Samples were obtained from burnt and unburned plots and analysed in the lab for soil-water holding capacity and permeability. In the laboratory, soil water holding capacity and permeability were studied using a pressure plate apparatus and an ICW permeameter. Soil-water holding capacity and permeability were determined using samples collected from burned and unburned plots. In the laboratory, soil water holding capacity and

permeability were studied using a pressure plate apparatus and an ICW permeameter.

The change in soil physical properties was observed after conducting field and laboratory investigations. The soil moisture holding capacity of the burned plots was found to be slightly less than that of the unburned plots. At field capacity (0.33bar), the percentage loss in soil moisture holding capacity was -14.22 % to 10.38% , and at wilting point, the percentage decrease was -28.85 % to 39.41% (15 bars). The decrease in soil moisture holding capacity can be linked to a decrease in organic matter content, which is the primary controlling parameter for soil moisture holding. Infiltration rate percent change varies between -6.19% and 25% at low burned sites and -12.09% to 50% for moderately burned sites. The permeability rate decreased from unburned to burned forest locations. It ranges from -5.04% to 97.56% for low burnt areas and from -1.85% to 70.75% for moderately burned areas. Coagulation is caused by ash deposit as well as its downward flow during the monsoon season and the establishment of soil aggregates, which act as an impervious type of media similar to a cement layer, reducing the rate of infiltration and resulting in a low permeability rate for burned sites when compared to unburned sites.

शोध सारांश

| | |
|------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| शोध का शीर्षक: | जंगल की आग का मिट्टी के भौतिक गुणों पर प्रभाव |
| छात्र का पूरा नाम: | कमल प्रकाश |
| प्रमुख विषय: | मृदा एवं जल अभियांत्रिकी |
| प्रमुख सलाहकार का नाम और पता: | डॉ. विनय कु. पांडे प्राध्यापक, विभागाध्यक्ष (एस डब्ल्यू ई) एवं अधिष्ठाता, एस.वी. कॉलेज ऑफ एग्रीकल्चरल इंजीनियरिंग एंड टेक्नोलॉजी & अनुसंधान केंद्र, रायपुर (छ.ग.), इंदिरा गाँधी कृषि विश्वविद्यालय, रायपुर |
| प्रदान की जाने वाली उपाधि: | कृषि अभियांत्रिकी में स्नातकोत्तर (एम.टेक.) |
|  प्रमुख सलाहकार का हस्ताक्षर |  छात्र का हस्ताक्षर |
| दिनांक: 20/10/2022 | विभागाध्यक्ष का हस्ताक्षर |

सारांश

वन मानव जीवन में एक महत्वपूर्ण भूमिका निभाते हैं; वे भोजन, लकड़ी, और कई अन्य सामान प्रदान करते हैं। जल विज्ञान चक्र में भी वन बहुत महत्वपूर्ण भूमिका निभाते हैं। वन वनस्पति वर्षा में मदद करती है, वर्षा की बूंदों के वेग को कम करती है, अपवाह और तलछट के उत्पादन को कम करती है, और रिसाव की दर को बढ़ाती है। पेड़ एक प्राकृतिक भूजल पुनर्भरण तकनीक है जो जैव जल निकासी प्रणाली के रूप में भी कार्य करती है। वन जानवरों और अन्य जीवित चीजों को आश्रय और सुरक्षा भी प्रदान करते हैं। भारत एक कृषि प्रधान देश है और इसकी आबादी जंगलों से घिरे गांवों में रहती है। इसलिए, वे अपनी दैनिक आवश्यकताओं जैसे लकड़ी, रेजिन और अन्य उत्पादों के लिए वन वनस्पति पर निर्भर हैं।

जंगल की आग हर देश में एक प्रमुख मुद्दा है। जंगल की आग के कारण प्राकृतिक और मानव निर्मित दोनों थे। जब जंगल में आग लगती है, तो यह पौधों, जानवरों और अन्य जीवित चीजों को नष्ट कर देती है। जंगल की आग के बाद, मिट्टी के भौतिक और रासायनिक गुण बदल जाते हैं। भारत में जंगल की आग हिमालयी क्षेत्र में सबसे आम है। उत्तराखंड और हिमाचल प्रदेश में जंगल की आग सबसे ज्यादा प्रभावित हुई है। इन राज्यों में, 90% आग मनुष्य के कारण लगी थी, जबकि 10% प्रकृति के कारण लगी थी। इसलिए वर्तमान अध्ययन मिट्टी की भौतिक विशेषताओं पर अग्नि प्रभावों के महत्व के ज्ञान को बढ़ाने के लिए किया गया था। अध्ययन की कार्यप्रणाली में उत्तराखंड में चयनित 15 वन स्थलों के दो पड़ोसी भूखंडों (एक जला हुआ और एक बिना जला हुआ) को समान या समान वर्षा इनपुट, पूर्व-जली हुई वनस्पति विशेषताओं, मिट्टी और भूवैज्ञानिक स्थितियों और अन्य कारकों को अपनाना शामिल है। मिट्टी के गुणों (मिट्टी की नमी धारण क्षमता, रिसाव दर और पारगम्यता) में परिवर्तन का आकलन करने के लिए जले हुए और बिना जलाए गए

भूखंडों का उपयोग उपचार और नियंत्रण भूखंडों के रूप में किया गया था। प्रयोग भूखंडों का उपयोग क्षेत्र और प्रयोगशाला जांच करने के लिए किया गया था। जले हुए और बिना जले हुए भूखंडों की रिसाव दर क्षमता और हाइड्रोलिक चालकता को मापने के लिए, डबल रिंग इन्फ्ल्ट्रोमीटर परीक्षण और गेलफ परमीमीटर परीक्षण क्षेत्र में आयोजित किए गए थे। जले हुए और बिना जले हुए भूखंडों से मिट्टी के नमूने एकत्र किए गए और मिट्टी-जल प्रतिधारण और पारगम्यता के लिए प्रयोगशाला में विश्लेषण किया गया। मृदा जल प्रतिधारण और पारगम्यता को प्रयोगशाला में एक प्रेशर प्लेट उपकरण और एक ICW परमीमीटर का उपयोग करके मापा गया।

मिट्टी के भौतिक गुणों में परिवर्तन खेत और प्रयोगशाला जांच करने के बाद देखा गया। जले हुए भूखंडों की मिट्टी की नमी धारण क्षमता बिना जले हुए भूखंडों की तुलना में थोड़ी कम पाई गई। खेत की क्षमता (0.33 बार) पर, मिट्टी की नमी धारण क्षमता में प्रतिशत हानि -14.22% से 10.38% थी, और गलने के बिंदु पर, प्रतिशत की कमी -28.85% से 39.41% (15 बार) थी। मिट्टी की नमी धारण क्षमता में कमी को कार्बनिक पदार्थ सामग्री में कमी से जोड़ा जा सकता है, जो मिट्टी की नमी धारण करने के लिए प्राथमिक नियंत्रण पैरामीटर है। कम जली हुई जगहों पर रिसाव दर प्रतिशत परिवर्तन -6.19% और 25% के बीच और मध्यम रूप से जली हुई जगहों के लिए -12.09% से 50% के बीच भिन्न होता है। असिंचित से जले हुए वन स्थानों में पारगम्यता दर घट गई। यह कम जले हुए क्षेत्रों के लिए -5.04% से 97.56% और मध्यम रूप से जले हुए क्षेत्रों के लिए -1.85% से 70.75% तक होता है। राख का जमाव, साथ ही मानसून के बाद के मौसम के दौरान इसकी नीचे की ओर गति, जमावट और मिट्टी के समुच्चय के निर्माण का कारण बनता है, जो सीमेंट की परत के समान एक अभेद्य माध्यम के रूप में कार्य करता है, इस प्रकार घुसपैठ की दर कम हो जाती है और इससे पारगम्यता दर कम भी होती है।

CHAPTER-I

INTRODUCTION

Forests have always been an important aspect of the human ecosystem. They are nature's greatest gift to humanity and play a vital part in its survival. They have been a major source of food, wood, and a range of other things, in addition to giving shelter and safety to a large number of living beings, including prehistoric man. Forests have benefited human life in a variety of material and psychological ways since ancient times, playing an essential part in social, economic, and religious activities.

Forest vegetation plays an important role in the hydrological cycle by intercepting rainfall, reducing the velocity of raindrops, reducing runoff and increasing water infiltration. Fire, common natural phenomena in forest ecosystems, is directly tied to forest hydrology. The influence of fire on water is reflected indirectly because post-fire changes in vegetation, surface cover, soil, and climate affect the water cycle, water quality, and aquatic life. The impact varies according to the severity and frequency of the fire. The impact varies according to the severity and frequency of the fire. Light wildfires or managed burns have little effect on the hydrology regime, but repeated burnings or strong flames can induce changes in the hydrological regime comparable to those caused by clear cutting.

Forest is defined by the United Nations Food and Agriculture Organization (FAO) as "land with a tree canopy cover of more than 10% and an area of more than 0.5 hectares." India is one of the few countries with a diverse biosphere. According to the Forest Survey of India Report for 2020, India has a forest cover of 7,12,249 km², accounting for 21.67 percent of the country's total geographic area. 2.89 percent of the country's geographical area is covered with trees.

Forest fires are natural forest disturbances that occur in the majority of terrestrial ecosystems. A forest fire in any ecosystem affects both the flora and the soil. However, the overall effect of forest fire on soil remains complicated; to some extent, it also helps sustain ecological variety and overall stability (Thompson *et*

al., 2009). The forest fire begins at the ignition site and spreads outward, leaving just a burned area behind. It is a widespread issue in both tropical and temperate woods throughout the country and the world. The abundance of flammable debris, high temperature, high wind speed, and sloping topography created favourable conditions for forest fires. (Attri *et al.*, 2020). Depending on the kind of vegetation burned, forest fires are also known as brush fires, bushfires, grass fires, hill fires, peat fires, vegetation fires, veld fires, and wild land fires. (Gupta *et al.*, 2014).

A Forest Survey of India report estimates that roughly 55% of the nation's forest lands are at risk of fire (ranging from 50 % in some states to 90 % in others). The risk of serious fire damage is around 6% of the forest. Fires caused by natural sources are quite rare in India. Ninety-nine percent of the nation's forest fires are caused by human activity. It is generally known that most of these fires are purposefully started by people and are closely related to their socioeconomic circumstances. (Attri *et al.*, 2020)

According to the Ministry of Environment and Forests, Government of India, 3.73 Mha of forests are affected by fires annually in India (Reddy *et al.* 2017b). According to information from the FSI's National Forest Inventory programme, forest fires have a mild impact on 54.40 percent of forest areas and a moderate impact on 9.89% of them. Consequently, almost two-thirds of our forestland is at risk of forest fires. According to the ISFR, approximately 33,000 fire alarms from the MODIS sensor were produced by the FSI over all of India in 2016, and this number increased in 2017. From the MODIS sensor, FSI generated 37059 fire alarms in India in 2018 (FSI, 2019b). Nearly all of the 647 districts and states in the country encounter forest fires each year. Additionally, according to one estimate, approximately 49,000 km² of forests an area greater than Haryana were destroyed in 2014 alone (Reddy *et al.* 2017b)

Uttarakhand has the highest rate of forest fires in India. Every year, several hectares of forest burn in this state as a result of fires, which can occur naturally or be caused by humans. In Uttarakhand Forest fire comes in the month of April-May because of this is peak season (summer season) in Uttarakhand. This is the time of year when the forest is very dry and pine dry leaves are scattered throughout the

area, making it easily flammable. Because "Shisha" by product is found in pine trees, which is utilised as fuel in this region, and because this product is present in pine trees, this tree can also help in heavy forest fires. According to forest service records, there were 989 fire incidents in the state's forests between October 1, 2020 and April 4, 2021. According to estimations, the flames destroyed 1,297.43 hectares of woodland.

Fire has a wide range of effects on forest resources. Regeneration is destroyed or dies back, causing the formation of a new crop to be delayed and the cycle to be extended. In Maharashtra, it is common practice to chop young trees to the ground when freshly planted Teak plantations are evaluated. This encourages a new, robust shoot from the base, but growth is lost for at least a year. Fires have been reported to significantly affect the regeneration of major tree species in the Sal Forest (Maithani *et al.*, 1986). Similarly, chir pine regeneration is destroyed or slowed. After a fire, young eucalyptus plantations typically require replanting, and coppice regrowth dies back (or must be pruned down). In older crops, powerful flames can be deadly, but the trees have thick bark that protects them. Eucalyptus undoubtedly suffers more than native plants, and the effects of fires were reflected in lower stocking per hectare and poorer maturity yields.. Scorching from the tree's base reduces timber quality by damaging the cambium, resulting in faulty butt logs. Rot can be caused by a fungal infection that spreads through damaged tissues.

Several physical soil qualities, including soil structure, texture, porosity, wet ability, infiltration rates, and water holding capacity, can be altered by fire. Fire intensity, severity, and frequency determine the amount to which fire affects various soil physical qualities. Low-intensity fires do not burn the soil sufficiently to induce major changes in its physical qualities.

Water infiltration rates are reduced as soil porosity decreases and water-resistant layers formed. Soil organic matter loss and increasing bulk density can reduce soil water storage capacity. This leads to soil desiccation on flat terrain, particularly in the surface soil layer. It can significantly increase runoff, ash transfer, erosion, and mass wasting on steep terrain. Soil erosion can also be caused by just exposing soil surfaces. Without vegetation to reduce the impact of rainfall, bare soil

surfaces can develop a sealed surface layer, resulting in substantially greater rates of surface runoff. When ground cover, surface litter, and duff that protects the mineral soil are eliminated, surface erosion by wind or gravity can rise.

There is a knowledge gap regarding the impact of forest fires on soils, because few researches have been undertaken in this area. Soil is an important component of forest and woodland ecosystems because it regulates key ecological processes such as nutrient intake, decomposition, and water availability. Many of the key functions of the soil are influenced by the environment as it changes. These changes can have a major influence on the overall productivity of a forest. Understanding the influence of fires on soil characteristics is essential for overall forest ecosystem health, long-term success, and improved soil management via burnt forest ecosystem recovery dynamics.

The goal of this study was to close a knowledge gap on which soil qualities are related to burned and unburned forests and to see how physical properties of soil, infiltration rate, permeability, and soil moisture retention change before and after forest fires. The study included a variety of methods, including field and laboratory analyses and experiments based on various principles.

Objectives:

1. To assess change in soil moisture holding capacity of forest fire area.
2. To assess change in transmission characteristics due to forest fire.
3. To suggest the manmade practices for the better moisture holding capacity and transmission characteristics of forest fire area.

CHAPTER– II

REVIEW OF LITERATURE

This chapter deals with previous research work done by the various investigators on related topic under study. The review has been divided as per the objective and presented under following heads.

- 2.1 Soil moisture holding capacity of soil
- 2.2 Infiltration rate of soil
- 2.3 Permeability of soil
- 2.4 Effect of forest fire on soil

2.1 Soil Moisture Holding Capacity of Soil

Wang *et al.* (2013) investigated physical and hydraulic parameters of soil samples obtained from Sabina przewalskii forest (south-facing slope with maximum solar radiation), shrubs (west-facing slope with medium radiation), and *Piceacrassifolia* forest (north-facing slope with minimal radiation). A statistical study of the three slope features demonstrated that different plant covers might result in various soil bulk densities and variations in soil moisture retention. According to the soil water retention curves, the soil water storage capacity of the *P. crassifolia* forest and shrubs was 39.14 % and 37.38 %.

Crutchfield (2016) found that there was different moisture retention for different fields that is Mean moisture content for the entire growing season, and for all depths in fields 1, 2, 3, and 4, was 14.21%, 15.97%, 18.38%, and 18.42% respectively. Which was changes due to soil type, soil organic matter and soil texture.

Sujatha *et al.* (2016) there experiment was cleared that the incorporation of waste organic residues in Badharpally soil can convert it into a fertile soil as these treatments were able to increase the range of all the required nutrients and were also successful to fulfil the physical, chemical and biological requirements needed in a healthy soil and water holding capacity of soil. Organic matter behaves somewhat like a sponge, with the ability to absorb and hold up to 90 percent of its weight in water. A great advantage of the water-holding capacity of organic matter is that the

matter will release most of the water that it absorbs to plants. In contrast, clay holds great quantities of water, but much of it is unavailable to plants.

Onwuka *et al.* (2018) investigated the impacts of soil temperature on several soil parameters and plant growth and concluded that soil is a significant heat storage medium, and that soil temperature aids numerous biological activities. Soil temperature influences soil moisture content, aeration, and plant nutrient availability, all of which are critical for plant development. It also affects the amount of water in the soil, as well as its conductivity and plant availability.

Rasyid *et al.* (2018) studied was confirmed the function of organic matter incorporation into soil continuously in improving soil water retention and plant growth environment. The effect of plastic mulch and nitrogen was not significant in soil organic matter. Water retention generally increased after twice the addition of organic matter into the soil.

Kausar *et al.* (2020) conducted their experiment on six sites for variation in soil moisture retention and there data regarding soil moisture contents showed a significant ($p \leq 0.05$) increase in availability of soil moisture contents by the addition of gypsum and green manuring alone and in combination as compared to control and farmer practice. Results revealed that the maximum soil moisture contents (15.94%) at site 4 in 3rd year were recorded where combination of gypsum and green manuring applied and almost similar results were observed at all the experimental sites while the lowest moisture contents (5.00%) was recorded at site 1 in 1st year of experiment.

Panagea *et al.* (2021) they examined the addition of organic materials alters soil structure, and it is far more probable that the improved soil structure enhances water availability owing to more macro and mesopores than the greater water holding capacity per soil volume created by an increase in soil organic carbon. Even under long-term wet conditions, the improved structure formed by greater amounts of more stable soil organic carbon, as well as the increase in soil water retention, are significant variables contributing to increased water penetration.

2.2 Infiltration Rate of Soil

Chandrashekaram *et al.* (1987) analyzed infiltration rate of five major soil group of soil and Infiltration rate were found to be exceptionally higher in the case

of laterite, red loam and coastal soils. For these soils the infiltration rate varies from 5 cm/h to 24cm/h. On the other hand, the black and riverine alluvium soils exhibited marked lower values varying from 0.2 to 1.2 cm/h.

Selim *et al.* (2011) they found that the infiltration rate in the cultivated field was initially low but gradually increased to attain a stable (constant) value of 18 mm/h. This low value is most likely related to soil composition and the initial high water content of the soil as a result of long-term water bonding during cultivation. In the natural field, the infiltration rate was initially high but gradually dropped to reach a stable (constant) value of 60 mm/h. In comparison to the first location, the rate of infiltration was high. The high initial infiltration rate is caused by the soil's low initial water content and the existence of deep vertical fractures in natural soil.

Kumar *et al.* (2014) used models to compare observed infiltration rates in the field with estimated infiltration rates. Single-ring and double-ring infiltration rates are estimated in the field using single-ring and double-ring infiltration rates. The infiltration rate is calculated using Horton's Infiltration Model and Horton's, Kostikov, and Green-Ampt models. The double ring infiltrometer was shown to have a greater infiltration rate than the single ring infiltrometers of 15 cm and 30 cm. According to the study's findings, a consistent rate of infiltration happens in a short period of time. A variable infiltration model was discovered. Horton's model was found to be the best fitting model based on correlation coefficient and standard error, with a high degree of correlation coefficient and a low standard error.

Champatiray *et al.* (2014) revealed that in both methods, the rate of infiltration is the same. Finally, because the garden soil had higher hydraulic conductivity values computed by Horton's equation, it penetrated faster than the forest soil. The soil shows high conductivity rates in September and October than in other months. Because of the large fractures in the soil and the low initial water content, the natural soil had a higher infiltration rate than the other areas.

Jejurkar *et al.* (2015) carried out their experiment on different soil conditions of red soil and used different infiltration models for results. They observed that the constant infiltration rate of red soil in ploughed, unploughed, compact, and continuous fallow land use patterns was 3.6cm/h, 2.4cm/h, 1.2cm/h, and 4.8cm/h, respectively. Soil conditions influence the infiltration rate. Because of the increase

in porosity, the cultivated land has shown a significant influence of greater infiltration rate. As time passes, the average infiltration rate falls, indicating that the soil is becoming more saturated. Horton's model can accurately predict infiltration rate in ploughed, compact, and continuous fallow land in red soils, whereas the Modified Kostiakov model can predict infiltration rate in unploughed soil.

Patle *et al.* (2018) carried out to estimate the infiltration rate from soil parameters using a regression model for agricultural land. The bulk density and particle density of the soil were determined to be 1.412–1.716 g/cm³ and 2–3.03 g/cm³, respectively. The basic infiltration rate has varied between 0.3 and 6.8 cm/h. Sand, particle density, and organic carbon content all exhibit positive correlations with infiltration rates of 0.75, 0.18, and 0.22, respectively, but silt, clay, bulk density, and moisture content all have negative correlations of 0.41, 0.73, 0.33, and 0.22.

Arsyad *et al.* (2019) studied the aspects of infiltration in natural forests in Hasanuddin University's teaching forest in Maros Regency. They determined that high-density natural forests had the highest infiltration rate value, whereas moderate-density natural forests had the lowest infiltration rate value.

Das *et al.* (2019) used a double ring infiltrometer to measure infiltration in Guwahati. Eastern Retreat had the greatest infiltration rate at 10.73cm/hr, while Bonda had the lowest at 1.73cm/hr. Soil tests were also done to identify the soil type and how the infiltration curve varied over time for each soil type. Slow-moderate infiltration occurs in loamy soil, moderate infiltration happens in sandy loam soil, and moderate-rapid infiltration occurs in sandy soil.

2.3 Permeability of Soil

Mishra (2002) studied the effect of *Dalbergia sissoo* plant on soil physical and chemical properties. The ameliorative effect of *Dalbergia sissoo*, planted on sodic land at Sultanpur, India, in a tropical environment, was studied at 3, 6 and 9 years of age. The soil properties of the sites improved significantly, showing marked reduction in pH, electrical conductivity (EC) and exchangeable sodium percentage (ESP) and an increase in organic carbon, nitrogen and availability of nutrients in the soil. Planting *D. sissoo* caused significant improvement in the soil permeability. The mean soil permeability in 0-10 cm soil depth was 0.300×10^{-10} cm² in the control, which increased to 0.980×10^{-10} and 2.133×10^{-10} cm², respectively, in the 3- and 6-

year-old plantations. However, after 9 years of planting the soil permeability increased to $11.690 \times 10^{-10} \text{ cm}^2$ from $0.370 \times 10^{-10} \text{ cm}^2$.

Goh *et al.* (2015) created a modified triaxial apparatus for measuring the permeability and shear strength of unsaturated soil. The equipment has been proven to be capable of measuring the permeability and shear strength of the same specimen in several cycles of drying and wetting routes for three distinct sand–kaolin mixes. During the testing, the water volume change, total volume change, pore-air, pore-water, and cell pressures, as well as room and water temperatures, were all measured and recorded using the modified triaxial apparatus.

The permeability of sand–kaolin specimens on drying pathways is greater than that of sand–kaolin specimens on wetting roads. This might be related to the soils' hysteresis effects during drying and wetting. The changes in permeability between the first and second cycles of drying and wetting routes are revealed to be more substantial than those between the third and fourth cycles of drying and wetting paths. The results demonstrate that the features of the permeability of sand–kaolin specimens are comparable to the characteristics of the sand–kaolin specimens' drying and wetting SWCCs.

Gobinath *et al.* (2015) investigated on the effect of reinforcing a landslide-affected soil with the roots of a locally accessible plant on the soil's strength and permeability. The effects of changing the lemon grass root content in the soil on the permeability of soil samples with varied densities, the permeability of the root-reinforced soil decreases with increasing lemon grass root content for soil samples with densities of 1200 kg/m^3 and 1450 kg/m^3 . However, the effect of varying the lemon grass root content on a soil sample with a density of 1600 kg/m^3 does not appear to be clearly characterised. The overall decrease in soil permeability with increased lemon grass root content can be attributed to the filling of empty areas in the soil by the roots. The general decrease in permeability of the soil samples with increased lemon grass root content can be attributed to the root system covering empty areas in the soil. The pore-water pressure in the root-reinforced soil is reduced as a result.

