NMHS-Himalayan Institutional Fellowship Grant

FINAL TECHNICAL REPORT (FTR)

Predicting climatically suitable future habitats for the range restricted Himalayan bird using species distribution modelling approach

Submitted to

National Mission on Himalayan Studies

(Ministry of Environment, Forest and Climate Change, New Delhi)

G.B. Pant National Institute of Himalayan Environment

Kosi-Katarmal, Almora-263 643, Uttarakhand, India

Submitted by

Dr Hukum Singh

Principal Investigator

Forest Research Institute

(Indian Council of Forestry Research and Education)

PO New Forest, Dehradun – 248006, Uttarakhand, India

NMHS-Himalayan Institutional Fellowship Grant

FINAL TECHNICAL REPORT (FTR)

NMHS Reference No.:	GBPNI/NMHS-2017-18/HSF-05

Date of Submission:	1	1	0	7	2	0	2	2
	d	**d**	**m**	**m**	**y**	**y**	**y**	**y**

PROJECT (FELLOWSHIP) TITLE

Predicting climatically suitable future habitats for the range restricted Himalayan bird using species distribution modelling approach

Sanctioned Fellowship Duration: April 2018 June 2021

Extended Fellowship Duration (if applicable): April 2021 to June 2021

***Submitted to*:**

Er. Kireet Kumar
Scientist 'G' and Nodal Officer, NMHS-PMU
National Mission on Himalayan Studies, GBP NIHE HQs
Ministry of Environment, Forest & Climate Change (MoEF&CC), New Delhi
E-mail: nmhspmu2016@gmail.com; kireet@gbpihed.nic.in; gupta.dharmendra@gov.in

***Submitted by*:**
Dr Hukum Singh, Scientist
Principal Investigator
Forest Research Institute,
PO New Forest Dehradun
+91 135 2224480

hukum@icfre.org

GENERAL INSTRUCTIONS:

1. The Final Technical Report (FTR) has to be commenced from the date of start of the Institutional Fellowship (as per the Sanction Order issued at the start of the Fellowship) till its completion. Each detail has to comply with the NMHS Sanction Order.
2. The FTR should be neatly typed (in Arial with font size 11 with 1.5 spacing between the lines) with all details as per the enclosed format for direct reproduction by photo-offset process. Colored Photographs (4-5 good action photographs), tables and graphs should be accommodated within the report or should be annexed with captions. Sketches and diagrammatic illustrations may also be given giving step-by-step details about the methodology followed in technology development/modulation, transfer and training. Any correction or rewriting should be avoided. Please give information under each head in serial order.
3. Training/ Capacity Building Manuals (with detailed contents of training programme, technical details and techniques involved) or any such display material related to fellowship activities along with slides, charts, photographs should be sent at the NMHS-PMU, GBP NIHE HQs, Kosi-Katarmal, Almora 263643, Uttarakhand. In all Knowledge Products, the Grant/ Fund support of the NMHS should be duly acknowledged.
4. The FTR Format is in sync with many other essential requirements and norms desired by the Govt. of India time-to-time, so each section of the NMHS-FTR needs to duly filled by the Fellowship Coordinator/ PI and verified by the Head of the Implementing Institution/ University.
5. Five (5) bound hard copies of the NMHS-Institutional Fellowship Final Technical Report (FTR) and a soft copy should be submitted to the **Nodal Officer, NMHS-PMU, GBP NIHE HQs, Kosi-Katarmal, Almora, Uttarakhand** *via* e-mail nmhspmu2016@gmail.com.

The FTR is to be submitted into following two parts:

Part A – Cumulative Fellowship Summary Report

Part B – Comprehensive Report

Following Financial and other necessary documents/certificates need to be submitted duly signed and verified along with Final Technical Report (FTR):

Annexure I	Consolidated and Audited Utilization Certificate (UC) & Statement of Expenditure (SE), including interest earned for the last Fiscal year including the duly filled GFR-19A (with year-wise break-up)
Annexure II	Consolidated Interest Earned Certificate
Annexure III	Consolidated Manpower Certificate and Direct Benefit Transfer (DBT) Details showing the education background, i.e. NET/GATE etc. qualified or not, Date of joining and leaving, salary paid per month and per annum (with break up as per the sanction Order and year-wise).
Annexure IV	Details and Declaration of Refund of Any Unspent Balance as Real-Time Gross System (RTGS) in favor of NMHS GIA General
Annexure V	Details of Technology Transfer and Intellectual Property Rights developed.