They determined that the application of the lemon grass root lowered soil permeability in general. The mixing of the soil sample with 4 percent lemon grass

root lowered its permeability by 29.9 percent and 56 percent, respectively, for samples with densities of 1200 kg/m^3 and 1450 kg/m^3 .

Shil and Pal (2015) investigated the permeability and volume change behaviors of soil stabilized with fly ash. The maximum dry density (MDD) of NIT Agartala soil decreases as fly ash concentration rises, but the optimum moisture content (OMC) rises. The hydraulic conductivity (k) values in soil samples, fly ash, and a soil-fly ash mixed sample were given throughout a seven-day period. The nearby silty soil has a hydraulic conductivity of $3.38 \times 10^{-6} \text{ cm/sec}$. The rate of permeability increased as the amount of fly ash in mixed samples increased. The hydraulic conductivity values were within the range of 3.43×10^{-6} to $2.21 \times 10^{-6} \text{ cm/sec}$ and 2.93×10^{-6} to $1.58 \times 10^{-6} \text{ cm/sec}$ with percentages of fly ash 20% and 30% respectively. The addition of fly ash enhances the permeability of mixed samples by increasing the size of silt particles in the soil.

Saghari *et al.* (2015) worked on the evaluation of Permeability Characteristics of Polymer Fibers-reinforced Soil through Laboratory Tests. Permeability tests on polymer-fibre reinforced soil using the Falling-Head technique show that increasing the weight percentage of fibres initially has a rising tendency on the permeability coefficient of fine-grained soil, but when it surpasses the 0.6 percent limit, it declines. Permeability testing on polymer-fibre reinforced soil using the Falling-Head method demonstrates that increasing the length and weight percentages of fibres initially raises the permeability coefficient, and when it passes 0.6 percent, a declining trend begins.

Sharma and Trivedi (2016) They conducted an experiment to determine the variability in permeability of sandy silt soil by mixing it with fly ash. The coefficient of permeability/hydraulic conductivity (k) for the local sandy silt-soil was calculated to be $3.92 \times 10^{-5} \text{ cm/sec}$. The rate of permeability decreases as the fly ash concentration in mixed samples increases. The hydraulic conductivity values were between 3.92×10^{-6} and $4.9 \times 10^{-6} \text{ cm/sec}$ for fly ash percentages of 5, 10, 15, and 20%, respectively. The addition of fly ash increases the size of silt particles in soil, making the mixed samples coarser and increasing permeability. The rate of permeability of sandy silt soil reduces as the amount of fly ash in the soil increases.

2.4 Effect of Forest Fire on Soil

Certini (2005) reviewed that the impact of fire on natural water repellence of soil, the formation of a continuous water-repellent layer a few centimetres beneath the surface regularly improves soil repellence. It suggests restrictions in soil permeability and, as a result, increased runoff and erosion, as well as increased bulk density due to aggregate collapse and blockage of voids by ash and scattered clay particles; as a result, soil porosity and permeability diminish.

Verma and Kumar (2012) reviewed that both managed fire and wildfire have a significant impact on forests. These fires increase the repellency of water in forest soil, resulting in infiltration and soil erosion. Fires also have an impact on soil colour, pH, bulk density, texture, and other factors.

Berber *et al.* (2013) they studied on the Effects of surface fire on soil properties in a mixed chestnut-beech-pine forest in Turkey. For this research, after a surface fire in December 2011 in Bursa, Turkey, a mixed forest stand dominated by *Castanea sativa* (sweet chestnut), *Fagus orientalis* (oriental beech), and *Pinus nigra ssp. pallasiana* (Anatolian black pine) was studied. Soil samples were obtained from burnt and unburned (control) places at two depths, 0-15 and 15-30 cm, 1 week after the fire and 7 months later in July 2012.

The findings revealed that while fire had no effect on soil nitrogen or organic matter, soil depth and sampling season did. The soil's electrical conductivity was stronger at the surface than in deeper layers, although it was unaffected by fire. The fire caused a significant increase in soil pH and a decrease in phosphate, and neither factor had recovered seven months later. The biological properties of the soil did not change significantly after the fire, although the season had a significant influence on enzyme activity. The physical components of the soil were minimally changed after the fire, resulting in more sand (%), less silt (%), and less clay (%) in the burned areas. The coarse-textured structure of the soil, on the other hand, remained unaffected by these changes (sandy loam). Except for a few variables, the current data show that soil chemical, physical, and biological properties in the studied mixed forest do not change much following surface fires. Finally, they came to the conclusion that surface fires had little impact on soil properties.

Fonseca *et al* (2013) researched on the effects of a prescribed fire, which was used at the Montesinho Natural Park (PNM) to study soil qualities and erosion processes. Chemical soil qualities were evaluated before the fire, two, six, and thirty-six months later. Despite the lower intensity of the fire, soil chemistry alterations were identified. Thirty-six months after the fire, soil organic matter, pH levels, and electrical conductivity were found to be identical to those seen before the fire. The same could not be said for the values of exchangeable bases, extractable potassium and phosphorus, and exchangeable acidity, which differed from those observed before the fire. Runoff and soil loss were measured in a series of 4 m² paired plots put in the research area 14 months after the fire, yielding yearly losses of 10.3 mm runoff and 1.3 Mg/ha soil loss. On average, soil permeability was classified as high or extremely high. The values of this measure, on the other hand, indicated a significant dispersion. It should be noted that the median values are substantially lower than the mean values, showing that most samples had non-unfavorable surface water flow conditions. The mean permeability values decreased over time, from 22 cm/h in the initial soil state to 14 cm/h soon after the fire. Two months later, the mean grew dramatically to 113 cm/h before dropping to 36 cm/h eight months after the fire, a number that differs greatly from the others.

Chandra and Bhardwaj (2015) found that fire has an influence on soil bulk density, and that bulk density increases due to aggregate collapse and blockage of voids by ash and scattered clay minerals, resulting in decreased soil porosity and permeability. Bulk density increases with ash depth.

Heydari *et al.* (2015) They investigated the impact of fire intensity on physical and biochemical soil qualities in Iranian Zagros oak (*Quercus brantii* Lindl.) woods. This research was carried out in the Miyan Tang district of Ilam Province in western Iran. The research area was 110 hectares, and soils were examined in regions classified by fire intensity: low (LS), high (HS), and medium severity (MS), as well as unburned (UB), which served as the control. They discovered that one year after the HS and MS fires, most of the soil physical-chemical and microbial basal respiration parameters investigated, particularly nitrate nitrogen and soluble or accessible potassium, were dramatically changed. Some alterations resulted in enhanced nutrient availability, such as soluble phosphorus,

nitrate nitrogen, potassium, and pH rises, which may be helpful. Some changes resulted in improved nutrient availability, such as soluble phosphorus, nitrate nitrogen, potassium, and pH rises, which may be helpful to plant development afterburning, particularly in the Zagros area, where soil fertility is frequently limiting to plant growth (Fattahi and Ildoromi2011). Other changes produced by moderate to high-severity fires, such as increased bulk density, decreased organic content, loss of tiny particle sizes (clays), loss of soil structure, and reduced moisture infiltration and moisture holding ability, might result in lower soil productivity. These alterations might lead to soil erosion after high-intensity fires. LS fire, on the other hand, had no influence on soil physical or chemical properties, nor on microbial respiration.

Allam *et al.* (2020) they studied on the effect of fires on certain properties of forest soils in western Algeria. In this study, Changes in the physicochemical and biological parameters of Aleppo pine forest soils in the semi-arid zone were found two years after the last fire. Only soil moisture remained considerably lower in the burned zone compared to the control zone among all physical characteristics studied. When it comes to chemical qualities, the only criterion that suffers is the rate of organic matter. In terms of biological features, the fire significantly reduced soil microorganisms by lowering basal respiration and microbial biomass.

The physicochemical property results demonstrate that, two years after the last fire, only the soil organic matter content and soil moisture are considerably changed, with lower rates in the burnt region compared to the control zone. A decrease in porosity induced by an increase in bulk and actual density causes a minor decrease in permeability and water retention capacity. In terms of the other chemical attributes, the recorded values were nearly identical, indicating that there was no substantial variation between the two zones.

Attri *et al.* (2020) reviewed that the Fire may alter several physical soil properties, such as soil structure, texture, porosity, wettability, infiltration rates, and water holding capacity (Jhariya and Raj, 2014).By devouring soil organic matter, intense burns may have a negative impact on soil physical qualities. Because soil organic matter holds sand, silt, and clay particles together, loss of soil organic matter results in a loss of soil structure. Severe fires can increase soil bulk density and

decrease soil porosity by modifying soil structure through the loss of macrospores (> 0.6 mm in diameter). Intense fires (more than 400 degrees Celsius) can also permanently alter soil texture by aggregating clay particles into stable sand-sized particles, making the soil texture coarser and more erodible.

By driving hydrophobic chemicals in the litter downward through the soil profile, intense burns may also induce the creation of a water-repellent soil layer. These hydrophobic organic molecules cover soil aggregates or minerals, forming a water-resistant layer parallel to the surface. Water-repellent soil layers are said to form at temperatures of 176-288 °C and be destroyed at temperatures of > 288 °C. Water resistant layers that are too thick can prevent water from infiltrating, causing runoff and erosion.

Parwada *et al.* (2020) their study was conducted on a long-term fire research trial in the semi-arid part of Eastern Cape Province, South Africa. The study compared the influence of different controlled fire frequency on pH, C, N, P, Ca, Mg, Cu, Zn, Mn, Na levels, and C:N ratios to determine the impact of outbreak on soil parameters. The treatments were no burn (control), sexennial, quadrennial, triennial, biennial, and yearly burns set out in uniform blocks at random. For soil sample from 0 to 75 mm depth, a line intercept sampling approach was utilised. The frequency of fire burning has a significant effect on soil chemical characteristics (P 0.05). The triennial frequency treatment had higher levels of C, Mg, and Ca than the other frequency treatments. There were significant positive relationships between N and P, Ca and Mg and pH, and Ca and Mg content and fire frequencies. Apart from triennial, the content of C and other components was lowered in the majority of burning frequencies. The triennial burning frequency could be an excellent choice for veld management.

Kamble (2020) researched on Impacts of Controlled Forest Fires on Soil Properties in Gadchiroli Forest Circle, Central India. As a result, if forest fires were controlled, they would replace the soil with carbon, resulting in plant growth and contributing to an increase in biodiversity. The soil water retention capacity before and after controlled forest fires was measured. Before a controlled forest fire, the minimum water retention capacity was 22.68 %, with a high of 37.32 % and an average of 29.87 %. After a controlled forest fire, it was decreased to a low of 21.58

% and a maximum of 34.63 %, with an average of 29.91 %. Before and after a controlled forest fire, the average water holding capacity value was comparable. Out of six sampling locations, half (n = 3) showed an increase in soil water holding capacity, while the other half (n = 3) showed a decrease in capacity. Kothari has the greatest improvement in water storage capacity (3.86%), followed by Ghot (1.99%). The largest drop in water storage capacity reported in Talwada was 3.37%. The average bulk density of the soil before and after a controlled forest fire in the selected sampling area was 1.03 g/cm³, which increased to 1.10 g/cm³ after a controlled forest fire.

Kim *et al.* (2021) found that the forest fire in South Korea's pine forest (dominated by *P. densiflora*) had physical and chemical effects on soil qualities. As a result of the collapse of the kaolinite structure, soil heating can produce thermal change of soil aggregation during a fire. The burned areas in the study area had higher soil water repellency than the unburned areas.

CHAPTER– III

MATERIAL AND METHOD

The present study entitled “**Effect of forest fire on soil physical characteristics**” was carried out at the National Institute of Hydrology, Roorkee (U.K.). This chapter deals with the materials and procedures employed in the experimental study, which included soil sampling followed by laboratory analysis of samples at the Soil and Water Laboratory, Department of Environmental Hydrology Division, National Institute of Hydrology (NIH) Roorkee. The information regarding the study area and other details are presented in the following sections.

3.1 Study Area

Uttarakhand, formerly Uttaranchal, is an Indian state in the country's northern region. It is bounded on the northwest by the Indian state of Himachal Pradesh; on the northeast by the Chinese Tibet Autonomous Region; on the southeast by Nepal and on the south and southwest by the Indian state of Uttar Pradesh. Its capital is Dehradun. Uttarakhand located at 30.0668° N latitude and 79.0193° E longitude. Uttarakhand has a land area of 53,483km², accounting for 1.63 % of the country's total land area (Forest Survey of India).

Uttarakhand's geography is extremely diverse, with snow-capped peaks, glaciers, deep valleys, roaring streams, lovely lakes, and a few sections of dusty plains in the south.

Uttarakhand has four primary forest types: alpine meadows in the far north, temperate forests in the Great Himalayas, tropical deciduous forests in the Lesser Himalayas, and thorn forests in the Siwalik Range and sections of the Tarai. Official figures show that more than 60% of Uttarakhand is covered by forest cover; in reality, the coverage is substantially lower. The forests not only supply timber and firewood but also vast pasture space for animals. Permanent pastures cover only a small percentage of the state's overall geographical area.

Himalayan cedar (Deodar cedar), Himalayan (blue) pine, oak, silver fir, spruce, chestnut, elm, poplar, birch, yew, cypress, and rhododendron are common temperate forest tree species. The submontane tract is home to tropical deciduous forests of sal, teak, and shisham, all of which are hardwoods. In the south, thorn woods of dhak (a sort of blooming tree), babul (a species of acacia), and different shrubs grow.

For this research work, two neighbouring plots (one burnt and another unburnt) of 1 ha size would be selected; one of these two plots in each of the finally selected burnt forest polygons i.e., 15 Nos. in Uttarakhand, 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 1 and 2.

The experiments have been performed at these 15 burnt sites and the adjoining 15 unburnt/control sites so that the changes that might have resulted due to forest fires can be evaluated.

Table 3.1: Forest fire sampling location details:

| S. No | District | Range | Beat | Type Of Forest | Severity |
|--------------|-------------------|--------------------|----------------------|---------------------------------------------|------------------|
| 1 | Dehradun | Langha Range | Batoli-II Beat | Group 5- Tropical Dry Deciduous Forests | Low Burnt |
| 2 | Dehradun | Haridwar Range | Kharkhari North Beat | Group 3- Tropical Moist Deciduous Forests | Low Burnt |
| 3 | Haridwar | Chiriyapur Range | Kotawali Beat | Group 3- Tropical Moist Deciduous Forests | Low Burnt |
| 4 | Haridwar | Haridwar Range | Ranipur East Beat | Group 5- Tropical Dry Deciduous Forests | Low Burnt |
| 5 | Nainital | Kishanpur Range | Kishanpur South Beat | Group - TOF/Plantations | Low Burnt |
| 6 | Nainital | South Jaspur Range | Tumaria Beat | Group - TOF/Plantations | Low Burnt |
| 7 | Uttarkashi | Purola Range | Purola Beat | Group 9- Sub-Tropical Pine Forests | Low Burnt |
| 8 | Bageshwar | Bageshwar Range | Khabdoli_South Beat | Group 9- Subtropical Pine Forest | Moderately Burnt |
| 9 | Bageshwar | Dharamgarh Range | Pungar-I Beat | Group 9- Subtropical Pine Forest | Moderately Burnt |
| 10 | Bageshwar | Bageshwar Range | Chhatina Beat | Group 9- Subtropical Pine Forest | Moderately Burnt |
| 11 | Bageshwar | Bageshwar Range | Jaulkande Beat | Group 12- Himalayan Moist Temperate Forests | Moderately Burnt |
| 12 | Champanawat | Danda Range | Durgapipal Beat | Group 3- Tropical Moist Deciduous Forests | Moderately Burnt |
| 13 | Nainital | Nandhaur Range | Ratarao Beat | Group 3- Tropical Moist Deciduous Forests | Moderately Burnt |
| 14 | Nainital | Haldwani Range | Tanda Center Beat | Group 3- Tropical Moist Deciduous Forests | Moderately Burnt |
| 15 | Udhamsi ngh Nagar | Kilpura Range | West Kilpura-I Beat | Group – ToF/ Plantations | Moderately Burnt |

Table 3.2: Abstract details of location adopted in present study

| S. No | Beat | Longitude | Latitude | Altitude | Slope (%) | Area(Ha.) |
|--------------|---------------------------|----------------------|---------------------|-----------------|------------------|------------------|
| 1 | Batoli-II Beat | 77° 56' 41.129" E | 30°27' 16.965" N | 0-900 | 18-36 | 9.251 |
| 2 | Kharkhari North Beat | 78°10' 1.027" E | 29°59' 12.042" N | 0-900 | 0-3 | 45 |
| 3 | Kotawali Beat | 78°18' 46.505" E | 29°48' 19.676" N | 0-900 | 0-3 | 42.8 |
| 4 | Ranipur East Beat | 78° 8' 36.240" E | 29°57' 35.779" N | 0-900 | 11-18 | 331.3 |
| 5 | Kishanpur South Beat | 79°36' 10.083" E | 29°6' 38.254" N | 0-900 | 0-3 | 4.233 |
| 6 | Tumaria Beat | 78°55' 45.193" E | 29°22' 2.906" N | 0-900 | 0-3 | 36.84 |
| 7 | Purola Beat | 78°4' 26.879" E | 30°54' 5.968" N | 900-1800 | 18-36 | 537.1 |
| 8 | Khabdoli South Beat | 79° 44' 7.012" E | 29°52' 59.338" N | 1800- 2200 | 18-36 | 104.734 |
| 9 | Pungar-I Beat | 79°50' 44.327" E | 29°52' 52.520" N | 900-1800 | 18-36 | 232.8 |
| 10 | Chhatina Beat | 79°47' 23.668" E | 29°51' 43.070" N | 900-1800 | 18-36 | 73.39 |
| 11 | Jaulkande Beat | 79°45' 44.887" E | 29°49' 6.926" N | 900-1800 | 18-36 | 7.1192 |
| 12 | Durgapipal Beat | 79°53' 48.073" E | 29°8' 36.115" N | 0-900 | 11-18 | 27.4792 |
| 13 | Ratarao Beat | 79°45' 18.295" E | 29°10' 41.157" N | 0-900 | 18-36 | 5.88 |
| 14 | Tanda Center Beat | 79°26' 53.546" E | 29°6' 7.058" N | 0-900 | 0-3 | 86.0592 |
| 15 | West Kilpura-I Beat | 79°59' 57.145" E | 29°1' 47.897" N | 0-900 | 0-3 | 103.8 |

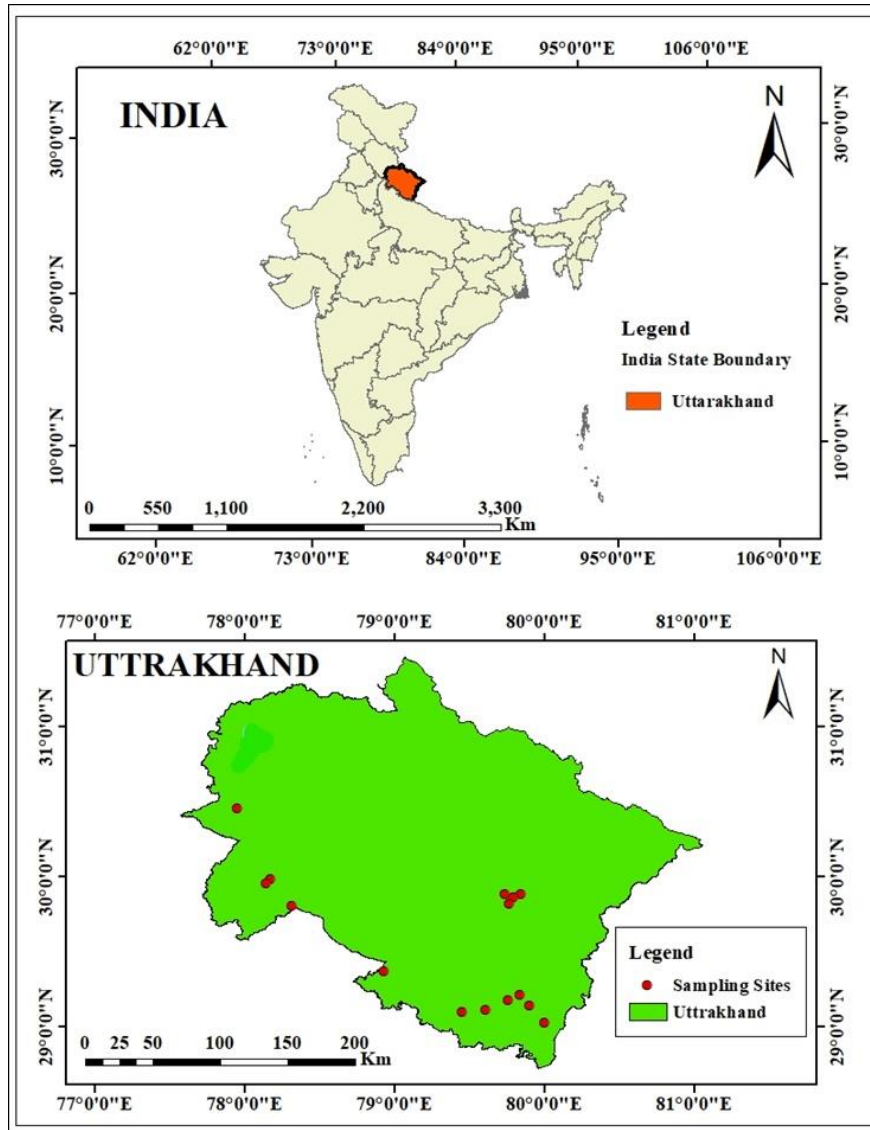


Figure 3.1 Location map

3.2 Data Collection and Analysis

3.2.1 Soil sampling

In this study, soil samples were collected at different burn severity sites to examine the direct effects on soil physical properties after forest fires. Plant litters and ash particles on the soil surface were removed prior to soil sampling. Two types of samples were collected from each site, one disturbed and the other undisturbed. Disturbed soil samples were used to determine soil moisture retention by pressure plate apparatus and undisturbed soil samples were used to assess the hydraulic

conductivity of soil by the ICW Permeameter. Soil sample was collected from the various site in two types:

1. Undisturbed soil sample: For undisturbed soil sample augers were used.
2. Disturbed soil sample: For disturbed soil collection spiral auger and spatula was used.

The stainless-steel sample rings (pF-rings) was used to collect undisturbed soil samples by manually pushing a cylindrical sample (50.0 mm in inner diameter and 51.0 mm in height) into the soil at the 0 -10 cm depth. Taking a ring sample should be done carefully. Check that the rings have an adequate amount of undisturbed soil and also that the sample doesn't attach to the cutting edges.

The simplest geotechnical investigations included utilising a backhoe to make a test hole where soil was taken from a bucket or by using hand augers to obtain a sample.



Figure 3.2 Soil sample collection from field

3.2.2 Field Measurements

3.2.2.1 Infiltration rate

The infiltration rate is determined as the amount of water per surface area per unit time, which enters into the soils. This rate can be calculated on the basis of the measurements and the DARCY's law. Double ring infiltrometer were used to estimate the infiltration rate of soil. It requires two rings: an inner and outer ring. The purpose is to create a one-dimensional flow of water from the inner ring, as the analysis of data is simplified. If water is flowing in one-dimension at steady state condition, and a unit gradient is present in the underlying soil, the infiltration rate is approximately equal to the saturated hydraulic conductivity.

An inner ring is driven into the ground and a second bigger ring around that to help control the flow of water through the first ring. Water is supplied either with a constant or falling head condition, and the operator records how much water infiltrates from the inner ring into the soil over a given time period. The ASTM (American Society for Testing and Materials) standard method specifies inner and outer rings of 30 and 60 cm diameters, respectively.

Both the inner and outer rings of double ring infiltrometer are driven into the ground for about 15 cm, using the suitable hammers. Water is supplied to inner and outer rings. The fall of the water level in the inner ring indicates the depth of water infiltrated. The amount of water to replenish the water level in the inner ring to reach a pre-determined level is measured which represents the amount of infiltration. The readings were taken at definite intervals till a constant amount of water to replenish the water level is obtained. This constant value is the ultimate infiltration capacity. The measurement using the double ring infiltrometer has been shown in Figure 2.2.