NMHS-Final Technical Report (FTR)

NMHS- Institutional Himalayan Fellowship Grant

DSL: *Date of Sanction Letter*

3	0	0	3	2	0	1	8
d	d	m	m	y	y	y	y

DFC: *Date of Fellowship Completion*

3	0	0	6	2	0	2	1
d	d	m	m	y	y	y	y

Part A: <u>CUMULATIVE SUMMARY REPORT</u>

1. Details Associateship/Fellowships

1.1 Contact Details of Institution/University

NMHS Fellowship Grant ID/ Ref. No.:	GBPNI/NMHS-2017-18/HSF-05
Name of the Institution/ University:	Forest Research Institute Dehradun
Name of the Coordinating PI:	Dr. Hukum Singh
Point of Contacts (Contact Details, Ph. No., E-mail):	Dr. Hukum Singh, Scientist, Forest Research Institute, Dehradun. Email: hukum@icfre.org Ph. No.-9675306791

1.2 Research Title and Area Details

i.	Institutional Fellowship Title:	Predicting climatically suitable future habitats for the range restricted Himalayan bird using species distribution modelling approach					
ii.	IHR State(s) in which Fellowship was implemented:	Uttarakhand, Himachal Pradesh, Jammu and Kashmir					
iv.	Scale of Fellowship Operation	Local	✓	Regional		Pan-Himalayan	
iii.	Study Sites covered (*site/location maps to be attached*)	Uttarakhand, Himachal Pradesh, Jammu and Kashmir (map Attached)					
v.	Total Budget Outlay:	2327687.00 (twenty three lakh twenty seven thousand six hundred eighty seven only)					

1.3 Details Himalayan Research /Project Associates/Fellows inducted

Type of Fellowship	Nos.	Work Duration	
		From	To
Research Associates	1	10/12/2018	30/06/2021
Sr. Research Fellow	Nil	NA	NA
Jr. Research Fellows	Nil	NA	NA
Project Fellows	Nil	NA	NA

2. Research Outcomes

2.1. Abstract

The Himalayan biodiversity is under severe threat of changing climatic variability. These changes threaten the persistence of several species and lead to shifts in community composition and function. The biological organism combats the dangers of climate change and anthropogenic pressure in several ways to survive in the environment. The organisms may try to (a) develop adaptations to novel environmental conditions, (b) shift their distribution to track suitable environmental conditions, and (c) face extinction if they are unable to move or develop adaptations. Therefore, the prediction of the distribution of Himalayan range-restricted bird species is a significant area of research to develop management options for conserving biodiversity via adapting to changing climatic. The checklist of Himalayan range-restricted bird species was prepared for the further selection of bird species to predict species distribution based on the suitable habitats in current and future climate change scenarios. In the present study, eleven bird species were identified for their distribution was restricted to the Himalayan region. Out of eleven, three range-restricted bird species were chosen for further modeling using the species distribution approach. Further, the modeling was performed to predict climatically suitable future habitats for the range of restricted Himalayan birds (*Catreus wallichii*, *Tragopan melanocephalus*, and *Sitta leucopsis*) using the species distribution modelling approach. To achieve the project objective, the data on the occurrence/absence of the bird species were collected from the primary and secondary resources, including field visits, consultation with officials of state forest departments, researchers, scientific reports, and documents. Besides, data were also assorted from online platform such as e-bird and bird international. The data on climatic variables of present and future were retrieved from the bio-clime open source. After that, the Species Distribution Modelling approach was used