Horton's Equation

Horton made one of the first attempts to define the process of infiltration in 1933. He found that the infiltration capability decreased exponentially from a maximum rate to a final constant rate.

$$f = f_c + (f_o - f_c)e^{-kt} \quad (3.1)$$

where

f is the infiltration capacity (depth/time) at some time t

k is a constant representing the rate of decrease in f capacity

f_c is a final or equilibrium capacity

f_0 is the initial infiltration capacity

It shows that when the rainfall supply exceeds the infiltration capability, infiltration decreases exponentially. Although this equation is simple in form, issues in choosing appropriate values for f_0 and k limit its applicability. For a given time interval, the area under the curve represents the depth of water infiltrated during that interval. The infiltration rate is normally expressed in centimeter per hour and the time t in minutes, but different time increments can be used, and the coefficient k is calculated accordingly.



Figure 3.3 Field investigations using Double Ring Infiltrometer

Procedure

1. Hammer the 30 centimeter diameter ring into the soil at least 15 cm.
2. Hammer the 60 centimeter ring into the soil or build an earth barrier around the 30 centimeter ring to protect the soil surface when putting in the water.
3. Begin the test by pouring water into the ring until it is entirely full.
4. The water in the bund or between the two rings prevents water from spreading laterally from the infiltrometer.

5. Record the clock time when the test begins.
6. After 1-2 minutes, add water to the ring using a measuring cylinder and record how much water was added to the ring and how much water remains in the cylinder.
7. Keep records of the remaining water in the measuring cylinder. Maintain the same water level outside the ring as you do within.
8. Repeat the test until the decline in water level remains constant during the same time frame.
9. Keep in mind that at least two infiltration tests should be performed at a site to get accurate results.

3.2.2.2 Hydraulic conductivity/ permeability

Numerous methods for detecting permeability in the field have been developed. The Guelph Permeameter is used to determine a soil's saturated hydraulic conductivity. After measuring the soil water suction, the hydraulic conductivity of that soil at that soil water suction can be easily determined.

The "Guelph Permeameter" (GP) method measures field-saturated hydraulic conductivity simultaneously and in-situ. It is a constant head device that employs the Mariotte syphon principle to calculate field saturated hydraulic conductivity/ permeability, matrix flux potential, and soil sorptivity in the field.

It is an in-hole constant head Permeameter that measures the steady state rate of water recharge into unsaturated soil from a cylindrical well hole that maintains a constant depth of water. Constant head level is established and maintained in the well hole by adjusting the level of the bottom of the air tube, which is placed in the centre of the Permeameter. As the water level in the reservoir falls, a vacuum forms in the air space above the water. When the Permeameter is turned on, equilibrium was stablished. Only until air from the surrounding atmosphere enters at the top of the Air Tube, bubbles out of the Air Inlet Tip, and rises to the reservoir's top can the vacuum be relieved. When the water level in the well begins to drop below the Air Inlet Tip, air bubbles form and rise into the reservoir air space. The vacuum is subsequently partially released, and water from the reservoir refills the water in the well. The size of the opening and the form of the Air Inlet Tip are designed to keep

the well water level steady by limiting the diameter of air bubbles. When a constant level of water is maintained in a cylindrical shaped hole in the soil, a "bulb" of saturated soil with fixed dimensions forms very quickly. The form of this "bulb" is defined by the kind of soil, well radius, and water head in the well. The outflow of water from the well reaches a steady-state flow rate that can be monitored once the unique "bulb" shape has been developed. The rate of this steady outflow of water, along with the diameter of the well and the height of the water in the well, may be utilised to precisely measure the soil's saturated conductivity, matric flux potential, parameter, and sorptivity.

The rate of this constant outflow of water, together with the diameter of the well and height of water in the well can be used to determine the field saturated hydraulic conductivity of the soils.

The Guelph Permeameter is essentially an "in hole" Mariotte bottle constructed of concentric transparent plastic tubes. The apparatus comprises the following sections:

- i. Tripod assembly
- ii. Support tubes and lower air tube fittings
- iii. Reservoir assembly
- iv. Well head scale and upper air tube fittings
- v. Auxiliary tools

Tripod assembly

The tripod assembly is made up of a tripod base with adjustable tripod rushing and three detachable tripod legs with end tips. The tripod legs are placed into three leg sockets on the flexible tripod base. Tripod chain is used to secure and support tripod legs.

Support tube and lower air tube fittings

The reservoir assembly is held in place above the well hole by a support tube that transports water from the reservoir to the water outlet. The water outlet tip serves as the basis for the Permeameter and transfers the energy of the outflowing water to

the tip via the ribbed vents at the bottom, reducing soil erosion in the well hole. The air intake tip is linked to the bottom of the lower air tube and is used to adjust the well head height. The air restriction washer, located within the air intake tip, limits air flow to generate a steady, non-varying well head.

Reservoir assembly

It consists of an inner reservoir tube, an outer reservoir tube, a reservoir valve, a base, and a reservoir cap. It is used to measure the outflow rate of water when the Guelph Permeameter is in use. The reservoir cap serves as an airtight cover for the reservoir's top, as the air tube's seal, and as a support for the well head scale. The inner reservoir tube contains the middle air tube. The reservoir top has two ports: a Fill port and a Fill plug. The vacuum port is made up of three parts: an Access tube, a Neoprene tube, and a clamping ring. When the reservoirs are not initially completely filled, the vacuum port makes it easier to pull a vacuum. For experiments in very low permeability soils, such as clay soil, the inner reservoir must be used alone to ensure an adequate outflow rate. While working in moderate to high permeable soils, such as sands and loamy soils, the reservoir combination is utilized. In both cases, the inner reservoir tube is graduated in centimetres to measure the rate of water flow out of the reservoir.

The Guelph Permeameter shows the sealed state with the air inlet tip shut against the air tip seating washer. When air tube is uplifted, with accompanying air inlet tip and well height indicator, water flows from the reservoir down the inside of the support tube through the water outlet tip and into the well. The height of the air inlet tip determines the water height in the well.

The reservoir valve is included in the reservoir base. The base is responsible for connecting and seating the inner and outer reservoir tubes to the support tube. The position of the reservoir valve controls the flow of water. When the valve position is up or in the 6 O' clock position, both reservoirs supply water to the well hole. When the valve position is straight down or in the 12 O' clock position.

Well head scale and upper air tube fittings

An air tube coupling connects the upper air tube to the middle air tube. It serves as an extension to facilitate setting the well head after the well head scale is put in place.

Auxiliary tools

The Guelph Permeameter kit comes with a soil auger, a sizing auger, a well peep brush, a vacuum hand pump for pulling a vacuum in the reservoir, and a foldable water container for transporting water to the field. The well peep brush is used to remove any smear layer that may occur in the auger well hole and obstruct the natural flow of water out of the well into the surrounding soil.

Procedure

Before using the Guelph Permeameter in the field, it is necessary to do a site and soil evaluation, construct a well hole, assemble the Permeameter, fill the reservoirs, and insert the Permeameter into the well hole. The procedure outlined below should be followed:

1. A well hole was excavated at the site using a soil auger and a sizing auger. The soil augers are used to remove large volumes of soil and rock. The sizing auger is used as a finishing tool to create a properly sized well hole with consistent geometry and to clear debris from the well hole's bottom. The hole was dug with a soil auger to a depth that was 15 cm less than the anticipated final well depth. The 15 cm was drilled with a sizing auger to produce a debris-free well hole with a diameter of 6 cm and a flat bottom. Tripod was centered over the well hole and Permeameter was lowered so that the support tube entered into the well hole.
2. After the Permeameter has been installed, it is filled with water. After that, verification was performed to ensure that both reservoirs were connected.
3. The air inlet tip was gradually raised to achieve the 5 cm well head height (H_1).
4. Monitor the rate at which the reservoir's water level falls. If it's too slow, turn the inner reservoir valve to the 6 o'clock position, with the notch pointing straight

down. If it is high, turn the reservoir combination valve so that the notch is pointing straight up, or at 12 o'clock.

5. Outflow from Permeameter is measured. The rate of fall of water in the reservoir indicates this. Readings should be taken at regular intervals, usually every 2 minutes. The difference between consecutive readings divided by the time interval represents the rate of fall of water, R_1 , in the reservoir. Continue to monitor the rate of fall of water in the reservoir until it does not vary considerably in three consecutive time intervals. This rate is known as R_1 , and it is defined as the "steady-state rate of fall" of water in the reservoir at height H_1 , which is always 5cm in the standardized technique.
6. Determine a well head height of 10 cm (H_2). Slowly increase the air inlet tip to a height of 10 cm for the second well head. Monitor the rate of fall of water in the reservoir, R_2 , until a stable value of R_2 is measured.
7. The following equation can be used to compute the field saturated hydraulic conductivity/ Permeability, K_s ,

$$K_s = 0.0041 \times X \times R_2 - 0.0054 \times X \times R_1 \quad (3.2)$$

Where,

X is the Reservoir constant, equal to 35.19 where reservoir combination is used and 2.16 when only inner reservoir is used.

R_2 is a steady rate of fall of water in the reservoir for a head of 10 cm.

R_1 is a steady rate of fall of water in the reservoir for a well head of 5 cm.

3.2.3 Laboratory Analysis

3.2.3.1 Soil moisture holding capacity

Water retention in soil is defined as the water retained by the soil after it has gone through the pores to join other bodies of water such as groundwater or surface streams. The air holes that exist between soil particles are referred to as pores in the soil. Water retention is defined as the amount of water in the soil at a specific soil suction. By varying the soil suction and observing the changes in soil water content,

a water retention function may be determined. The water retention function is influenced by particle size distribution, clay mineralogy, organic content, and hysteresis.

Pressure plate apparatus is a standard method for determining the soil moisture retention curve. When an air pressure greater than atmospheric pressure is applied to a ceramic plate with saturated soil on it, the higher pressure forces excess water through the microscopic pores in the ceramic plate and out of the outlet system via the path provided by the screen. The diameter of the biggest pore determines the maximum air pressure that any specific wetted porous ceramic plate can withstand before allowing air to pass through. The smaller the pore size, the higher the air pressure required to allow air to pass through. The pressure that ultimately breaks down these water menisci is referred to as bubbling pressure or air entry value. Soil water will flow out of the soil sample until the unsaturated flow's metric potential equals the applied air pressure. The air pressure is then released, and the moisture content of the soil is calculated gravimetrically.

During a run, soil moisture will flow from each soil particle and out through the ceramic plate until the effective curvature of the water film through the soil is the same as at the pores in the plates. When this happens, equilibrium is attained and the moisture flow stops. When the air pressure in the chamber is raised, the flow of water from the samples resumes and continues until a new equilibrium is obtained. At equilibrium, the air pressure (positive force) in the Extractor and the soil suction (negative force) has an exact but opposite relationship.

All extraction work involves the use of a regulated gas pressure source. The most efficient source of supply is compressed air from a compressor. The water content of a sample that was at equilibrium with the pressure in the Extractor can be calculated by weight or volume.

The pressure plate apparatus is made up of a pressure chamber in which a saturated soil sample is placed on a porous ceramic plate through which the soil solution but not soil particles or air can flow. Ceramic plates are available in a variety of sizes. Each ceramic pressure plate cell is made up of a porous ceramic plate that

is covered on one side by a thin neoprene diaphragm that is sealed to the ceramic plate's borders. An interior screen between the plate and diaphragm allows water to flow through. An output stem that runs through the plates connects this channel to an outflow tube that connects to the atmosphere outside the extractor. To use the ceramic pressure plate cell, one or more soil samples are put on the porous ceramic surface and held in place by the appropriate height of retaining rings. Water is then applied to the soil samples and the porous ceramic plate. This is commonly accomplished by allowing an excess of water to stand on the cell's surface for several hours. When the saturation has been completed, the cell can be placed in the pressure extractor. Under regulated circumstances, air pressure is utilised to remove moisture from soil samples. The 1 bar ceramic plates are perfect for routinely determining the soil suction ranges of 1/1 bar and 1/3 bar. The 3 bar pressure plate cells are utilised in the 0-3 bar range. The 15 bar ceramic cells are generally used for soil moisture suction measurement in the 5-15 bar range.



Figure 3.4 Pressure plate apparatus



Figure 3.5 Sample preparation before putting in Pressure plate chamber



Figure 3.6 Pressure chamber

The moisture retention curve of a soil sample can be measured in general by equilibrating a soil sample at a succession of known tension values and calculating the amount of moisture each time. The soil moisture retention curve is obtained by

plotting the graph between the tension and the associated soil moisture value. Distinct soil types produce different retention curves.

Moisture retention curves or soil moisture characteristics are graphs that show the relationship between soil moisture tension and soil moisture content. The graph is known as a pF-curve when the tension is given as the logarithmic value of cm water. Curves of moisture retention are used:

- a) To calculate an index of accessible moisture in soil (the amount of water that may be readily absorbed by plant roots) and classify soils appropriately, for example, for irrigation applications.
- b) Determining the drainable pore space (effective pore space, effective porosity, specific yield) for drainage design,
- c) Checking changes in the structure of a soil caused by tillage, mixing of soil layers, etc.,
- d) Determining the relationship between soil moisture tension and other physical properties of a soil (e.g. capillary conductivity, thermal conductivity, clay and organic matter content)

Procedure

Soil samples usually are received in a moist and aggregated state which is unsuitable for the analysis. We must prepare the soil sample in accordance with the applicability of the analysis.

Soil samples were prepared after drying, light hammering and passing through 2.0mm sieve. The passing soils from 2.0mm sieve were used for determining soil moisture retention by applying 0.10, 0.33, 0.50, 0.70, 1.00, 3.00, 5.00, 10.00, 15.00 bars respectively. Each of these samples was tested against a one bar pressure plate at 0.10, 0.33, 0.50, and 1.0 bar. For measurement, a 3 bar by 3 bar plate, a 5 bar by 5 bar plate, a 10 bar and a 15 bar with a 15 bar pressure plate, and the following process should be used.

1. Collect soil samples from the field using an auger and air dry them in the shade. Soil samples should be crushed with a wooden hammer and sieved through a 2 mm aperture sieve.

2. The pressure plates were saturated for duration of 24 hours.
3. Level the soil samples inside the rubber rings that have been placed over the appropriate ceramic plates. Each plate can hold approximately 12 rings. To avoid the error, we took three rings of each sample. Every sample's final moisture content will be the average of all three rings.
4. Saturate the samples by immersing the plate containing the rings in a trough of water for 24 hours. Water should be just enough to reach the rings' upper edge.
5. After saturation, put the plates to their corresponding pressure chambers and apply the desired pressure until equilibrium is reached.
6. Connect the nylon tube and rubber sleeve to the pressure plate apparatus's outflow pipe.
7. Using a pipette or syringe, remove any surplus water from the ceramic plates.
8. Close all the unused outlets with the provided plug bolts.
9. Set the pressure in the pressure chamber to the desired level by adjusting the appropriate regulator.
10. As the pressure inside the pressure chamber rises, water will escape through the outflow tubes.
11. Water flow stops when soil water pressure normalises with air pressure.
12. Once equilibrium has been attained (there is no outflow of water), gently close the regulator to relieve the pressure in the chamber.
13. To open the chamber, remove the clamping bolts and lid.
14. As soon as feasible, transfer the samples to moisture boxes and weigh them on the high precision micro balance to record the moist weight of the samples in order to avoid water loss due to evaporation.
15. . These weighed samples placed in the oven at 105° C-110° C until the weight became constant after drying. The weighing was used to estimate the dry weight, and moisture by weight was calculated using the moist and dry weights of the sample.
16. Using the formula below, calculate the moisture content at the corresponding pressure based on these facts

Observation and calculation

Gravimetric moisture content of soil,

$$w (\%) = \frac{M_2 - M_3}{M_3 - M_1} \times 100 \quad (3.3)$$

Where

M_1 is mass of empty container

M_2 is mass of container + wet soil

M_3 is mass of container + oven-dry soil

3.2.3.2 Permeability

Hydraulic conductivity/ Permeability is a measure of the ability to conduct water under a unit hydraulic potential gradient and is defined as the volume, and rate of flow of water through a unit area of soil under a unit gradient. This term is based on the amount of moisture available. Saturated conductivity is the conductivity of the soil when it is saturated. The saturated hydraulic conductivity of soil including entrapped air is known as field saturated hydraulic conductivity.

The ICW Permeameter (Laboratory Permeameter) operates on the basis of measuring the difference in water pressure at both ends of saturated soil and monitoring the resultant flow of water to determine the saturated hydraulic conductivity of the soil sample. An undisturbed soil sample is required for measuring hydraulic conductivity with an ICW Permeameter.

The undisturbed soil sample was taken using Kopecky rings (50 mm diameter, 51 mm length, 1.5 mm thickness). The ring was fitted with an augur and hammered into the soil. The sample was taken to the laboratory and progressively saturated in the laboratory Permeameter container using an adjustable water head regulator. This saturation procedure was carried out for 24 hours. After that, we monitored the flow of water to determine the conductivity of the soil sample using ICW.



Figure 3.7 Undisturbed soil samples

Working

In a closed system water was pumped up from a storage reservoir (1) by a circulation pump (2) to an adjustable level regulator (4) via a filter in a closed system (3). The regulator is linked to a plastic container (5) and has a pipe leading back to the storage cistern. To decrease evaporation during measurement, a cover is placed over the cistern. Water flows directly from the main water supply into the level regulator in an open system. Because the level regulator and the container are both part of a communication vessel, the regulator will keep the water level in the container constant (the water in the regulator is level with the water in the container).

A saturate ring specimen (6) is placed in a ring holder, and a sieve disc is placed on top. In turn, the ring holder is put within a container. A plastic syphon (7) transports the oozing water from the sample to a burette (8). The burettes varied in length, allowing for simple manipulation of the stop cocks. A leak basin (9) collects water from the burettes and redirects it to the storage cistern. Water is carried from the leaking basin to a wash stand in an open system.

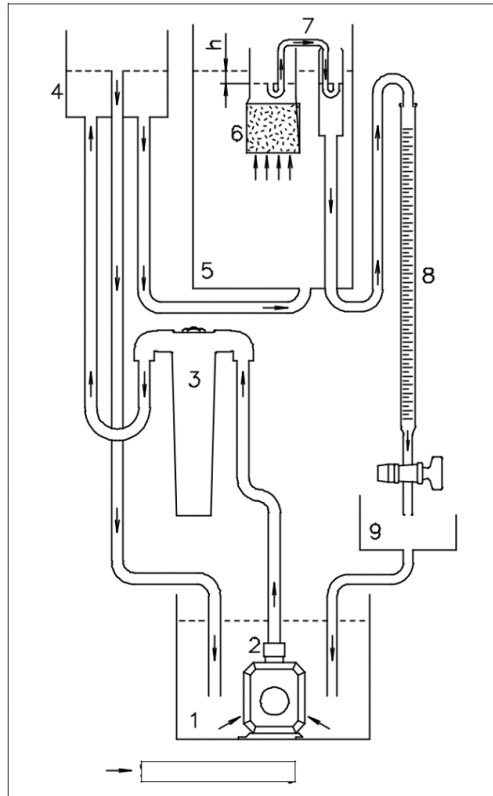


Figure 3.8 Line diagram of ICW Permeameter



Figure 3.9 Reading measurement of ICW Permeameter

The effect of the siphon is that it creates a difference in water level inside and outside the ring holder. This difference induces a continuous flow of water through the sample. A one-point (battery operated) measuring bridge is used to

measure the water levels (see figure 3.10). The measuring bridge measures the height h (see drawing at the right) of the water column.

By collecting the drained off water in a burette during a fixed period of time, the permeability coefficient(K-factor) of a sample can be established by applying a formula.(ICW manual).



Figure 3.10 Plastic container of ICW permeameter with saturated samples

The constant head approach was used for this layer experiment. Darcy's law is utilized in the constant head approach to calculate the Coefficient of Conductivity of Saturated Soil. Darcy's law states that

$$V = K \times i \times A \times t \quad (3.4)$$

Where,

V is volume of the water which is flowing through the sample (cm^3);

K is coefficient of permeability or “K-factor” (cm/day)

h is difference of water level inside and outside ring holder or sample cylinder (cm)

L is soil sample length (cm)

i is hydraulic gradient, or: h / L (Unitless)

A is cross-section surface of the sample (cm^2)

t is time required for V volume of water flow-through the sample (day)

During measuring the following parameters have been determined:

L and a is constants, which depends on the available type of sample ring.

V is volume measured using the burette (1 ml = 1 cm³)

t is length of time lapse

h is calculated with the water levels measured with the water level meter.

And calculate the K as:

$$K = \frac{V \times L}{A \times t \times h} \quad (3.5)$$

For calculating using permeability of the soil using Falling Head method, we use the equation:

$$K = \frac{aL}{A(t_2 - t_1)} \ln \frac{h_2}{h_1} + \frac{xaL}{A\sqrt{h_1 h_2}} \quad (3.6)$$

Where,

L, A and a is constants, depending on the type of sample ring or cylinder used.

V is volume measured in the burette (1 ml = 1 cm³)

$t_2 - t_1$ is time interval between the beginning and end of the measuring.

h_1 and h_2 is water level difference inside and outside the ring holder at respectively t_1 (start) and t_2 (end)

3.3 Statistical Analysis

Statistics is a branch of science dealing with the collecting, organisation, and analysis of data, as well as the drawing of conclusions from samples to the total population. Statistical methods are required for scientific study. In reality, statistical methods predominate scientific studies since they involve planning, designing, collecting data, analysing, drawing relevant interpretations, and publishing study findings. Furthermore, the findings of a research project are worthless raw data until they are investigated with statistical methods. As a result, determining statistics in research is important to justifying study findings.

3.3.1 Correlation coefficient (CC)

The correlation coefficient can be used to check the validity of empirical models. It explains the relationship between infiltration rate observed data and estimated data.

The correlation coefficient can have values ranging from -1.0 to 1.0. In other words, the numbers cannot be more than 1.0 or less than -1.0. A correlation of -1.0 represents a perfect negative correlation, whereas a correlation of 1.0 represents a perfect positive correlation. A positive relationship exist if the correlation coefficient is larger than zero. If the value is less than zero, the connection is negative. A value of zero implies that no relationship exists between the two variables.

The mathematical formula for computing cc is

$$CC = \frac{z\sum ab - (\sum a)(\sum b)}{\sqrt{z(\sum a^2) - (\sum a)^2} \sqrt{z(\sum b^2) - (\sum b)^2}} \quad (3.7)$$

Where

a is the calculated and b is observed values of the infiltration rate
z is the number of observations.

3.3.2 Root mean square error (RMSE)

The root mean square error is denoted as RMSE. When employing a statistical model to predict a numerical outcome, expected values usually match actual outcomes perfectly. This mistake is the difference between what was expected and what happened. To calculate the RMSE, square each error, average, and square the root.

$$RMSE = \sqrt{\frac{1}{N} \sum_{i=1}^n (a_i - b_i)^2} \quad (3.8)$$

where a is the calculated and b is observed values of the infiltration rate

N is the number of observations

CHAPTER– IV

RESULTS AND DISCUSSION

Field experiments and laboratory analysis were carried out for the assessment of various soil characteristics. Paired plot approach (selected burnt polygons as well as in the nearby unburnt locations in the similar forest) was used for the assessment of changes in various components of the forest site. This chapter covers the results obtained from field and laboratory investigations, the changes in transmission characteristics, and soil moisture holding capacity of soil in pre-fire and post-fire condition.

4.1 Assessment of Change in Soil Moisture Holding Capacity

The soil moisture holding capacity at different suctions viz. 0.1 bar, 0.33 bar, 0.50 bar, 0.70 bar, 1 bar, 3 bar, 5 bar, 7 bar, 10 bar and 15 bar has been measured using the pressure plate apparatus. The soil moisture holding capacity at 0.33 bar (field capacity) and 15 bar (permanent wilting point) are usually considered more critical for the hydrological assessments. Therefore, the soil moisture holding capacity at field capacity and permanent wilting point for the burnt and unburnt sites are summarized in table 4.1. The soil moisture holding capacity for the burnt plots have been found to be slightly on the lower side in comparison to those of the unburnt plots. This may be attributed to the reduction in organic matter content which is the main governing factor for soil moisture retention. According to result, moderately burnt polygons areas are found to be least affected as compare to some of the low burnt polygon areas. In moderately burnt sites % change in soil moisture retention has been observed 6.58% to 14.04% at field capacity and 4.4% to 15.41% at wilting point.

In table 4.1 percent changes shows between burnt and unburnt sites. Where at field capacity percent change ranges from -14.22% to 11.42% and at wilting point -28.85% to 39.41%. Here negative percent change means burnt site had high soil moisture holding capacity as compare unburnt sites and positive percent change means uburnt site had high soil moisture holding capacity as compare burnt sites.

Table 4.1: Soil moisture holding capacity at field capacity and wilting point for burnt and unburnt forest plots

| S. No. | Site Name | Soil Moisture Holding Capacity (%) | | | | | |
|--------|----------------------|------------------------------------|---------|----------|---------------------------|---------|----------|
| | | at Field Capacity(0.33 bar) | | | at Wilting Point (15 bar) | | |
| | | Burnt | Unburnt | % change | Burnt | Unburnt | % change |
| 1 | Batoli-II Beat | 12.26 | 13.68 | 10.38 | 6.01 | 6.7 | 10.30 |
| 2 | Kharkhari North Beat | 12.64 | 12.16 | -3.95 | 9.64 | 9.37 | -2.88 |
| 3 | Kishanpur South Beat | 19.61 | 21.82 | 10.13 | 3.29 | 5.43 | 39.41 |
| 4 | Kotawali Beat | 12.29 | 10.76 | -14.22 | 7.19 | 5.58 | -28.85 |
| 5 | Ranipur East Beat | 15.58 | 15.71 | 0.83 | 7.63 | 7.7 | 0.91 |
| 6 | Purola Beat | 15.07 | 16.16 | 6.75 | 7.38 | 7.92 | 6.82 |
| 7 | Tumaria Beat | 3.45 | 3.67 | 5.99 | 3.27 | 2.97 | -10.10 |
| 8 | Chhatina Beat | 11.27 | 12.36 | 8.82 | 5.41 | 5.93 | 8.77 |
| 9 | Durgapipal Beat | 13.49 | 15.23 | 11.42 | 6.61 | 7.46 | 11.39 |
| 10 | Jaulkande Beat | 17.63 | 15.46 | -14.04 | 8.64 | 7.58 | -13.98 |
| 11 | Khabdoli_South Beat | 10.38 | 11.25 | 7.73 | 4.98 | 5.4 | 7.78 |
| 12 | Pungar-I Beat | 12.21 | 13.07 | 6.58 | 5.86 | 6.27 | 6.54 |
| 13 | Ratarao Beat | 14.18 | 15.77 | 10.08 | 6.95 | 7.73 | 10.09 |
| 14 | Tanda Center Beat | 12.44 | 14.17 | 12.21 | 3.23 | 3.38 | 4.44 |
| 15 | West Kilpura-I Beat | 16.02 | 18.42 | 13.03 | 4.61 | 5.45 | 15.41 |

Results show that the highest % change in soil moisture holding capacity is recorded in the Kishanpur South Beat as 10.13% at field capacity and 39.41% at wilting point. Soil moisture holding capacity values of this site are higher due to loamy type soil texture. Loamy soils have higher holding capacity values as compare to sandy soils. Decrease in soil moisture retention may be attributed to the reduction in organic matter content which is the main governing factor for soil moisture holding capacity. Scarcity of plant cover, evaporation from the exposed soil and the effect of limited vegetation regrowth are also responsible factors for the reduction in soil moisture holding capacity. Allam *et al.*, (2020) observed slight decrease in soil moisture retention in burnt soil as compare to unburnt soil. He also observed increase in bulk density and real density, decrease in porosity, moisture content, and organic matter in burnt soil as compare to unburnt soil.

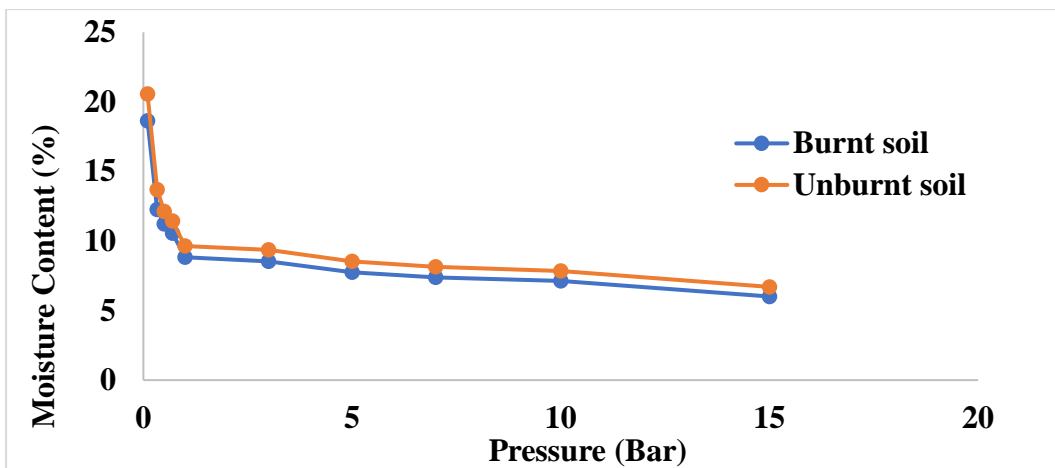


Figure 4.1 Soil moisture holding capacity at the burnt and unburnt sites in Batoli II beat (Low Burnt)

Soil moisture holding capacity curve for Batoli-II beat forest site is shown in figure 4.1. Batoli-II beat forest burnt site is low burnt site. Result shows slight decrease in soil moisture retention in burnt site as compare to unburnt site. This may be attributed to the reduction in organic matter content which is the main governing factor for soil moisture retention. At lowest pressure 0.10 bar, soil moisture retention is found as 18.62% and 20.56% for burnt and unburnt site, respectively. At field capacity 10.38% decrease was observed in burnt site. Soil moisture retention, at wilting point was observed 6.01% and 6.7% for burnt and unburnt site, respectively. There was 10.30% change was observed at wilting point in burnt and unburnt site.

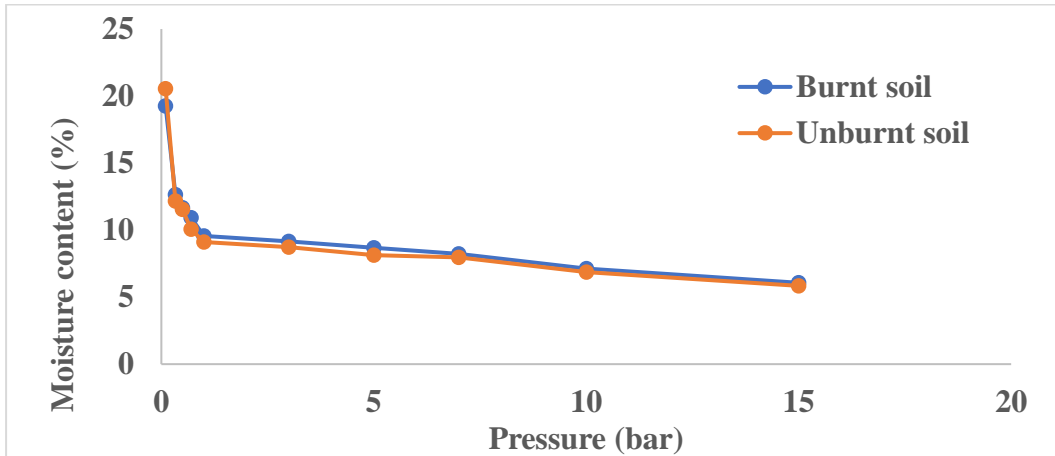


Figure 4.2 Soil moisture holding capacity at the burnt and unburnt sites in Kharkhari north beat (Low Burnt)

In Kharkhari north beat site, result shows slight increase in soil moisture retention in burnt forest site. There was 3.95% of increase at field capacity and 2.88% of increase at wilting point was observed in soil moisture retention in burnt site as compare to unburnt site. According to Scharenbroch *et al.* (2012), organic matter of soil were not affected by low intensity fires and sometimes this kind of fires are beneficial for soil. We can say that increase in soil moisture retention in Basegaon forest site is due to low severity of fire. Reason behind this was still not very clear due to fewer studies was done on fire effect on soil moisture retention. Soil moisture retention values at field capacity was found 12.64% and 12.16%, respectively for burnt and unburnt site. Soil moisture retention curve for Basegaon forest site is shown in figure 4.2.

Soil moisture retention curve for Burnt and unburnt plot of Kishanpur south beat forest site is shown in figure 4.3. Result shows slight decrease in soil moisture retention in burnt site as compare to unburnt site. Reduction in soil moisture retention was observed 10.13% at field capacity and 39.41% at wilting point. This may be attributed to the reduction in organic matter content and increase in bulk density which is the main governing factor for soil moisture retention. Soil moisture retention is decreasing as pressure increasing (Patil *et al.*, 2013). This site shows highest percentage change in both burnt and unburnt sites among all low burnt sites.

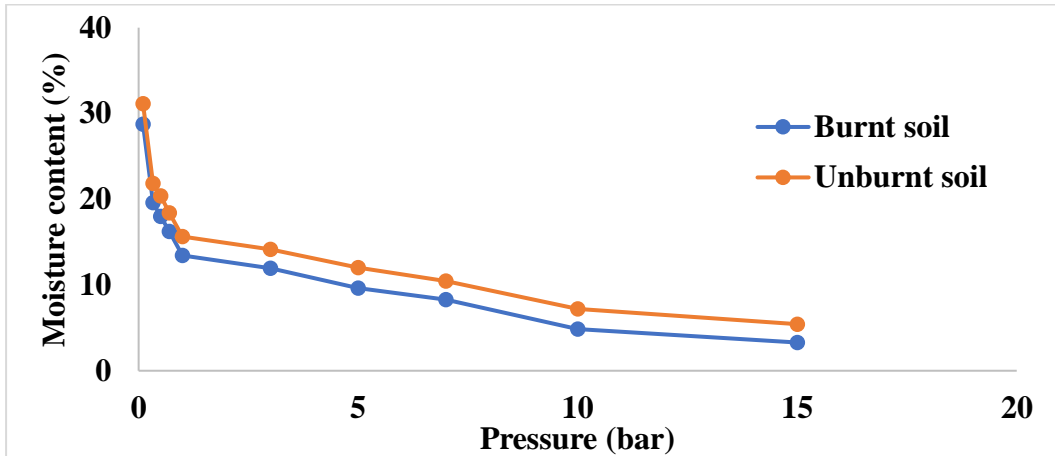


Figure 4.3 Soil moisture holding capacity at the burnt and unburnt sites in Kishanpur south beat forest site (Low Burnt)

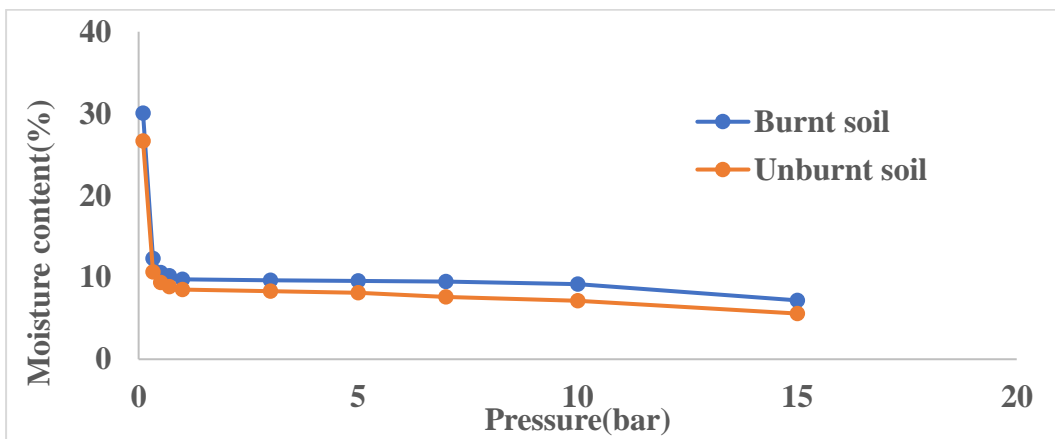


Figure 4.4 Soil moisture holding capacity at the burnt and unburnt sites in Kotawali beat forest site (Low Burnt)

In Kotawali beat forest site, result shows slight increase in soil moisture holding capacity in burnt forest site. There was 12.22% of increase at field capacity and 28.85% of increase at wilting point was observed in soil moisture retention in burnt site as compare to unburnt site. Soil moisture holding capacity values at field capacity was found 12.29% and 10.76%, respectively for burnt and unburnt site. Soil moisture holding curve for Basegaon forest site is shown in figure 4.19.

In Ranipur east beat forest site, result shows slight decrease in soil moisture holding capacity in burnt forest site. There was 0.83% of reduction at field capacity and 0.91% of reduction at wilting point was observed in soil moisture holding capacity in burnt site as compare to unburnt site. Soil moisture retention at field capacity was estimated 15.58% and 15.71% for burnt and unburnt sites, respectively.

Figure 4.5 shows the soil moisture retention curve for burnt and unburnt sites of Ranipur east beat forest site.

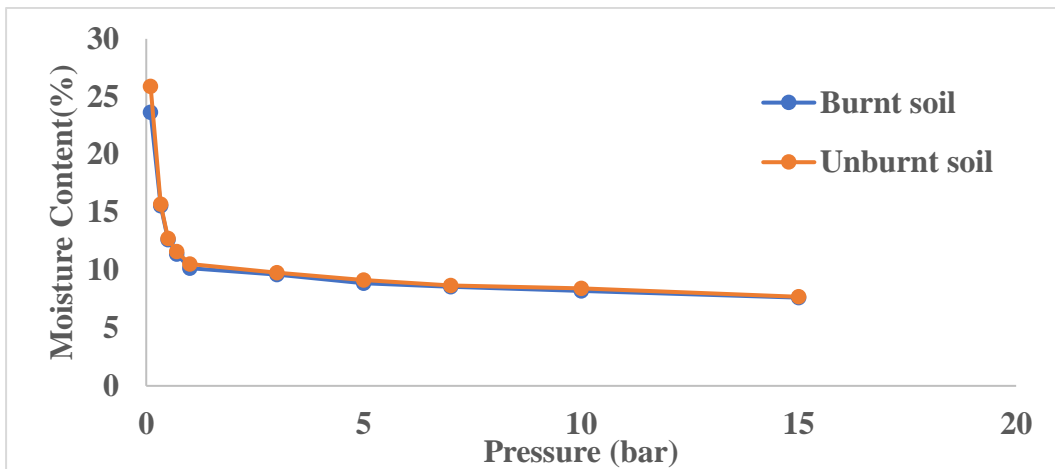


Figure 4.5 Soil moisture holding capacity at the burnt and unburnt sites in Ranipur east beat forest site (Low Burnt)

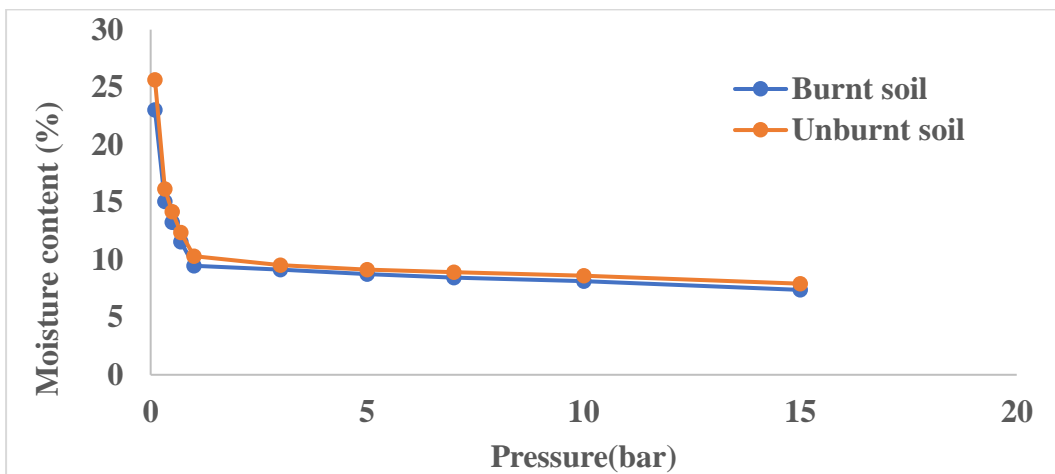


Figure 4.6 Soil moisture at the burnt and unburnt sites in Purola beat forest site (Low Burnt)

Soil moisture retention curve for Burnt and unburnt plot of Purola beat forest site is shown in figure 4.6. Result shows slight decrease in soil moisture retention in burnt site as compare to unburnt site. Reduction in soil moisture retention was observed 6.75% at field capacity and 6.82% at wilting point. Soil moisture retention at field capacity was estimated 15.07% and 16.16% for burnt and unburnt sites, respectively.

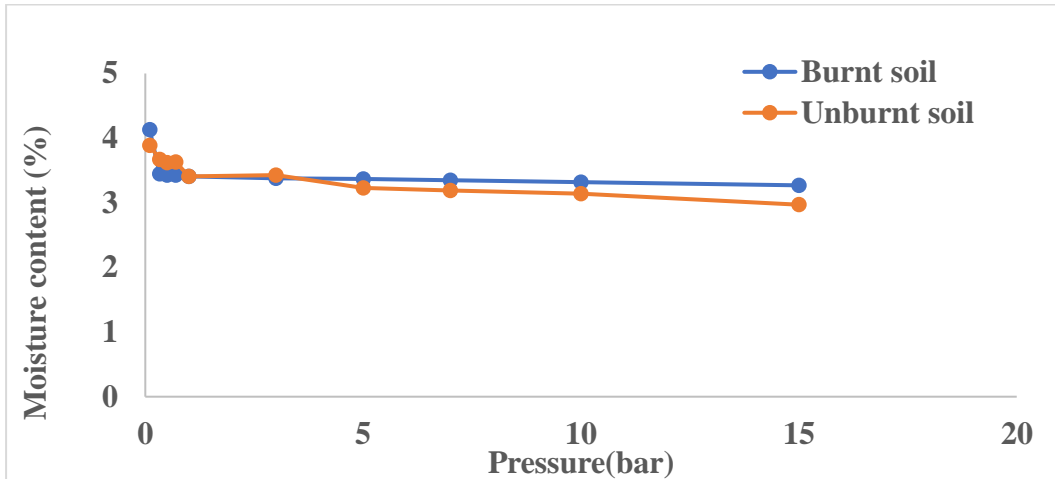


Figure 4.7 Soil moisture holding capacity at the burnt and unburnt sites in Tumaria beat forest site (Moderately Burnt)

Soil moisture retention curve for Burnt and unburnt plot of Tumaria beat forest site is shown in figure 4.7. Result shows slight decrease in soil moisture holding capacity in burnt site as compare to unburnt site at filed capacity and increase in soil moisture holding capacity in unburnt site as compare to unburnt site. Reduction in soil moisture holding was observed 5.99% at field capacity and addition in soil moisture 10.10% at wilting point. Soil moisture retention at field capacity was estimated 3.45% and 3.67% for burnt and unburnt sites, respectively. This site shows less moisture holding capacity as compare to all other sites. This site had sandy soil type, there for here accumulation of ash increases the soil moisture holding capacity of soil at burnt site.

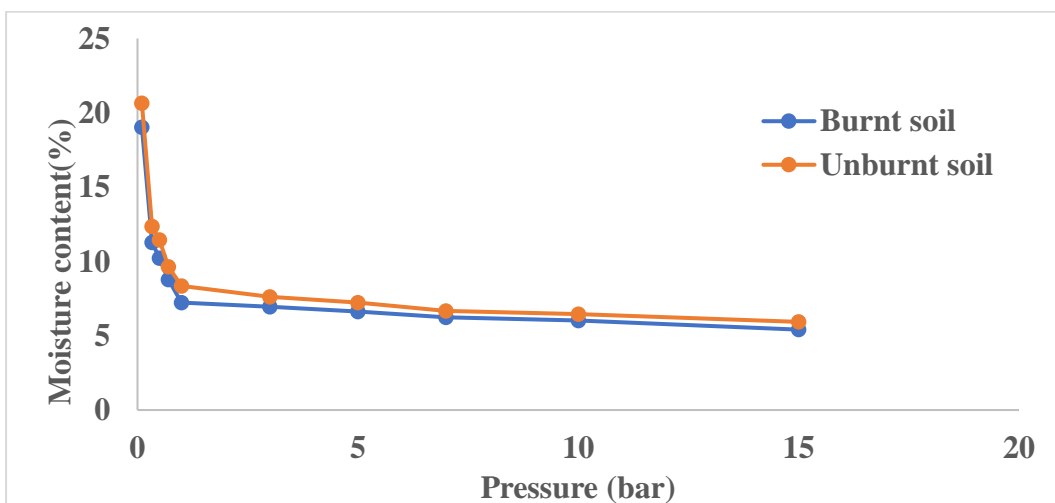


Figure 4.8 Soil moisture holding capacity at the burnt and unburnt sites in Chhatina beat forest site (Moderately Burnt)

Results shows reduction in soil moisture holding capacity in burnt site of Chhatina beat forest. Due to moderate severity, loss of organic matter was higher in this site as compare to low burnt soil. Reduction in soil moisture retention was observed 8.82% at field capacity and 8.77% at wilting point. Soil moisture retention at field capacity was estimated 11.27% and 12.36% for burnt and unburnt sites, respectively. Soil moisture holding curve for burnt and unburnt sites of Chhatina beat forest site was shown in figure 4.8.

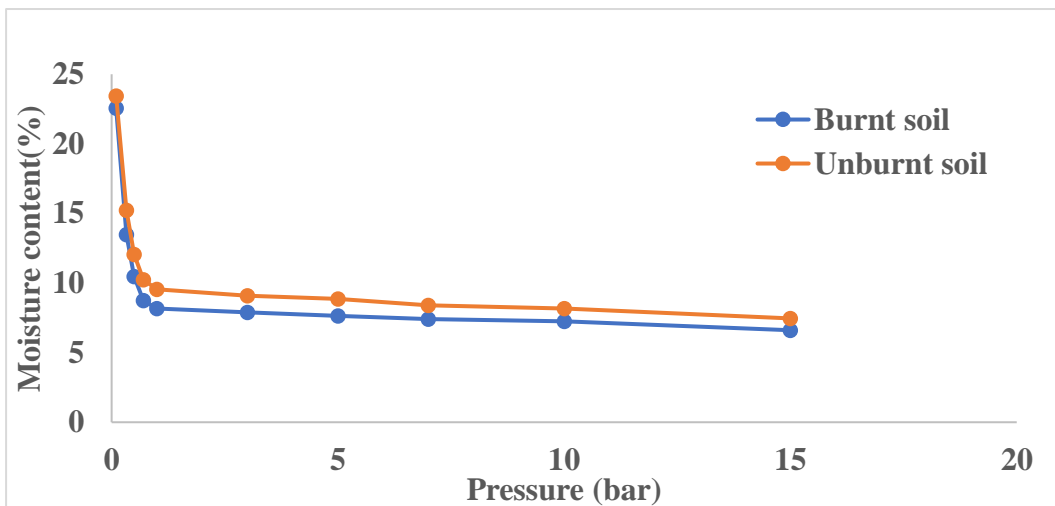


Figure 4.9 Soil moisture holding capacity at the burnt and unburnt sites in Durgapipal Beat forest site (Moderately Burnt)

Results shows high amount of reduction in soil moisture holding capacity in burnt site of Durgapipal beat forest site . Due to moderate severity, loss of organic matter was higher in this site as compare to low burnt soil. Reduction in soil moisture holding capacity was observed 11.42% at field capacity and 11.39% at wilting point. Soil moisture retention at field capacity was estimated 13.49% and 15.23% for burnt and unburnt sites, respectively. Soil moisture holding curve for burnt and unburnt sites of Durgapipal Beat forest site was shown in figure 4.9.

Soil moisture holding curve for burnt and unburnt sites of Jaulkande Beat forest site was shown in figure 4.10. Addition in soil moisture retention was observed 14.04% at field capacity and 13.98 % at wilting point. Soil moisture retention at field capacity was estimated 17.63% and 15.46% for burnt and unburnt sites, respectively. Soil moisture retention at wilting point was estimated 8.64% and 7.58% for burnt and unburnt sites, respectively. In this site burnt site had high

moisture holding capacity as compare to unburnt site, because of change in soil texture of burnt and unburnt sites.

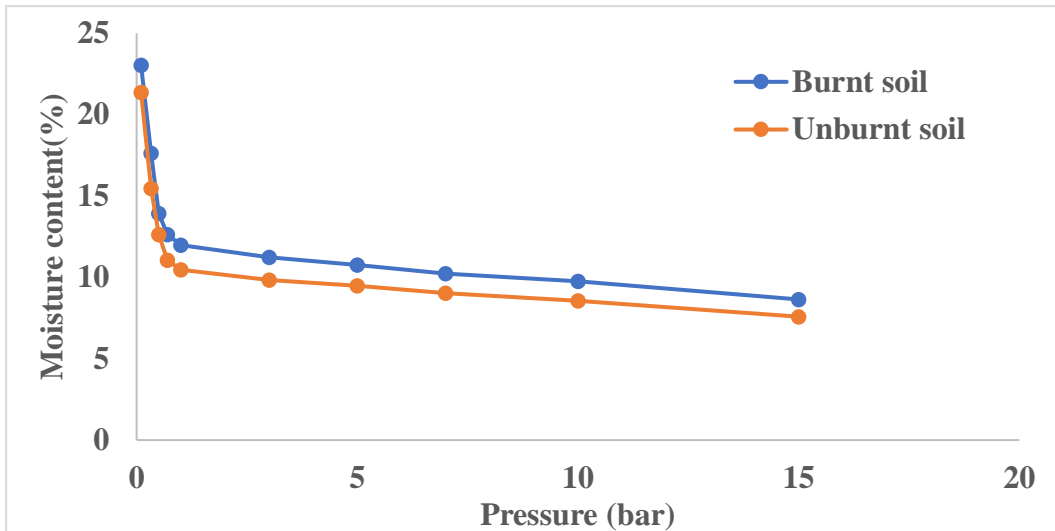


Figure 4.10 Soil moisture holding capacity at the burnt and unburnt sites in Jaulkande Beat site (Moderately Burnt)

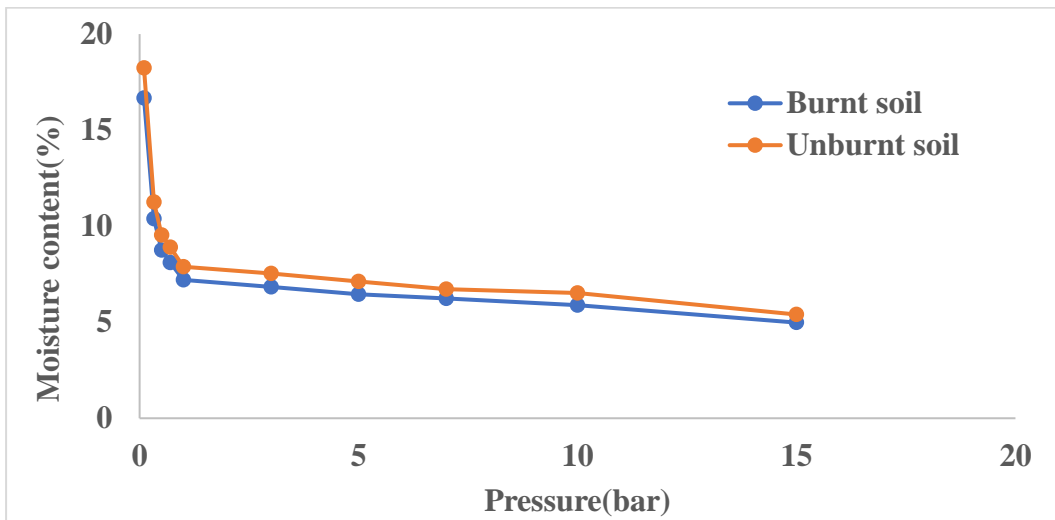


Figure 4.11 Soil moisture holding capacity at the burnt and unburnt sites in Khabdoli South Beat forest site (Moderately Burnt)

In figure 4.11, Reduction in soil moisture retention in Khabdoli South Beat forest site was observed 7.73% at field capacity and 7.78% at wilting point. Soil moisture retention at field capacity was estimated 10.38% and 11.25% for burnt and unburnt sites, respectively. Soil moisture retention at wilting point was estimated 4.98% and 5.4% for burnt and unburnt sites, respectively.

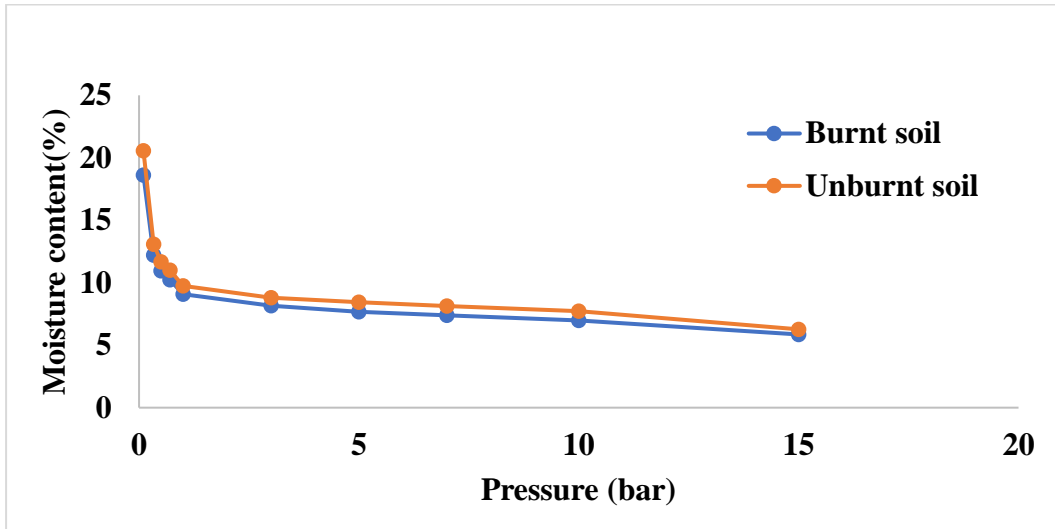


Figure 4.12 Soil moisture holding capacity at the burnt and unburnt sites in Pungar-I Beat forest site (Moderately Burnt)

Soil moisture holding curve for burnt and unburnt sites of Pungar-I Beat forest site is shown in figure 4.12. Reduction in soil moisture holding capacity in Pungar-I Beat forest site was observed 6.58% at field capacity and 6.54% at wilting point. Reduction in soil moisture holding capacity in burnt site was observed more at field capacity (0.33 Bar) as compare to wilting point (15 Bar). Soil moisture retention at field capacity was estimated 12.21% and 13.07% for burnt and unburnt sites, respectively. Soil moisture retention at wilting point was estimated 5.86% and 6.27% for burnt and unburnt sites, respectively.

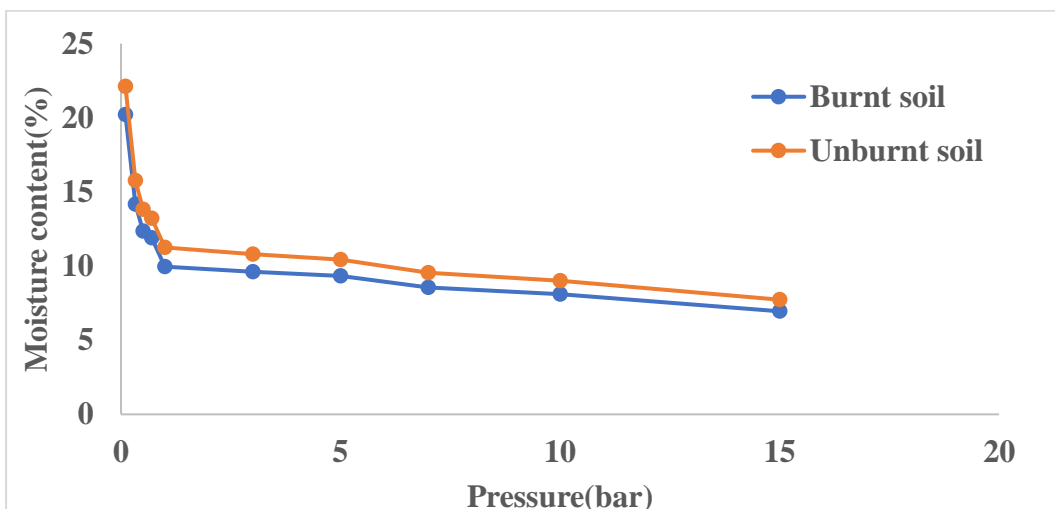


Figure 4.13 Soil moisture holding capacity at the burnt and unburnt sites in Ratarao Beat forest site (Moderately Burnt)

Results shows high amount of reduction in soil moisture retention in burnt site of Ratarao Beat forest. Due to moderate severity, loss of organic matter was second higher in this site as compare to low burnt sites. Reduction in soil moisture retention was observed 10.08% at field capacity and 10.09% at wilting point. Reduction in soil moisture retention in burnt site was observed more at wilting point (15 Bar) as compare to field capacity (0.33 Bar). Soil moisture retention at field capacity was estimated 14.18% and 15.77% for burnt and unburnt sites, respectively. Soil moisture holding curve for burnt and unburnt sites of Ratarao Beat forest site was shown in figure 4.13.

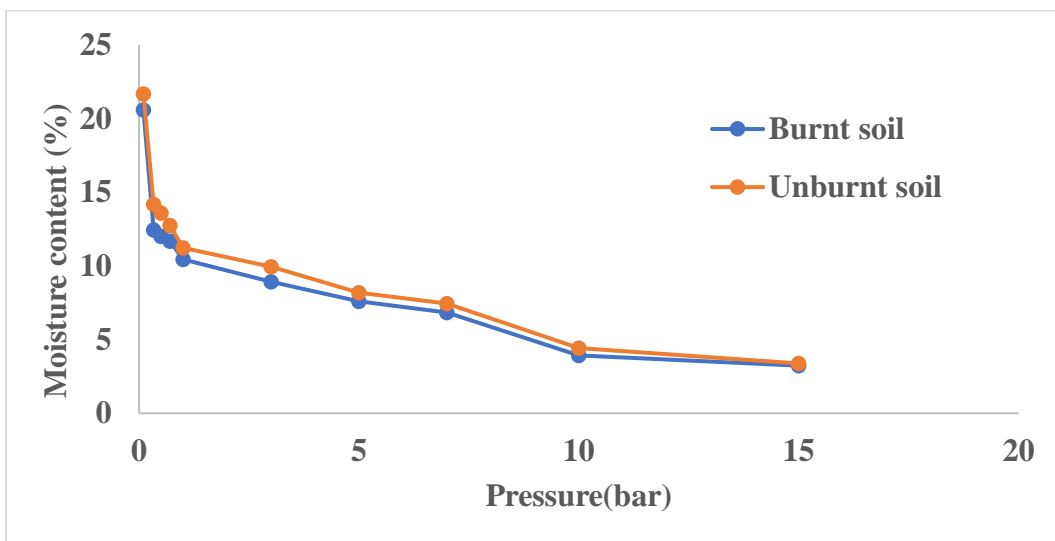


Figure 4.14 Soil moisture holding capacity at the burnt and unburnt sites in Tanda Center Beat Forest site (Moderately Burnt)

Soil moisture holding curve for burnt and unburnt sites of in Tanda Center Beat forest site is shown in figure 4.14. Reduction in soil moisture holding capacity in Pungar-I Beat forest site was observed 12.21% at field capacity and 4.44% at wilting point. Reduction in soil moisture holding capacity in burnt site was observed more at field capacity (0.33 Bar) as compare to wilting point (15 Bar). Soil moisture retention at field capacity was estimated 12.44% and 14.17% for burnt and unburnt sites, respectively. Soil moisture retention at wilting point was estimated 3.23% and 3.38% for burnt and unburnt sites, respectively.

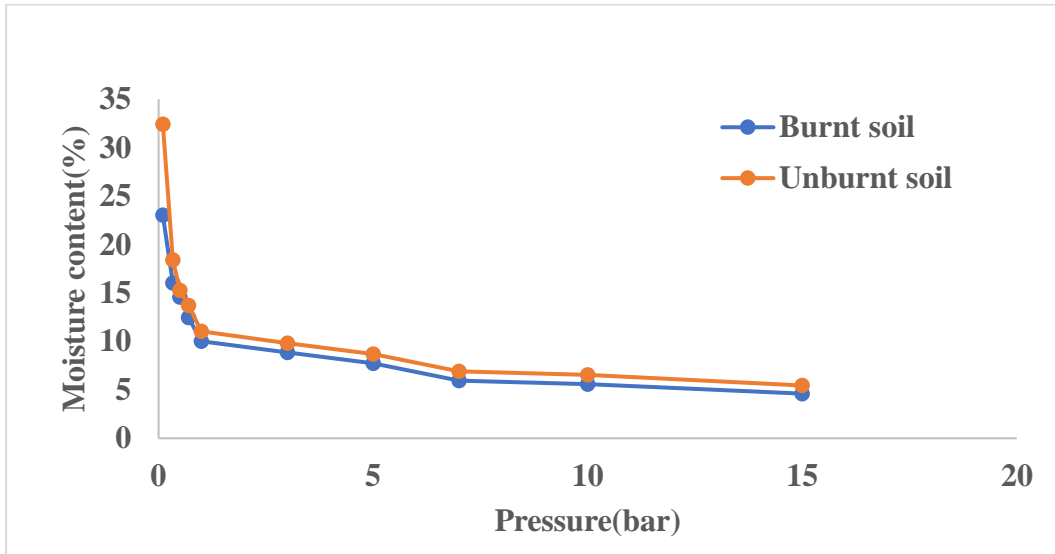


Figure 4.15 Soil moisture holding capacity at the burnt and unburnt sites in West Kilpura-I Beat Forest site (Moderately Burnt)

Results shows high amount of reduction in soil moisture retention in burnt site of West Kilpura-I beat. Due to moderate severity, loss of organic matter was higher in this site as compare to low burnt soil. Reduction in soil moisture retention was observed 13.03% at field capacity and 15.41% at wilting point. Reduction in soil moisture retention in burnt site was observed more at wilting point (15 Bar) as compare to field capacity (0.33 Bar). Soil moisture retention at field capacity was estimated 16.02% and 18.42% for burnt and unburnt sites, respectively. This sites shows highest reduction change in soil moisture holding capacity at unburnt to burnt site among all moderately burnt sites. Soil moisture retention curve for burnt and unburnt sites of West Kilpura-I Beat Forest site was shown in figure 4.15.

4.2 Assessment of Change in Transmission Characteristics

4.2.1 Assessment of Change in Infiltration Characteristics

Infiltration tests using the double ring infiltrometer were conducted at selected burnt polygons in the forests of Uttarakhand as well as in the nearby unburnt locations in similar forest areas. The infiltration rates obtained in the field are shown in Table 4.2.

Table 4.2: Measured infiltration rates at burnt and unburnt forest plots

| S. No. | Site Name | Fire Severity | NBSS & LUP Soil Class | Measured Infiltration Rate (cm/hr) | | % Change |
|--------|----------------------|---------------|-----------------------|------------------------------------|--------------|----------|
| | | | | Burnt Plot | Unburnt Plot | |
| 1 | Batoli-II Beat | LB | Loamy | 2.39 | 2.32 | -3.02 |
| 2 | Kharkhari North Beat | LB | Loamy skeletal | 2.53 | 2.56 | 1.17 |
| 3 | Kishanpur South Beat | LB | Loamy | 2.73 | 2.96 | 7.77 |
| 4 | Kotawali Beat | LB | Loamy | 0.57 | 0.76 | 25.00 |
| 5 | Ranipur East Beat | LB | Loamy | 2.13 | 2.17 | 1.84 |
| 6 | Purola Beat | LB | Loamy | 1.64 | 1.72 | 4.65 |
| 7 | Tumaria Beat | LB | Sandy | 4.29 | 4.04 | -6.19 |
| 8 | Chhatina Beat | MB | Loamy skeletal | 3.56 | 3.58 | 0.56 |
| 9 | Durgapipal Beat | MB | Loamy | 2.26 | 2.29 | 1.31 |
| 10 | Jaulkande Beat | MB | Loamy | 1.66 | 2.04 | 18.63 |
| 11 | Khabdoli_South Beat | MB | Loamy skeletal | 3.81 | 3.88 | 1.80 |
| 12 | Pungar-I Beat | MB | Loamy skeletal | 3.18 | 3.24 | 1.85 |
| 13 | Ratarao Beat | MB | Loamy | 2.63 | 2.65 | 0.75 |
| 14 | Tanda Center Beat | MB | Loamy | 0.51 | 1.02 | 50.00 |
| 15 | West Kilpura-I Beat | MB | Loamy | 2.04 | 1.82 | -12.09 |

For all the sites, the infiltration rates at unburnt (control) sites have been found to be more than that at the burnt forest sites. Results shows that the decrease

in infiltration rate is higher in the moderately burnt site. The infiltration rates of low burnt (LB) sites showed negligible difference as compare to moderately burnt (MB) 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 there by reducing the infiltration rate. The infiltration rates of low burnt sites showed negligible difference as compare to moderate burnt sites. According to Deban, (2000) infiltration rate decreases and runoff increases as a result of increasing hydrophobicity (water repellency), which often leads to greater erosion. Where as Wieting *et al.*, (2017) found that infiltration rates decreased from unburned to low-temperature burned soils, but increased in high-temperature burned soils. 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. According to Attri *et al.*, (2020), by driving hydrophobic substances in litter downward through the soil profile, severe fires may also induce the formation of a water repellent soil layer. These hydrophobic organic compounds coat soil aggregates or minerals, forming a discrete layer of water-repellent soil parallel to the surface. Extensive water repellent layers can block water infiltration into the soil and contribute to runoff and erosion. Peter R. Robichaud *et al.*, (2016) had found high rates of soil water repellency and little ground cover in the burned areas results the low infiltration capacity and increased runoff rates after the fire. According to P. R. Robichaud, (2000), water repellency in burned soils is affected by soil texture, fire intensity, and antecedent soil-water content, and fuel conditions. Macdonald & Huffman, (2004) found that water repellency is strongest at the soil surface in regions burned at a high and moderate severity, and weakens as the burn severity and depth decrease. Water repellency in soil restricts wetting or infiltration of dry soils (Doerr *et al.*, 2009).

In Table 4.2 percent changes shows in between burnt and unburnt site with respect to unburnt site. Here percent change varies from -12.09 % to 50 %. In Table

4.2 Batoli-II Beat, Tumaria Beat and West Kilpura-I Beat sites had negative percent change, which means burnt sites had high infiltration rate as compare to unburnt sites and others sites shows positive percent change, which means which means unburnt sites had high infiltration rate as compare to burnt sites. Negative percent changes shows due to change in soil type and texture in sites.

Table 4.3: Performance evaluation of infiltration rate with Horton's model

| S.No. | Site Name | Coefficient of Correlation | | Root Square Mean Error | |
|-------|-------------------------|----------------------------|--------------|------------------------|--------------|
| | | Burnt Plot | Unburnt Plot | Burnt Plot | Unburnt Plot |
| 1 | Batoli-II Beat | 0.9353 | 0.9352 | 0.7365 | 0.8364 |
| 2 | Kharkhari North Beat | 0.9603 | 0.9636 | 2.625 | 2.1196 |
| 3 | Kishanpur South Beat | 0.9798 | 0.979 | 0.5116 | 0.5776 |
| 4 | Kotawali Beat | 0.9939 | 0.9953 | 0.1945 | 0.1647 |
| 5 | Ranipur East Beat | 0.9499 | 0.9791 | 1.8444 | 1.3716 |
| 6 | Purola Beat | 0.9805 | 0.9747 | 0.994 | 1.1729 |
| 7 | Tumaria Beat | 0.9819 | 0.9964 | 0.7655 | 0.605 |
| 8 | Chhatina Beat | 0.9816 | 0.9915 | 0.7654 | 0.6248 |
| 9 | Durgapipal Beat | 0.9883 | 0.9822 | 0.9944 | 1.6019 |
| 10 | Jaulkande Beat | 0.9922 | 0.9926 | 0.7023 | 0.8241 |
| 11 | Khabdoli_Sout h Beat | 0.977 | 0.9788 | 0.3059 | 0.3671 |
| 12 | Pungar-I Beat | 0.9965 | 0.9797 | 0.438 | 0.7493 |
| 13 | Ratarao Beat | 0.925 | 0.9094 | 0.6627 | 0.8514 |
| 14 | Tanda Center Beat | 0.9018 | 0.9757 | 0.5133 | 0.2752 |
| 15 | West Kilpura-I Beat | 0.9928 | 0.9934 | 0.889 | 0.9376 |

In Table 4.2 burnt sites infiltration rate varies from 0.51 cm/hr to 4.29 cm/hr and unburnt sites 0.76 cm/hr to 4.04 cm/hr. In table Tumaria beat had high infiltration rate because this site soil was sandy soil and also shows negative percent change due to the ashes of the burnt vegetation getting accumulated over the soil surface and soil pores.

In Table 4.3 Horton's model is best suited to Jaulkande Beat and West Kilpura-I Beat, which had CC values of 0.9922 and 0.9928 at burnt sites and 0.9926 and 0.9934 for unburnt sites. The RMSE values for these locations are 0.7023 (burnt site), 0.8241 (unburnt site), and 0.889 (burnt site), 0.9376 (unburnt site) respectively. The value of CC ranges from 0.9018 to 0.9965 at burnt sites and 0.9094 to 0.9964 at unburnt sites and value of RMSE ranges from 0.1945 to 2.625 at burnt sites and 0.1647 to 2.1196 at unburnt sites.

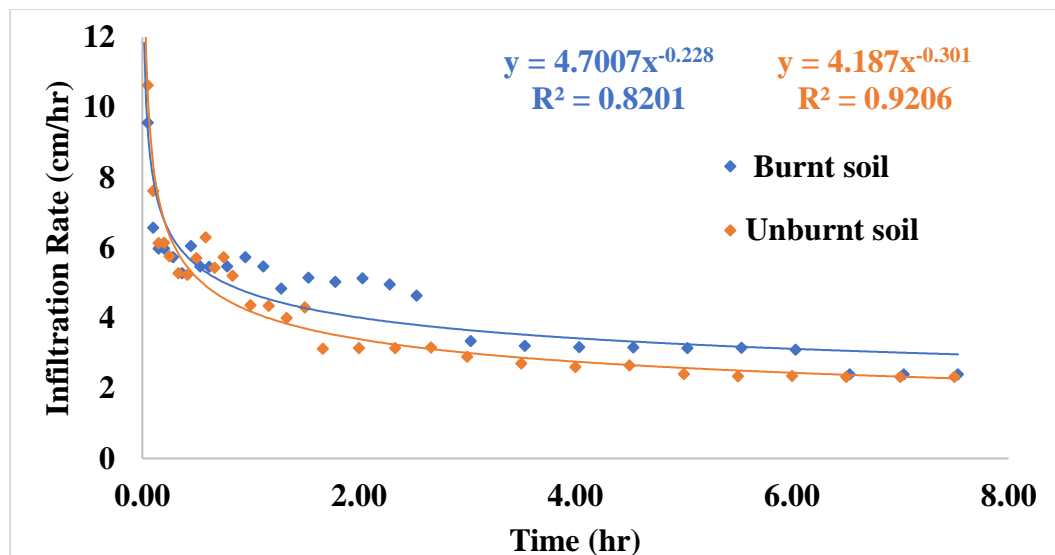


Figure 4.16 Infiltration rate at the burnt and unburnt sites in Batoli-II beat (Low Burnt)

In figure 4.16 Infiltration rate is observed high in the beginning of experiment and after 4 to 5 hours infiltration rate was observed almost constant. The total duration of experiment is almost 8 hours. After some elapsed time, a certain amount of water had infiltrated into the soil and then the rate of infiltration was observed constant. The final rate of infiltration in unburnt and burnt soil was found 2.32 cm/hr and 2.39 cm/hr. There was 3.02% change found in infiltration rate of unburnt and burnt soils. Batoli-II beat results shows that high infiltration rate in burnt site as compare to unburnt site due to change in soil texture.

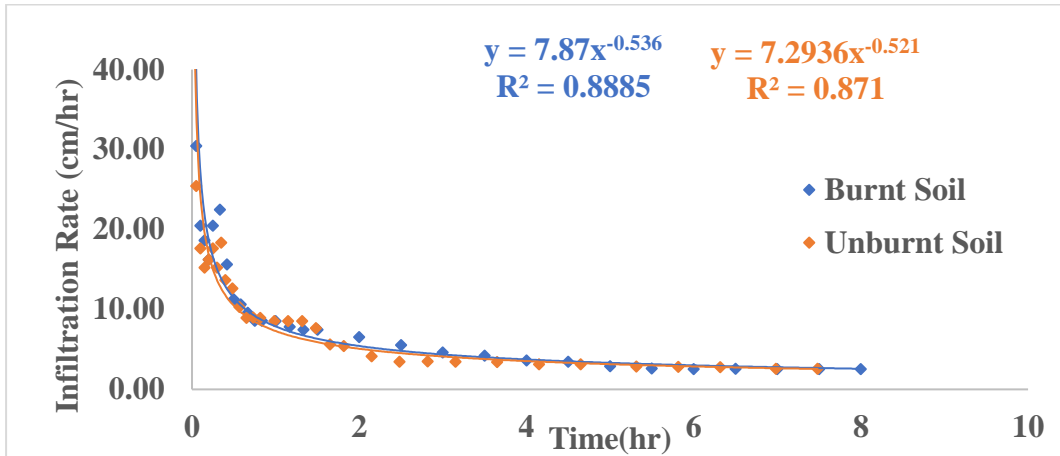


Figure 4.17 Infiltration rate at the burnt and unburnt sites in Kharkhari north beat (Low Burnt)

Infiltration curve of Basegaon forest site for burnt and unburnt soil is shown in figure 4.17. Infiltration rate in starting of experiment is 25.45 cm/hr for unburnt site and 30.45 cm/hr for burnt site. Total duration of experiment is about 8 hours. Figure shows the clear difference between unburnt and burnt forest infiltration rate. Infiltration rate was observed almost constant after 4 hours. The final value of infiltration rate was observed as 2.56 cm/hr and 2.53 cm/hr for unburnt and burnt sites, respectively. Decrease in infiltration rate in Kharkhari north beat site was observed 1.17%. Low severity results as less decrease in infiltration rate.

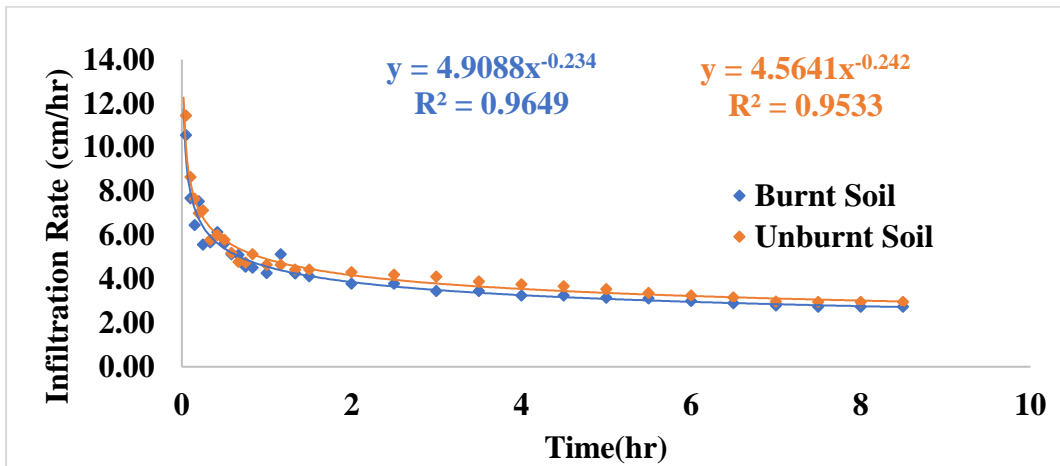


Figure 4.18 Infiltration rate at the burnt and unburnt sites in Kishanpur south beat forest site (Low Burnt)

Infiltration curve for Kishanpur south beat site for unburnt and burnt sites is shown in figure 4.18. infiltration value in the beginning was found 11.45 cm/hr at unburnt site and 10.56 cm/hr at burnt site. Total duration of experiment was almost

8 hours. Due to low severity, least difference was found in the infiltration values of Dungariya forest site. The final value of infiltration rate was observed as 2.96 cm/hr and 2.73 cm/hr for unburnt and burnt sites, respectively. Decrease in infiltration rate in Kishanpur south beat burnt site was observed 7.77%.

Infiltration curve for Kotawali beat forest site for unburnt and burnt sites is shown in figure 4.19. Total duration of experiment was almost 7 hours 30 minutes. Due to low severity, least difference was found in the infiltration values of Kotawali beat forest site. The final value of infiltration rate was observed as 0.76 cm/hr and 0.57 cm/hr for unburnt and burnt sites, respectively. Decrease in infiltration rate in Kotawali beat forest burnt site was observed 25%.

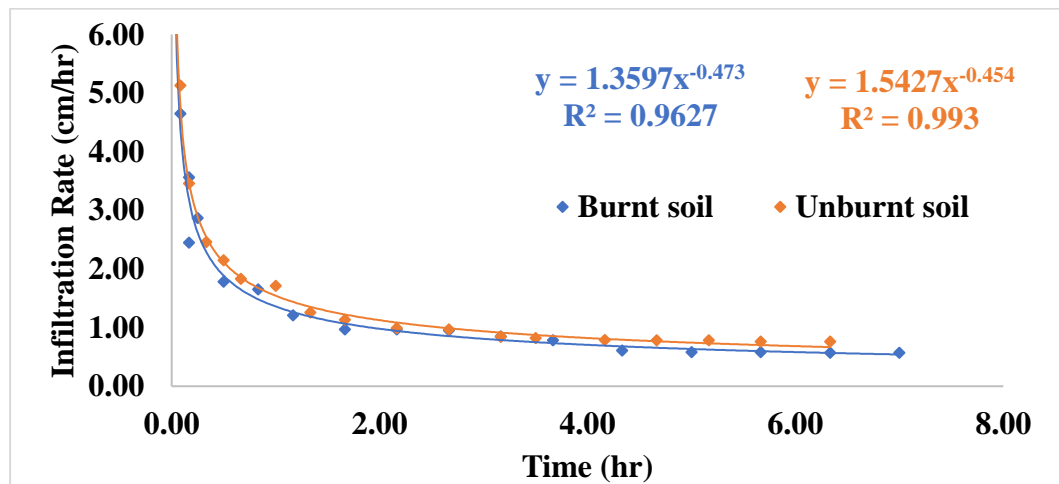


Figure 4.19 Infiltration rate at the burnt and unburnt sites in Kotawali beat forest site (Low Burnt)

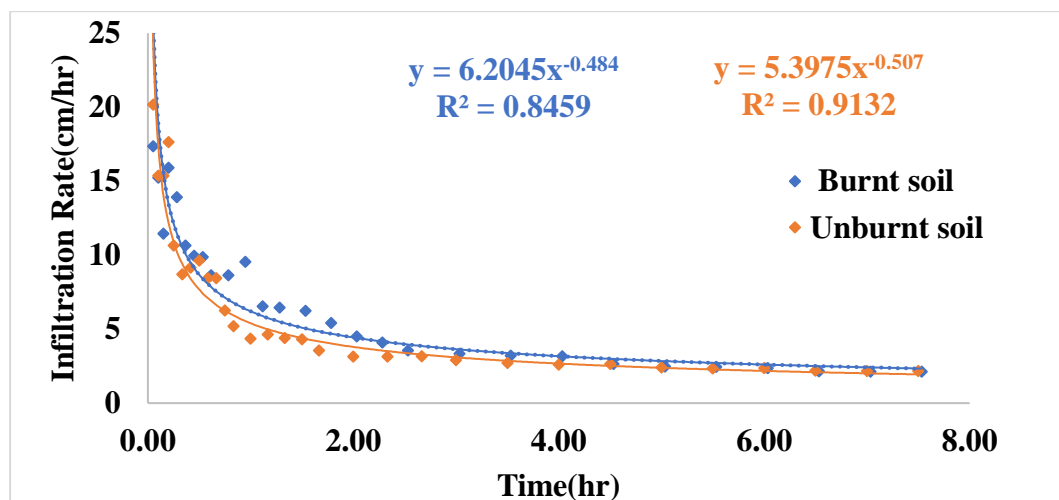


Figure 4.20 Infiltration rate at the burnt and unburnt sites in Ranipur east beat forest site (Low Burnt)

Infiltration rate in starting of experiment was 20.16 cm/hr for unburnt site and 17.36 cm/hr for burnt site. Infiltration curve for Ranipur east beat forest site for unburnt and burnt sites is shown in figure 4.20. Total duration of experiment was almost 8 hours. The final value of infiltration rate was observed as 2.17 cm/hr and 2.13 cm/hr for unburnt and burnt sites, respectively. Decrease in infiltration rate in Ranipur east beat forest burnt site was observed 1.84%. Ranipur east beat forest site is low burnt site.

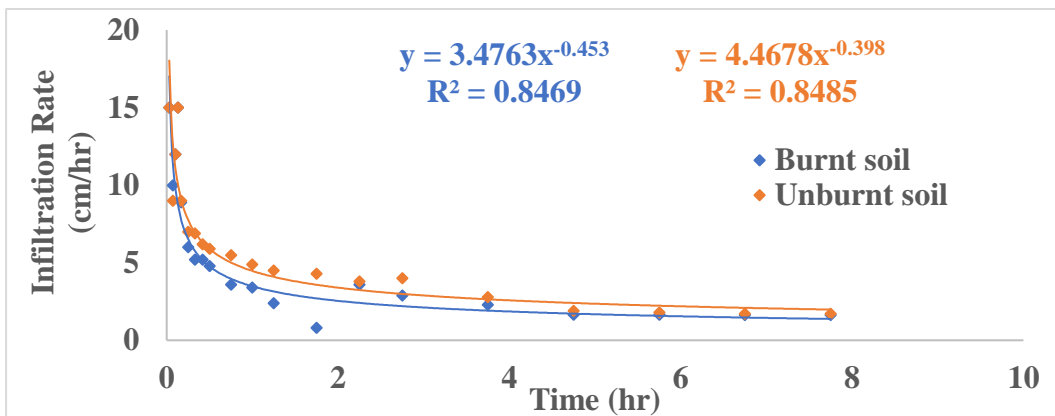


Figure 4.21 Infiltration rate at the burnt and unburnt sites in Purola beat forest site (Low Burnt)

Infiltration curve for Purola beat forest site for unburnt and burnt sites is shown in figure 4.21. Infiltration rate in starting of experiment was observed as 15 cm/hr for both sites. The total duration of experiment was about 8 hours. The final value of infiltration rate was observed as 1.72 cm/hr and 1.64 cm/hr for unburnt and burnt sites, respectively. Decrease in infiltration rate in Purola beat forest burnt site was observed 4.65%.

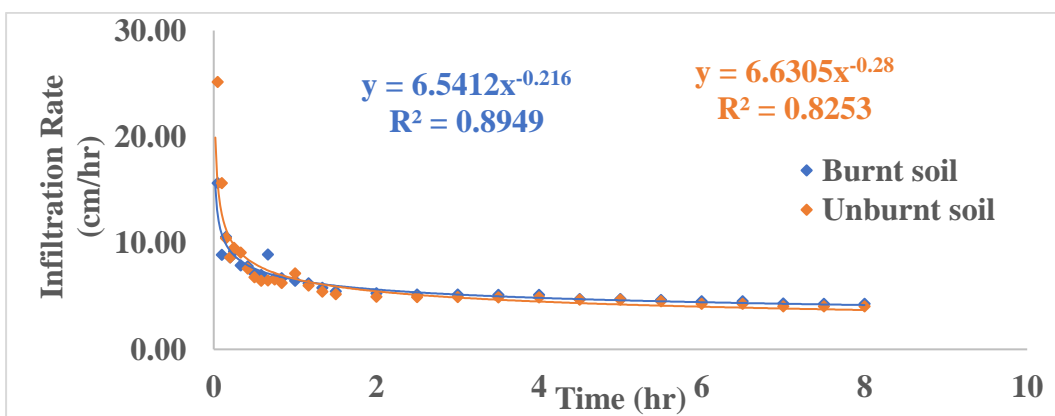


Figure 4.22 Infiltration rate at the burnt and unburnt sites in Tumaria beat forest site (Moderately Burnt)

Infiltration rate in Tumaria beat forest site observed high as compare to all other sites because of soil type. In this region sandy soil commonly found. Infiltration curve for Tumaria beat forest site for unburnt and burnt sites is shown in figure 4.22. The total duration of experiment was about 8 hours. The final value of infiltration rate was observed as 4.04 cm/hr and 4.29 cm/hr for unburnt and burnt sites, respectively. There was 4.65% change found in infiltration rate of burnt to unburnt soils. Due to high infiltration rate Tumaria beat forest site had sandy soil. This site has high infiltration rate in burnt soil as compare to unburnt site.

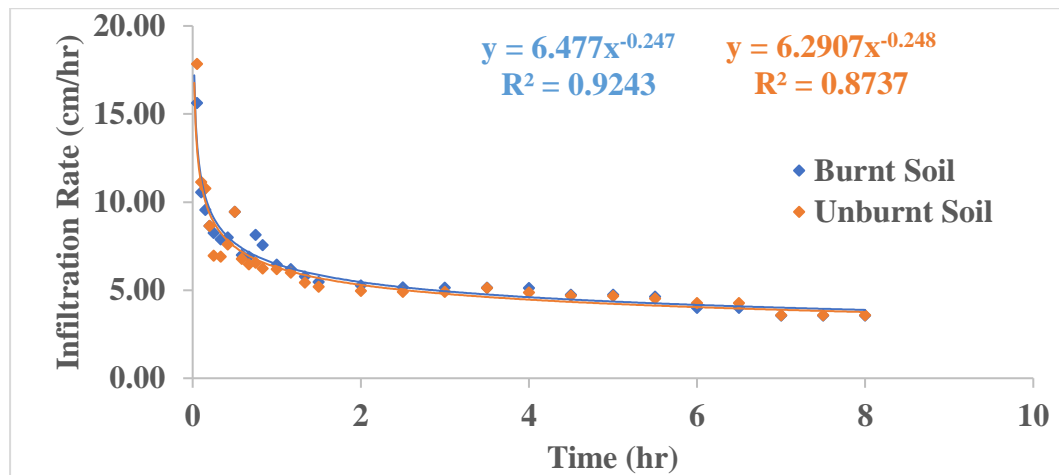


Figure 4.23 Infiltration rate at the burnt and unburnt sites in Chhatina beat forest site (Moderately Burnt)

Infiltration curve for Chhatina beat forest site for unburnt and burnt sites is shown in figure 4.23. Infiltration rate in starting of experiment was observed as 17.85 cm/hr for unburnt site and 15.65 cm/hr for burnt site. The total duration of experiment was 8 hours. The final value of infiltration rate was observed as 3.58 cm/hr and 3.56 cm/hr for unburnt and burnt sites, respectively. There was 0.56% change found in infiltration rate of unburnt to burnt soils. This site had least change in infiltration rate.

Infiltration rate in the beginning of experiment was observed as 25.36 cm/hr for unburnt site and 20.56 cm/hr for burnt site. Infiltration curve for Durgapipal beat forest site for unburnt and burnt sites is shown in figure 4.24. The total duration of experiment was almost 8 hours minutes for both the sites. The final value of infiltration rate was observed as 2.26 cm/hr and 2.29 cm/hr for unburnt and burnt

sites, respectively. There was 1.31% change found in infiltration rate of unburnt to burnt soils.

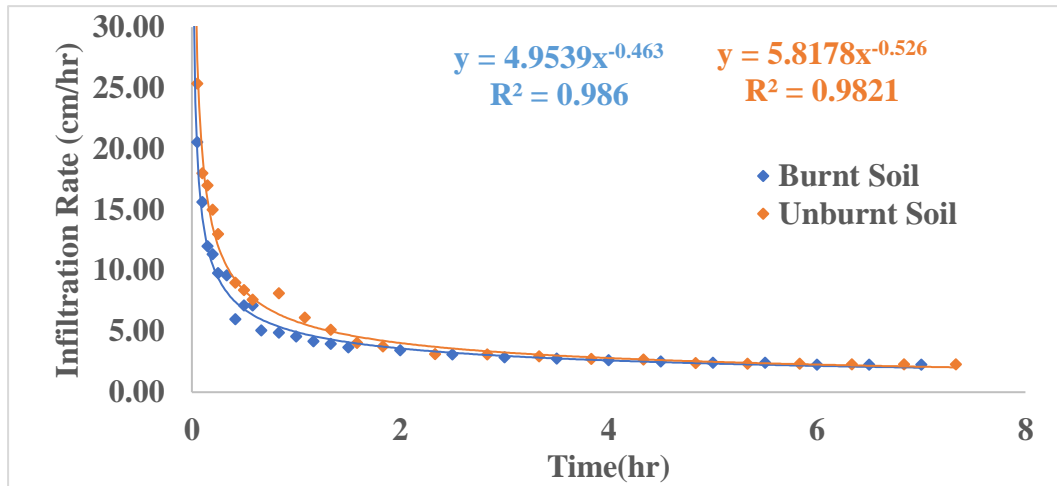


Figure 4.24 Infiltration rate at the burnt and unburnt sites in Durgapipal Beat forest site (Moderately Burnt)

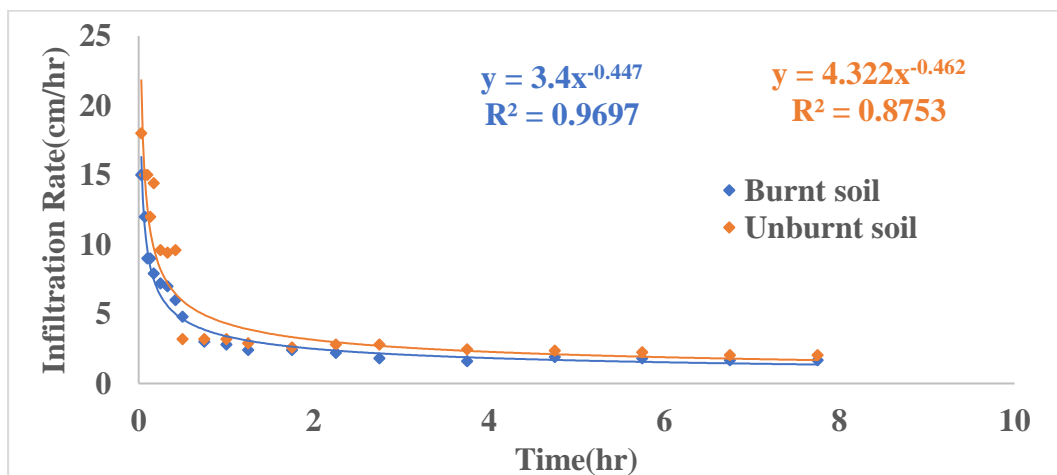


Figure 4.25 Infiltration rate at the burnt and unburnt sites in Jaulkande Beat site (Moderately Burnt)

Infiltration curve for Jaulkande Beat forest site for unburnt and burnt sites is shown in figure 4.25. Infiltration rate in the beginning of experiment was observed as 18 cm/hr for unburnt site and 15 cm/hr for burnt site. The total duration of experiment was 7 hours 50 minutes for both the sites. As result of its severity, third highest % change was observed in this site as 18.63%. The final value of infiltration rate was observed as 2.04 cm/hr and 1.66 cm/hr for unburnt and burnt sites, respectively.

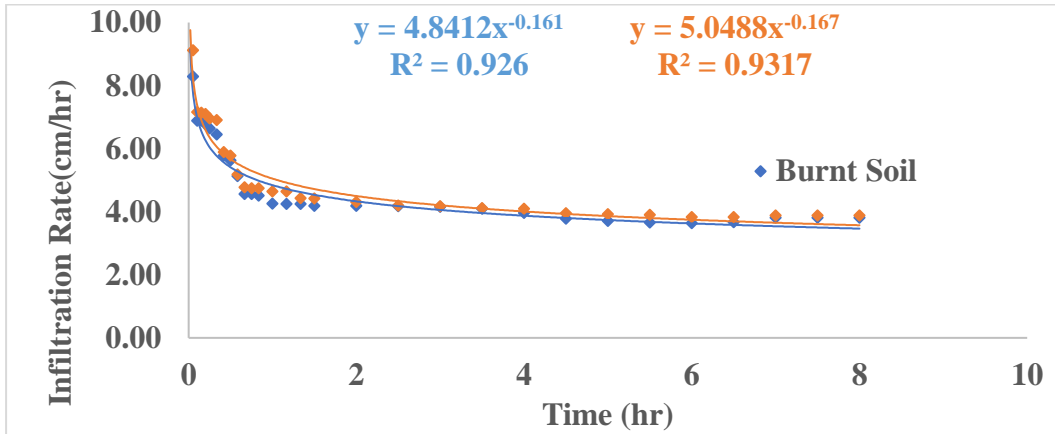


Figure 4.26 Infiltration rate at the burnt and unburnt sites in Khabdoli South Beat Forest site (Moderately Burnt)

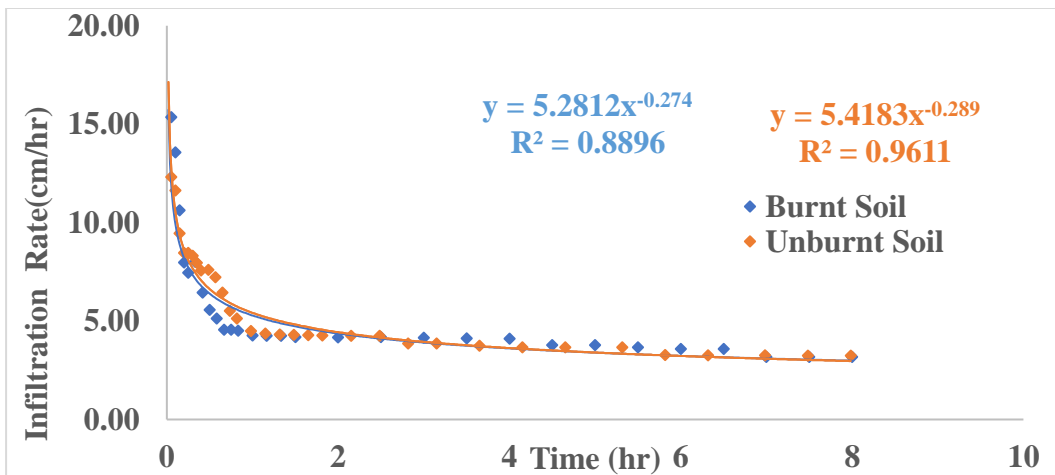


Figure 4.27 Infiltration rate at the burnt and unburnt sites in Pungar-I Beat forest site (Moderately Burnt)

Infiltration curve for Khabdoli South beat forest site for unburnt and burnt sites is shown in figure 4.26. The total duration of experiment was 8 hours. The final value of infiltration rate was observed as 3.88 cm/hr and 3.81 cm/hr for unburnt and burnt sites, respectively. There was 1.80% change found in infiltration rate of unburnt to burnt soils. This site had second highest infiltration rate among all sites.

In figure 4.27 Infiltration rate is observed high in the beginning of experiment and after 4 to 5 hours infiltration rate was observed almost constant. The total duration of experiment is almost 8 hours. After some elapsed time, a certain amount of water had infiltrated into the soil and then the rate of infiltration was observed constant. The final rate of infiltration in unburnt and burnt soil was found 3.24 cm/hr and 3.18 cm/hr. There was 1.85% change found in infiltration rate of

unburnt to burnt soils. Pungar-I beat results shows fourth highest infiltration rate in both burnt and unburnt sites as compare to other sites.

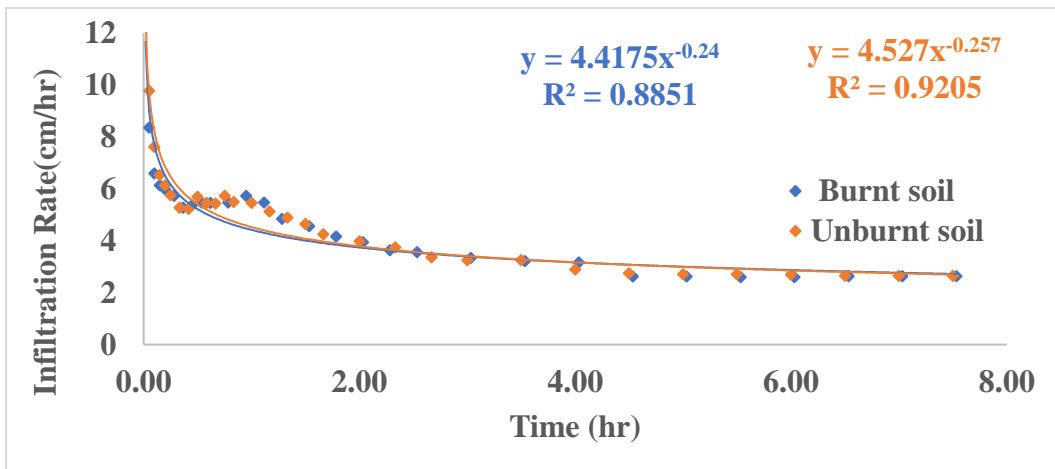


Figure 4.28: Infiltration rate at the burnt and unburnt sites in Ratarao Beat forest site (Moderately Burnt)

Infiltration rate in the beginning of experiment was observed as 9.78 cm/hr for unburnt site and 8.36 cm/hr for burnt site. Infiltration curve for Ratarao Beat forest site for unburnt and burnt sites is shown in figure 4.28. The final value of infiltration rate was observed as 2.65 cm/hr and 2.63 cm/hr for unburnt and burnt sites, respectively. There was 0.75% change found in infiltration rate of unburnt and burnt soils.

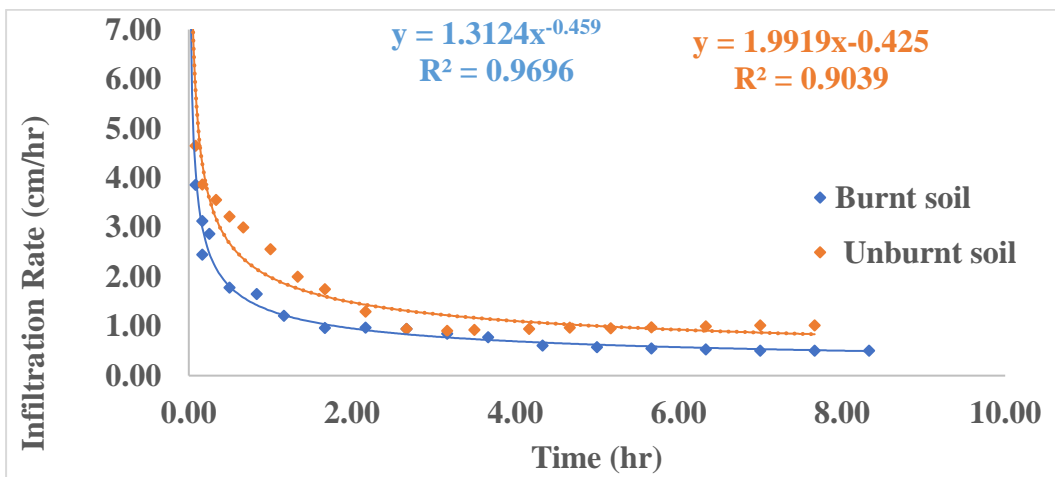


Figure 4.29 Infiltration rate at the burnt and unburnt sites in Tanda Center Beat Forest site (Moderately Burnt)

Infiltration rate in starting of experiment was observed as 4.65 cm/hr for unburnt site and 3.86 cm/hr for burnt site. Infiltration curve for Tanda Center Beat

forest site for unburnt and burnt sites is shown in figure 4.29. The total duration of experiment was almost 8 hours. The final value of infiltration rate was observed as 1.02 cm/hr and 0.51 cm/hr for unburnt and burnt sites, respectively. There was 50% change found in infiltration rate of unburnt to burnt soils. This sites shows highest percentage change among all sites. This site also had lowest infiltration rate at both burnt and unburnt sites.

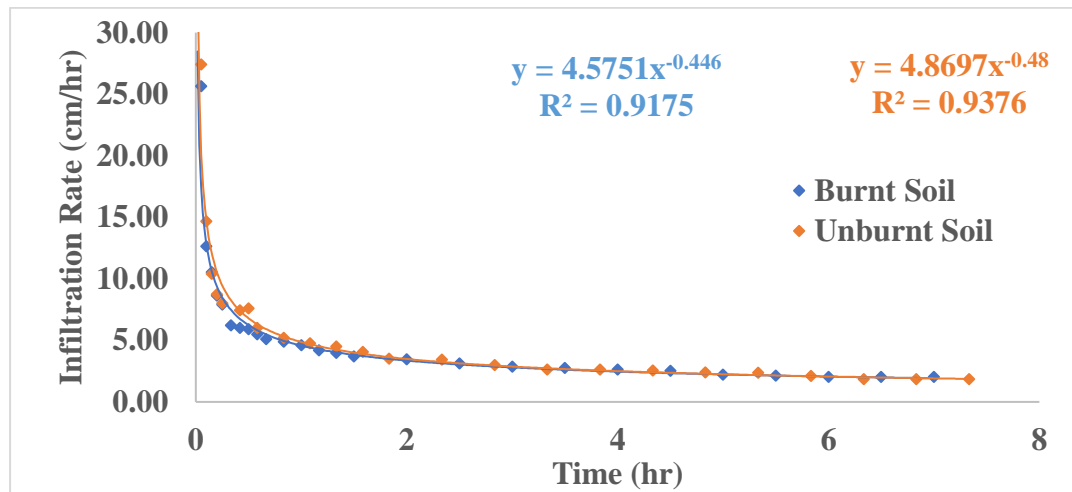


Figure 4.30 Infiltration rate at the burnt and unburnt sites in West Kilpura-I Beat Forest site (Moderately Burnt)

Infiltration curve for West Kilpura-I Beat forest site for unburnt and burnt sites is shown in figure 4.30. Infiltration rate in the beginning of experiment was observed as 27.41 cm/hr for unburnt site and 25.63 cm/hr for burnt site. The total duration of experiment is about 7 hours 45 minutes for both the sites. The final value of infiltration rate was observed as 1.84 cm/hr and 2.04 cm/hr for unburnt and burnt sites, respectively. This site had high infiltration rate at burnt site as compare to unburnt site. This shows due to change in soil texture at burnt and unburnt sites. There was 12.05% change found in infiltration rate of burnt to unburnt soils

4.2.2 Assessment of Change in Permeability 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 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 4.4.

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 there by reduces the permeability.

Results shows that soil permeability changes shown in burnt and unburnt sites. Where this percent changes were varying from -5.04 % to 97.56 %. Here some sites shows negative changes, which means burnt site had high permeability as compare to unburnt sites. In burnt sites permeability was ranges from 0.01cm/hr to 3.04cm/hr. and unburnt sites 0.41cm/hr to 3.53 cm/hr. Where Chhatina Beat shows high permeability among all sites. Here Ratarao Beat, Pungar-I Beat, Durgapipal Beat, Chhatina Beat, Purola Beat, and Batoli-II Beat shows less changes on permeability in burnt and unburnt sites.

Yang *et al.*, (2021) estimated that the topsoil of his study area had significant reduction in permeability in contrast to that of the unburnt zone. He observed that reduction in severely burnt sites is more as compare to low burnt sites. The formation of a crust on the soil surface as a result of forest fires drastically reduced permeability values and remarkable peak runoff value seen following the first autumn rainfalls (Soulis *et al.*, 2012). P. R. Robichaud, (2000) found lower values of permeability because surface crusting and sealing have been documented in soil after forest fire. The beating action of raindrops, or the spontaneous slaking and dissolution of soil aggregates during wetting, can both contribute to the formation of thin crust in soil after burning of soil (Hillel, 1982).

Table 4.4: Measured permeability rates for burnt and unburnt forest plots

| S. No. | Site Name | Fire Severity | Measured Permeability (cm/hr) | | |
|--------|----------------------|------------------|-------------------------------|--------------|----------|
| | | | Burnt Plot | Unburnt Plot | % Change |
| 1 | Batoli-II Beat | Low Burnt | 1.97 | 2.03 | 2.96 |
| 2 | Kharkhari North Beat | Low Burnt | 1.48 | 2.3 | 35.65 |
| 3 | Kishanpur South Beat | Low Burnt | 0.01 | 0.41 | 97.56 |
| 4 | Kotawali Beat | Low Burnt | 0.83 | 1.25 | 33.60 |
| 5 | Ranipur East Beat | Low Burnt | 1.88 | 1.92 | 2.08 |
| 6 | Purola Beat | Low Burnt | 1.46 | 1.39 | -5.04 |
| 7 | Tumaria Beat | Low Burnt | 1.75 | 3.53 | 50.42 |
| 8 | Chhatina Beat | Moderately Burnt | 3.04 | 3.03 | -0.33 |
| 9 | Durgapipal Beat | Moderately Burnt | 1.95 | 1.92 | -1.56 |
| 10 | Jaulkande Beat | Moderately Burnt | 1.41 | 1.73 | 18.50 |
| 11 | Khabdoli_South Beat | Moderately Burnt | 3.3 | 3.24 | -1.85 |
| 12 | Pungar-I Beat | Moderately Burnt | 2.7 | 2.75 | 1.82 |
| 13 | Ratarao Beat | Moderately Burnt | 2.25 | 2.24 | -0.45 |
| 14 | Tanda Center Beat | Moderately Burnt | 0.56 | 0.64 | 12.50 |
| 15 | West Kilpura-I Beat | Moderately Burnt | 0.98 | 3.35 | 70.75 |

In West Kilpura-I Beat, there is 70.75% of increase in permeability of soil has been observed in the burnt polygon as compared to unburnt polygon. Burning of soil may induce the formation of a water repellent soil layer by forcing hydrophobic substances in litter downward through the soil profile. These hydrophobic organic compounds coat soil aggregates or minerals creating a discrete layer of water repellent soil parallel to the surface. Extensive water repellent layers can block water transmission (Doerr *et al.*, 2009). This may be caused due to low severity of forest fire in Bori forest site. Sometimes low temperature fire improves the soil properties. Varela *et al.*, (2015) found decrease in hydraulic conductivity of soil after forest fire due to loss of soil organic carbon and reduced soil aggregation. Results show that the decrease in permeability rate for burnt and unburnt forest sites are vary between -5.04% to 97.56% for low burnt sites, and -1.85% to 70.75% for moderately burnt sites.

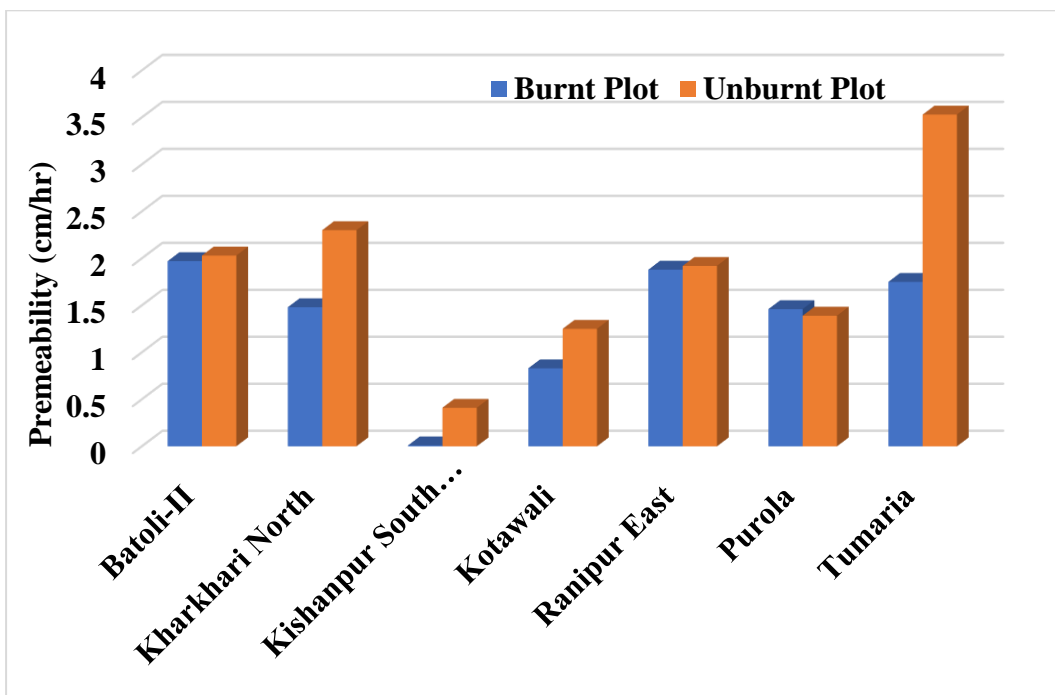


Figure 4.31 Soil permeability at burnt and unburnt plots of Low Burnt sites

Figure 4.31 shows permeability of low burnt sites, where Purola beat had high permeability at burnt site as compare to unburnt site. Due to change in soil texture of burnt site. In low burnt sites Kishanpur south beat forest site shows less permeability as compare to all other sites and Batoli-II beat shows high permeability among all low burnt sites. Results shows reduction in permability of Batoli-II Beat,

Kharkhari North Beat, Kishanpur South Beat, Kotawali Beat, Ranipur East Beat and Tumaria Beat sites and percent change were observed 2.96%, 35.65%, 97.56%, 33.60%, 2.08% and 50.42% respectively.

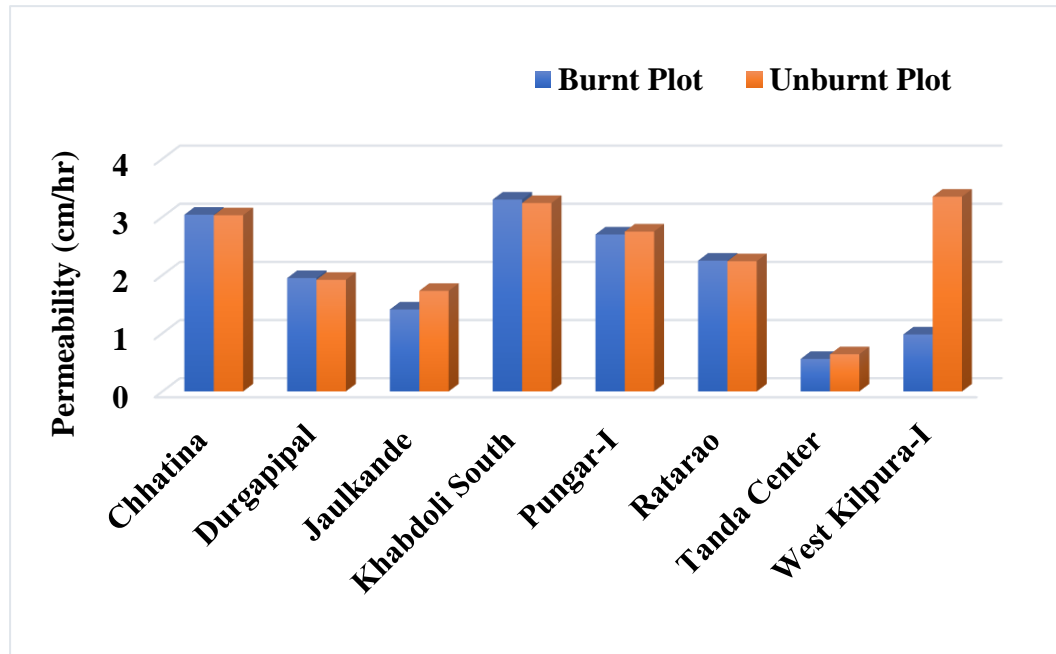


Figure 4.32 Soil permeability at burnt and unburnt plots of Moderately Burnt sites

Figure 4.32 shows the permeability change of moderately burnt sites, where reduction in permeability observed at Jaulkande Beat, Pungar-I Beat, Tanda Center Beat and West Kilpura-I Beat from unburnt to burnt sites. And addition of permeability observed at Chhatina Beat, Durgapipal Beat, Khabdoli_South Beat and Ratarao Beat. Results shows highest percentage change at West Kilpura-I beat (70.75%).

Based on the field investigation and laboratory measurement, 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.

The soil moisture retention for the burnt plots have been found to be slightly on the lower side in comparison to those of the unburnt plots. This may be attributed

to the reduction in organic matter content which is the main governing factor for soil moisture retention.

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.

4.3 Manmade Practices to Improve Soil Condition in Burnt Area

4.3.1 Practices to improve better soil moisture holding capacity in burnt area

Practices that Help Increase Soil Organic Matter Conservation practices such as no-till, cover-cropping with high-residue crops, and diversifying crop rotations are some of the practices that increase WHC and improve soil health (Ashworth *et al.* 2017).

For better soil moisture holding capacity following practices will be made:-

- 1. Soil organic matter-** Soil organic matter (SOM) is a component that can assist in increasing water retention capacity. Organic stuff in soil has a natural attraction to water. The soil water retention capacity will rise as the proportion of organic matter in the soil grows. In addition, organic matter in burnt soil increases soil moisture content, and organic matter also aids plant development.

SOM is decomposed substance derived from a live organism. SOM can be raised by including plant or animal matter. Here are some simple methods for increasing SOM

1. Use cover crops
 2. Add manure
 3. Add compost.
- 2. Trench-** In a burned region, we can create trenches, which aid in the penetration of water into the soil. This increases soil moisture holding capacity while simultaneously working to improve soil infiltration and permeability. Because the upper layer layer of soil became cemented as a

result of the fire, we may utilize this construction to remove the upper layer of burnt soil. Because damaged dirt is put into this structure, it also helps to reduce soil erosion. Tranches are two types;-

1. Staggered tranches
2. Contour tranches

3. Cover crop/ vegetation- Soil water retention curves are used for predicting water storage. The ability of the soil to retain water is dependent on soil porosity which can be impacted by management practices such as cover cropping. The bio pores generated by CC roots can improve soil water retention. Cover crops have been reported to increase water retention at field capacity (Basche *et al.*,2016). We can cultivate plants in burned fields to assist boost the moisture retention capacity of the soil. In a forest fire, vegetation, plant litter, and tree litter are burned and turned into ashes. As these ashes are high in carbon, they aid in the growth of vegetation and the increase of soil moisture content.

4.3.2 Practices to improve better transmission characteristics in burnt area

Several conservation strategies, such as increasing plant cover and soil organic matter, serve to maintain or increase water infiltration into soil.

Conservation practices resulting in infiltration rates favorable to soil function include:

1. Vegetation
2. Infiltration Tranches
3. Application of organic material

1. Vegetation- Vegetation has roots that penetrate into the soil and cause cracks and fissures, allowing for faster penetration and higher capacity. Vegetation can also aid to minimise soil surface compaction, allowing for enhanced infiltration and permeability. So we can grow vegetation in burned areas (plants and grasses). This can help with infiltration and permeability.

- 2. Infiltration trenches-** Infiltration trenches are linear ditches that collect rain water from neighbouring surfaces and allow it to swiftly sink into the earth due to their extremely permeable soils. On a burned site, we can create normal and infiltration trenches, which aid in water infiltration and permeability.
- 3. Application of organic material-** Organic matter has a number of effects on the physical characteristics of a soil. Plant residues that cover the soil surface prevent it from sealing and crusting caused by raindrop impact, improving rainfall penetration. Surface infiltration is affected by several parameters, including aggregation and stability, pore continuity and stability, crack presence, and soil surface quality. Increased organic matter indirectly helps to soil porosity.

Increased levels of organic matter and associated soil fauna lead to greater pore space with the immediate result that water infiltrates more readily and can be held in the soil (Roth, 1985). The increased pore space is due to the bioturbating activities of earthworms and other microorganisms, as well as the channels left in the soil by decaying plant roots. So, in a burned region, we may add organic stuff, which will aid in increasing the speed of infiltration.

CHAPTER – V

SUMMARY AND CONCLUSION

Forest vegetation contributes to the hydrological cycle by intercepting rainfall, lowering raindrop velocity, reducing runoff, and enhancing water infiltration. Forest hydrology is strongly tied to fire, a typical natural event in forest ecosystems. The effect of fire on the water is reflected indirectly because post-fire changes in vegetation, surface cover, soil, and environment affect the water cycle, water quality, and aquatic life. The impact varies based on the severity and recurrence of the fire. In India, very limited efforts have been made to understand the hydrologic effects of fires. Therefore, it is necessary to monitor and quantify these effects by direct catchment experimentation and to answer many of the hydrological issues which are still less understood. The present study is therefore conducted to estimate the effect of forest fire on physical characteristics of soil and hydrological response. Forests are dynamic ecosystems that are susceptible to both gradual and episodic disturbances that vary in frequency, intensity, and scope. The woods are maintained for a variety of reasons, including timber harvesting, wildness, habitat, and leisure, but water is arguably their most essential product. Precipitation is cycled through trees and soil, with some eventually reaching recipient bodies of water as stream flow. The impacts of fire on the hydrological behaviour of watersheds can be classed as direct or indirect. Direct consequences include the removal of vegetative cover, decreased interception, and evapotranspiration, while secondary impacts include changes in physical, chemical, and hydraulic soil qualities. In particular, the indirect consequences include organic matter degradation, decreased soil porosity and infiltration capacity, and the establishment of a hydrophobic soil profile. The present study is therefore carried out to improve the understanding of the importance of fire effects on hydrology and investigate the changes in the hydrological response of a watershed following a fire event.

The study's methodology comprises the utilisation of two neighbouring plots (one burned and one unburned) of chosen 15 forest sites in Uttarakhand with similar/identical rainfall inputs, pre-burnt vegetation features, soil and geological structures, and other factors. The burnt and un-burnt plots shall serve as treated and

control plots for estimating the changes in soil characteristics (Soil moisture retention capacity, infiltration rate, and permeability). Experiment plots were used for field and laboratory experiments. Double Ring Infiltrometer Tests and Guelph Permeameter Tests were conducted in field to determine the infiltration capacity and hydraulic conductivity of the burnt and unburnt plots. The soil samples were collected from the burnt and unburnt plots and analyzed in the laboratory for determination of soil-water retention characteristics and soil permeability. Pressure plate apparatus and ICW permeameter was used to determine soil water retention and permeability in the laboratory.

CONCLUSIONS

The study has been carried out for the assessment of changes induced by forest fires in physical properties of soil. The finally selected polygons burnt during Apr-May of 2019 were provided by the FSI. Based on the field investigations, laboratory investigation, assessment of changes in soil infiltration capacity, permeability and soil moisture holding capacity, the following conclusions may be drawn from the study:

1. Infiltration rates have been found to be decreasing due to forest fire. The percentage of decrease in infiltration rate in burnt sites is observed -6.19% to 25% in low burnt sites and -12.09% to 50% in moderately burnt sites. The ash deposition, as well as its downward motion during the coming monsoon season, induces coagulation and the production of soil aggregates, which operate as an impenetrable medium identical to a cement layer, limiting the rate of penetration.
2. The soil moisture holding capacity for the burnt plots has been found to be slightly lower in comparison to those of the unburnt plots. The percentage of decrease in soil moisture holding capacity in low burnt sites has been observed as -14.22% to 10.38% at field capacity (0.33bar) and -28.85% to 39.41% at wilting point (15 bars).

In Kharkhari North Beat and Kotawali Beat increase in percentage change respectively 3.95% and 14.22% at field capacity and 2.88% and 28.85% at wilting point in soil moisture holding capacity has been observed in burnt polygon as compare to unburnt polygon. The percentage change in

soil moisture holding capacity in moderately burnt sites has been observed as -14.04% to 13.03% at field capacity and -13.98% to 15.41% at wilting point. Reduction in soil moisture holding capacity may be attributed to the reduction in organic matter content which is the main governing factor for soil moisture retention.

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. There is decrease in permeability rate for burnt and unburnt forest sites. It varies between -5.04% to 97.56% for low burnt sites and -1.85% to 70.75% for moderately burnt sites. In Purola Beat, Chhatina Beat, Durgapipal Beat, Khabdoli_South Beat and Ratarao Beat permeability of soil has been observed high in the burnt polygon as compared to the unburnt polygon.

3. In burnt forest areas, measures to restore the soil moisture transmission properties and moisture holding capacity are proposed to be the trenches and vegetative cover (plants and grasses). The addition of manure and compost enhances soil organic matter, which increases soil moisture holding capacity. This SOM also stimulates rapid vegetative growth.

REFERENCES

- Allam, A., Borsali, A. H., Kefifa, A., Zouidi, M., & Gros, R. (2020). Effect of fires on certain properties of forest soils in Western Algeria. *Acta Technologica Agriculturae*, 23(3), 111-117.
- Amreeta Champatiray, Vinay Balmuri, K. C. Patra, Mrunmayee M Sahoo, Standard Test for Determination of Infiltration Rate of Soil Using Double Ring Infiltrometer, 2014, “Innovative Trends in Applied Physical, Chemical, Mathematical Sciences and Emerging Energy Technology for Sustainable Development” ISBN: 978-93-83083-71-8.
- Arsyad, U. (2019, May). The characteristics of infiltration in natural forest in teaching forest of Hasanuddin University University at Maros Regency. In *IOP Conference Series: Earth and Environmental Science* (Vol. 270, No. 1, p. 012004). IOP Publishing.
- Attri, V., Dhiman, R., & Sarvade, S. (2020). A review on status, implications and recent trends of forest fire management. *Archives of Agriculture and Environmental Science*, 5(4), 592-602.
- Bahuguna VK, Singh S (2002) Fire situation in India. *Int For Fire News* 26:23–27
- Berber, A. S., Tavşanoğlu, Ç., & Turgay, O. C. (2015). Effects of surface fire on soil properties in a mixed chestnut-beech-pine forest in Turkey. *Flamma*, 6(2), 78-80.
- Certini, G. (2005). Effects of fire on properties of forest soils: a review. *Oecologia*, 143(1), 1-10.
- Champatiray, A. (2014). *Experimental study for determination of infiltration rate of soils in field using double ring infiltrometer* (Doctoral dissertation).
- Chandra, K. K., & Bhardwaj, A. K. (2015). Incidence of forest fire in India and its effect on terrestrial ecosystem dynamics, nutrient and microbial status of soil. *International Journal of Agriculture and Forestry*, 5(2), 69-78.

- Chandrashekaram, D., & Ushakumari, S. (1987). Metal adsorption capacity of laterites and clays. In *Proceedings of the National Symposium on Role of Earth Sciences in Environment* (pp. 203-214). Indian Institute of Technology, Bombay.
- Crutchfield, C. (2016). Effect of land management practices on soil moisture retention (Doctoral dissertation, University of Illinois at Urbana-Champaign).
- Fonseca, F., de Figueiredo, T., Nogueira, C., & Queirós, A. (2017). Effect of prescribed fire on soil properties and soil erosion in a Mediterranean mountain area. *Geoderma*, 307, 172-180.
- Gayatri, D., & Das, M. (2016). Experimental Study on Infiltration in Guwahati Using Double Ring Infiltrometer. *Int. J. Innov. Res. Sci. Eng. Technol.*, 5(12).
- Goh, S. G., Rahardjo, H., & Leong, E. C. (2015). Modification of triaxial apparatus for permeability measurement of unsaturated soils. *Soils and Foundations*, 55(1), 63-73.
- Gobinath, R., Ganapathy, G. P., & Akinwumi, I. I. (2015). Evaluating the use of lemon grass roots for the reinforcement of a landslideaffected soil from Nilgris district, Tamil Nadu, India. *Journal of materials and environmental science*, 6(10), 2681-2687.
- Gupta, B., Sarvade, S. and Mehta, R. (2014). Effect of chir pine trees and fire on herbaceous flora in North Western Himalaya, India. Published in 101st Indian Science Congress. Part II, abstracts of oral/poster presentation. Sub section- Ecology and Ecosystem. 78p
- Heydari, M., Rostamy, A., Najafi, F., & Dey, D. C. (2017). Effect of fire severity on physical and biochemical soil properties in Zagros oak (*Quercus brantii* Lindl.) forests in Iran. *Journal of Forestry Research*, 28(1), 95-104.

- Jhariya, M. K., & Raj, A. (2014). Effects of wildfires on flora, fauna and physico-chemical properties of soil-An overview. *Journal of Applied and Natural Science*, 6(2), 887-897.
- Juárez-Orozco, S. M., Siebe, C., & Fernández y Fernández, D. (2017). Causes and effects of forest fires in tropical rainforests: a bibliometric approach. *Tropical Conservation Science*, 10, 1940082917737207.
- Kamble, R. (2021). Impacts of Controlled Forest Fires on Soil Properties in Gadchiroli Forest Circle, Central India. *Sustainability, Agri, Food and Environmental Research*, 9(2).
- Kausar, R., Akram, M. I., Choudhary, M. I., Malik, A., Zahid, A. R., & Ali, B. (2020). Soil moisture retention and rainfed wheat yield variations by the addition of gypsum and green manure. *Journal of Soil Science and Environmental Management*, 11(1), 6-16.
- Li, Q., Ahn, S., Kim, T., & Im, S. (2021). Post-fire impacts of vegetation burning on soil properties and water repellency in a pine forest, South Korea. *Forests*, 12(6), 708.
- Maithani, G. P., Bahuguna, V. K., & Lal, P. (1986). Effect of forest fires on the ground vegetation of a moist deciduous sal (*Shorea robusta*) forest. *Indian Forester*, 112(8), 646-678.
- Mishra, A., Sharma, S. D., & Khan, G. H. (2002). Rehabilitation of degraded sodic lands during a decade of *Dalbergia sissoo* plantation in Sultanpur district of Uttar Pradesh, India. *Land Degradation & Development*, 13(5), 375-386.
- ONWUKA, B. M., & UZOMA, K. C. (2018). Effects of organic mulch materials on soil surface evaporation. *Notulae Scientia Biologicae*, 10(3), 387-391.
- Panagea, I. S., Berti, A., Čermak, P., Diels, J., Elsen, A., Kusá, H., ... & Wyseure, G. (2021). Soil Water Retention as Affected by Management Induced

Changes of Soil Organic Carbon: Analysis of Long-Term Experiments in Europe. *Land*, 10(12), 1362.

Parwada, C., Magomani, M. I., & van Tol, J. J. (2020). Impacts of different prescribed fire frequencies on selected soil chemical properties in a semi-arid savannah thornveld. *Cogent Environmental Science*, 6(1), 1868171.

Patle, G. T., Sikar, T. T., Rawat, K. S., & Singh, S. K. (2019). Estimation of infiltration rate from soil properties using regression model for cultivated land. *Geology, Ecology, and Landscapes*, 3(1), 1-13.

Ramulu, I., Ramachandrappa, B. K., Maruthi Sankar, G. R., Sathish, A., Sandhya Kanthi, M., & Archana, A. M. (2017). Assessment of Changes in Soil Infiltration, Water-Holding Capacity, Bulk Density and Fertility Parameters under Different Tree-and Crop-Based Systems in Semiarid Alfisols. *Communications in Soil Science and Plant Analysis*, 48(5), 477-500.

Rasna Sharma, Dr. M.K. Trivedi(2016).Experimental Determination Of Variability In Permeability Of Sandy Silt Soil Mixed With Fly Ash In Proportionate, International Journal Of Engineering Sciences & Research Technology, Issn: 2277-9655, 399-407.

Rasyid, B., Oda, M., & Omae, H. (2018, May). Soil water retention and plant growth response on the soil affected by continuous organic matter and plastic mulch application. In *IOP Conference Series: Earth and Environmental Science* (Vol. 157, No. 1, p. 012008). IOP Publishing.

Reddy, C. S., Bird, N. G., Sreelakshmi, S., Manikandan, T. M., Asra, M., Krishna, P. H., ... & Diwakar, P. G. (2019). Identification and characterization of spatio-temporal hotspots of forest fires in South Asia. *Environmental monitoring and assessment*, 191(3), 1-17.

Saghari, S., Bagheri, G., & Shabanzadeh, H. (2015). Evaluation of permeability characteristics of a polymer fibers-reinforced soil through laboratory tests. *Journal of the Geological Society of India*, 85(2), 243-246.

- Satendra, & Kaushik, A. D. (2014). *Forest fire disaster management*. New Delhi: National Institute of Disaster Management, Ministry of Home Affairs, Government of India.
- Shil, S., & Pal, D. S. K. (2015). Permeability and Volume Change Behaviour of Soil Stabilized with Fly ash. *International Journal of Engineering Research & Technology (IJERT) ISSN, 2278-0181*.
- Sreejani, T. P., Abhishek, D., Srinivas Rao, G. V. R., & Abbulu, Y. (2017). A Study on Infiltration Characteristics of Soils at Andhra University Campus, Visakhapatnam. *International Journal of Environmental Research and Development, 7(1), 29-44*.
- Sujatha, K. N., Kavya, G., Manasa, P., & Divya, K. (2016). Assessment of soil properties to improve water holding capacity in soils. *International Research Journal of Engineering and Technology, 3(3), 1777-1783*.
- Tarek Silem, 2011, "The effect of Land use on Soil Infiltration Rate in Heavy Clay Soil in Egypt"; VATTEN 67 ,Vol..3.No.4 pp.161-166 .
- Thompson, I., Mackey, B., McNulty, S., & Mosseler, A. (2009). Forest resilience, biodiversity, and climate change. In *Secretariat of the Convention on Biological Diversity, Montreal. Technical Series no. 43. 1-67*. (Vol. 43, pp. 1-67).
- Verma, S., & Jayakumar, S. (2012). Impact of forest fire on physical, chemical and biological properties of soil: A review. *proceedings of the International Academy of Ecology and Environmental Sciences, 2(3), 168*.
- Wang, C., Zhao, C., Xu, Z., Wang, Y., & Peng, H. (2013). Effect of vegetation on soil water retention and storage in a semi-arid alpine forest catchment. *Journal of arid land, 5(2), 207-219*.

APPENDIX
Appendix A

Table 1. Soil moisture holding capacity of all burnt and unburnt sites.

| Pressure (Bar) | 0.10 | 0.33 | 0.50 | 0.70 | 1.00 | 3.00 | 5.00 | 7.00 | 10.0 | 15.0 |
|------------------------------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| In | 0010 | 0033 | 0050 | 0071 | 0101 | 0305 | 0509 | 0713 | 1019 | 1529 |
| H(Cm)> | 1.98 | 6.53 | 9.90 | 3.16 | 9.80 | 9.40 | 9.00 | 8.60 | 8.00 | 7.00 |
| Site Name | | | | | | | | | | |
| Batoli-II Beat (Unburnt) | 20.5 6 | 13.6 8 | 12.1 3 | 11.4 2 | 9.63 | 9.36 | 8.52 | 8.13 | 7.84 | 6.70 |
| Batoli-Ii Beat (Burnt) | 18.6 2 | 12.2 6 | 11.2 3 | 10.5 5 | 8.83 | 8.54 | 7.75 | 7.38 | 7.12 | 6.01 |
| Kharkha ri North Beat (Unburnt) | 20.5 6 | 12.1 6 | 11.5 5 | 10.0 7 | 9.12 | 8.74 | 8.12 | 7.97 | 6.87 | 5.84 |
| Kharkha ri north beat (Burnt) | 19.2 5 | 12.6 4 | 11.6 6 | 10.9 3 | 9.56 | 9.16 | 8.67 | 8.22 | 7.13 | 6.07 |
| Kishanp ur South Beat (Unburnt) | 31.1 3 | 21.8 2 | 20.0 4 | 18.4 2 | 15.6 3 | 14.1 6 | 12.0 1 | 10.4 5 | 7.19 | 5.43 |
| Kishanp ur South Beat (Burnt) | 28.7 4 | 19.6 1 | 18.0 1 | 16.2 4 | 13.4 5 | 11.9 3 | 9.65 | 8.28 | 4.85 | 3.29 |
| Kotawal i Beat (Unburnt) | 18.3 6 | 10.6 7 | 9.37 | 8.87 | 8.52 | 8.31 | 8.11 | 7.59 | 7.13 | 5.58 |
| Kotawal i Beat (Burnt) | 20.1 6 | 12.2 9 | 10.5 7 | 10.1 7 | 9.77 | 9.63 | 9.57 | 9.48 | 9.18 | 7.19 |
| Ranipur East Beat (Unburnt) | 25.9 0 | 15.7 1 | 12.7 4 | 11.6 0 | 10.5 2 | 9.78 | 9.14 | 8.69 | 8.43 | 7.70 |

| | | | | | | | | | | |
|-------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|------|------|
| Ranipur East Beat (Burnt) | 23.65 | 15.58 | 12.64 | 11.38 | 10.17 | 9.63 | 8.86 | 8.57 | 8.21 | 7.63 |
| Purola Beat (Unburnt) | 25.63 | 16.16 | 14.18 | 12.36 | 10.30 | 9.53 | 9.14 | 8.91 | 8.60 | 7.92 |
| Purola Beat (Burnt) | 23.03 | 15.07 | 13.26 | 11.56 | 9.48 | 9.14 | 8.76 | 8.45 | 8.15 | 7.38 |
| Tumaria Beat (Unburnt) | 3.89 | 3.67 | 3.62 | 3.63 | 3.41 | 3.43 | 3.23 | 3.19 | 3.14 | 2.97 |
| Tumaria Beat (Burnt) | 4.13 | 3.45 | 3.43 | 3.43 | 3.41 | 3.38 | 3.37 | 3.35 | 3.32 | 3.27 |
| Chhatina Beat (Unburnt) | 20.64 | 12.36 | 11.46 | 9.65 | 8.34 | 7.61 | 7.23 | 6.67 | 6.45 | 5.93 |
| Chhatina Beat (Burnt) | 19.03 | 11.27 | 10.23 | 8.78 | 7.23 | 6.96 | 6.62 | 6.23 | 6.03 | 5.41 |
| Durgapal Beat (Unburnt) | 23.45 | 15.23 | 12.06 | 10.24 | 9.56 | 9.09 | 8.85 | 8.40 | 8.16 | 7.46 |
| Durgapal Beat (Burnt) | 22.56 | 13.49 | 10.46 | 8.74 | 8.16 | 7.89 | 7.65 | 7.40 | 7.26 | 6.61 |
| Jaulkan de Beat (Unburnt) | 21.36 | 15.46 | 12.63 | 11.06 | 10.47 | 9.83 | 9.48 | 9.03 | 8.56 | 7.58 |
| Jaulkan de Beat (Burnt) | 23.03 | 17.63 | 13.92 | 12.63 | 11.97 | 11.23 | 10.76 | 10.23 | 9.75 | 8.64 |
| Khabdoli_South Beat (Unburnt) | 18.23 | 11.25 | 9.53 | 8.91 | 7.89 | 7.53 | 7.12 | 6.72 | 6.52 | 5.40 |
| Khabdoli_South | 16.67 | 10.38 | 8.76 | 8.11 | 7.21 | 6.83 | 6.45 | 6.24 | 5.89 | 4.98 |

| | | | | | | | | | | | |
|-----------------------------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|------|------|------|--|
| Beat (Burnt) | | | | | | | | | | | |
| Pungar-I Beat (Unburnt) | 20.5 6 | 13.0 7 | 11.6 7 | 11.0 1 | 9.76 | 8.79 | 8.43 | 8.13 | 7.73 | 6.27 | |
| Pungar-I Beat (Burnt) | 18.6 2 | 12.2 1 | 10.9 6 | 10.2 3 | 9.09 | 8.16 | 7.68 | 7.38 | 6.97 | 5.86 | |
| Ratarao Beat (Unburnt) | 22.1 2 | 15.7 7 | 13.8 2 | 13.2 3 | 11.2 6 | 10.8 1 | 10.4 4 | 9.56 | 9.00 | 7.73 | |
| Ratarao Beat (Burnt) | 20.2 2 | 14.1 8 | 12.3 6 | 11.9 0 | 9.96 | 9.61 | 9.33 | 8.56 | 8.10 | 6.95 | |
| Tanda Center Beat (Unburnt) | 21.6 7 | 14.1 7 | 13.6 0 | 12.7 5 | 11.2 3 | 9.95 | 8.19 | 7.45 | 4.43 | 3.38 | |
| Tanda Center Beat (Burnt) | 20.5 8 | 12.4 4 | 12.0 1 | 11.6 7 | 10.4 5 | 8.92 | 7.59 | 6.83 | 3.93 | 3.23 | |
| West Kilpura- I Beat (Unburnt) | 32.4 2 | 18.4 2 | 15.2 7 | 13.7 3 | 11.0 3 | 9.81 | 8.68 | 6.91 | 6.56 | 5.45 | |
| West Kilpura- I Beat (Burnt) | 23.0 3 | 16.0 2 | 14.5 6 | 12.4 5 | 10.0 0 | 8.87 | 7.72 | 5.94 | 5.60 | 4.61 | |

Appendix B

Table 2. Infiltration rate of some burnt and unburnt sites

1. Batoli-II Beat

| Cumulative Time (hr) | Burnt soil Infiltration rate | Cumulative Time (hr) | Unburnt soil infiltration rate |
|----------------------|------------------------------|----------------------|--------------------------------|
| 0.00 | | 0.00 | |
| 0.05 | 9.56 | 0.05 | 10.63 |
| 0.10 | 6.57 | 0.10 | 7.62 |
| 0.15 | 5.98 | 0.15 | 6.13 |
| 0.20 | 5.98 | 0.20 | 6.14 |
| 0.28 | 5.73 | 0.25 | 5.76 |
| 0.37 | 5.28 | 0.33 | 5.28 |
| 0.45 | 6.05 | 0.42 | 5.23 |
| 0.53 | 5.47 | 0.50 | 5.7 |
| 0.62 | 5.46 | 0.58 | 6.3 |
| 0.78 | 5.47 | 0.67 | 5.43 |
| 0.95 | 5.73 | 0.75 | 5.73 |
| 1.12 | 5.47 | 0.83 | 5.2 |
| 1.28 | 4.84 | 1.00 | 4.36 |
| 1.53 | 5.15 | 1.17 | 4.35 |
| 1.78 | 5.03 | 1.33 | 4 |
| 2.03 | 5.13 | 1.50 | 4.3 |
| 2.28 | 4.96 | 1.67 | 3.12 |
| 2.53 | 4.64 | 2.00 | 3.14 |
| 3.03 | 3.34 | 2.33 | 3.14 |
| 3.53 | 3.21 | 2.67 | 3.16 |
| 4.03 | 3.17 | 3.00 | 2.9 |
| 4.53 | 3.16 | 3.50 | 2.7 |
| 5.03 | 3.14 | 4.00 | 2.6 |
| 5.53 | 3.15 | 4.50 | 2.65 |
| 6.03 | 3.1 | 5.00 | 2.4 |
| 6.53 | 2.39 | 5.50 | 2.34 |
| 7.03 | 2.39 | 6.00 | 2.35 |
| 7.53 | 2.39 | 6.5 | 2.32 |
| | | 7.00 | 2.32 |
| | | 7.50 | 2.32 |

2. Kharkhari North Beat

| Cumulative time (hr) | Burnt Soil | Cumulative time (hr) | Unburnt Soil |
|----------------------|------------|----------------------|--------------|
| 0 | | 0 | |
| 0.05 | 30.45 | 0.05 | 25.45 |
| 0.10 | 20.46 | 0.10 | 17.63 |
| 0.15 | 18.65 | 0.15 | 15.23 |

| | | | |
|------|-------|------|-------|
| 0.20 | 16.25 | 0.20 | 16.23 |
| 0.25 | 20.46 | 0.25 | 17.63 |
| 0.33 | 22.48 | 0.30 | 15.23 |
| 0.42 | 15.63 | 0.35 | 18.36 |
| 0.50 | 11.26 | 0.40 | 13.67 |
| 0.58 | 10.63 | 0.48 | 12.64 |
| 0.67 | 9.59 | 0.57 | 10.30 |
| 0.75 | 8.59 | 0.65 | 8.96 |
| 0.83 | 8.59 | 0.73 | 8.97 |
| 1.00 | 8.56 | 0.82 | 8.96 |
| 1.17 | 7.83 | 0.98 | 8.56 |
| 1.33 | 7.46 | 1.15 | 8.54 |
| 1.50 | 7.45 | 1.32 | 8.53 |
| 2.00 | 6.54 | 1.48 | 7.65 |
| 2.50 | 5.53 | 1.65 | 5.64 |
| 3.00 | 4.63 | 1.82 | 5.41 |
| 3.50 | 4.21 | 2.15 | 4.13 |
| 4.00 | 3.63 | 2.48 | 3.46 |
| 4.50 | 3.45 | 2.82 | 3.48 |
| 5.00 | 2.91 | 3.15 | 3.46 |
| 5.50 | 2.61 | 3.65 | 3.41 |
| 6.00 | 2.55 | 4.15 | 3.12 |
| 6.50 | 2.56 | 4.65 | 3.12 |
| 7.00 | 2.53 | 5.32 | 2.86 |
| 7.50 | 2.53 | 5.82 | 2.81 |
| 8.00 | 2.53 | 6.32 | 2.77 |
| | | 6.98 | 2.56 |
| | | 7.48 | 2.56 |

3. Kishanpur South Beat

| Time (hr) | Burnt soil | Time (hr) | Unburnt soil |
|-----------|------------|-----------|--------------|
| 0.00 | | 0.00 | |
| 0.05 | 17.36 | 0.05 | 20.16 |
| 0.10 | 15.23 | 0.10 | 15.36 |
| 0.15 | 11.45 | 0.15 | 15.36 |
| 0.20 | 15.91 | 0.20 | 17.63 |
| 0.28 | 13.91 | 0.25 | 10.64 |
| 0.37 | 10.65 | 0.33 | 8.69 |
| 0.45 | 9.96 | 0.42 | 9.15 |
| 0.53 | 9.86 | 0.50 | 9.64 |
| 0.62 | 8.63 | 0.58 | 8.45 |
| 0.78 | 8.63 | 0.67 | 8.45 |
| 0.95 | 9.55 | 0.75 | 6.26 |
| 1.12 | 6.54 | 0.83 | 5.2 |

| | | | |
|------|------|------|------|
| 1.28 | 6.45 | 1.00 | 4.36 |
| 1.53 | 6.23 | 1.17 | 4.63 |
| 1.78 | 5.42 | 1.33 | 4.4 |
| 2.03 | 4.5 | 1.50 | 4.3 |
| 2.28 | 4.1 | 1.67 | 3.56 |
| 2.53 | 3.56 | 2.00 | 3.14 |
| 3.03 | 3.34 | 2.33 | 3.14 |
| 3.53 | 3.21 | 2.67 | 3.16 |
| 4.03 | 3.17 | 3.00 | 2.9 |
| 4.53 | 2.64 | 3.50 | 2.7 |
| 5.03 | 2.47 | 4.00 | 2.6 |
| 5.53 | 2.45 | 4.50 | 2.65 |
| 6.03 | 2.36 | 5.00 | 2.4 |
| 6.53 | 2.15 | 5.50 | 2.34 |
| 7.03 | 2.13 | 6.00 | 2.35 |
| 7.53 | 2.13 | 6.50 | 2.18 |
| | | 7.00 | 2.17 |
| | | 7.50 | 2.17 |

RESUME

Name: Kamal Prakash

Contact Information

Email ID : k.prakash1004@gmail.com

Permanent Address : Village- Sirli, Post-Boida, Tahsil- Pali, Korba (C.G.)

Personal Information

Father's Name : Mr. Har Prasad

Mother's Name : Mrs. Gouri Bai

Sex : Male

Date of Birth : 10-04-1998

ACADEMIC QUALIFICATION

| Degree | Year of Passing | Division | Aggregate % of Marks | Institution/ University | Major Subject |
|------------------------|-----------------|-----------------|----------------------|----------------------------------------------|----------------------------------------------------------------|
| High School | 2013 | 1 st | 86.67% | CGBSE | Hindi, Mathematics, Science, Social, Science, Sanskrit, Hindi. |
| Higher Secondary | 2015 | 1 st | 82.60% | CGBSE | Mathematics, Hindi, English, Physics, Chemistry, Maths. |
| B.Tech (Agril. Engg.) | 2020 | 1 st | 76.30% | IGKV | All subject of Agril. Engg. |
| M.Tech. (Agril. Engg.) | Pursuing | Pursuing | Pursuing | S.V.C.A.E.T & R.S, FAE I.G.K.V, Raipur(C.G.) | SWE (92 nd Academic Council Meeting of IGKV) |

K. Prakash
Signature