to predict the future suitable habitat of *Catreus wallichii*, *Tragopan melanocephalus* and *Sitta leucopsis* species under various climatic conditions scenarios of Representative Concentration Pathways (RCPs) viz RCP2, RCP4.5, 6RCP and RCP8.5 by 2050, and 2070. The future suitable distribution maps were developed for the selected species i.e. *Catreus wallichii*, *Tragopan melanocephalus* and *Sitta leucopsis,* under current and different RCPs. Based on the analysis and results, it was revealed that the selected species would migrate towards the higher altitude for their survival in future climatic conditions as compared to current climatic conditions. It was concluded that the suitable habitat of *Catreus wallichii*, *Tragopan melanocephalus* and *Sitta leucopsis* would shift their habitats towards higher altitudes with different RCPs of climate change for the years 2050 and 2070. This study will help policymakers to develop and formulate policies/strategies for conserving and managing biological diversity in the Himalayan region under future climate change. Besides, this study will allow policymakers to identify priority species for conservation and protection, especially those on the verge of extinction. It is further suggested that similar research would be implemented for other Himalayan range-restricted species to predict future suitable habitats to conserve and manage Himalayan bird species in the wake of climate change.

2.2. Objective-wise Major Achievements

S.N.	Cumulative objectives	Major achievement (in bullets points
	Predicting climatically suitable future habitats for the range-restricted Himalayan bird using species distribution modelling approach	✓ Generated baseline data on Himalayan range restricted bird species. ✓ Generated database on the occurrence of Western tragopan (*Tragopan melanocephalus*) and Cheer Pheasant (*Catreus wallichii*) and white-cheeked nuthatch (*Sitta leucopsis*) in the state of Uttarakhand, Himachal Pradesh, and Jammu and Kashmir. ✓ Developed potential habitat suitability distribution maps of Western tragopan (*Tragopan melanocephalus*) and Cheer Pheasant (*Catreus wallichii*) and white-

		cheeked nuthatch (*Sitta leucopsis*) in current climate in the state of Uttarakhand, Himachal Pradesh, and Jammu and Kashmir. ✓ Reported bioclimatic and other variables contributing toward habitat suitability of the selected range restricted bird species in the Himalayan states (Uttarakhand, Himachal Pradesh, and Jammu and Kashmir). ✓ Predicted distribution of suitable future habitat of Western tragopan (*Tragopan melanocephalus*) and Cheer Pheasant (*Catreus wallichii*) and white-cheeked nuthatch (*Sitta leucopsis*) in the state of Uttarakhand, Himachal Pradesh, and Jammu and Kashmir under the climate change scenario developed by IPCC in the form of Representative Concentration Pathways (RCPs) viz. RCP 2.6, RCP 4.5, 6.0 and 8.5 by 2050, and 2070. ✓ Generated database on the habitat shifting of chosen range restricted bird species towards high attitude under the influence of climate change. ✓ Disseminated findings through publishing a manuscript entitled "Modelling habitat suitability of western tragopan (*Tragopan melanocephalus*) a range-restricted vulnerable bird species of the Himalayan region, in response to climate change" in peer reviewed journal

		"Climate Risk Management" with impact factor 5.27. ✓ Disseminated knowledge and finding through paper presentation on "Predicting climatically suitable future habitats for the range-restricted Himalayan bird using species distribution modelling approach" during the India International Science Festival held in Kolkata from 5-8 November 2019. ✓ Himalayan Research Associate (HRA) got travel grant to present findings during the India International Science Festival held in Kolkata from 5-8 November 2019. ✓ Developed and communicated one manuscript "Ensemble species distribution modeling approach for predicting habitat suitability of Himalayan cheer pheasant (*Catreus wallichii*) in response to future climate change".

2.3. Outputs in terms of Quantifiable Deliverables*

S. No.	Quantifiable Deliverables*	Monitoring Indicators*	Quantified Output/ Outcome achieved	Deviations made, if any, and Reason thereof:
1	Generation of database encompassing Himalayan range	Eleven Himalaya range restricted were identified. A check list was prepared.	Generated baseline data on Himalayan range restricted bird species through various	NA

	restricted bird species		approaches	
2	Generation of modeling protocol for further use for other birds of the Indian Himalayan region	Prepared the modelling protocol for three bird species i.e. Western tragopan (*Tragopan melanocephalus*) and Cheer Pheasant (*Catreus wallichii*) and white-cheeked nuthatch (*Sitta leucopsis*)	Generated modeling protocol for selected Himalayan range restricted birds species which could be used for bird species in the future	NA
3	Species distribution model maps for the range restricted Himalayan bird species	Generated current and future habitat distribution maps for the Western tragopan (*Tragopan melanocephalus*) and Cheer Pheasant (*Catreus wallichii*) and white-cheeked nuthatch (*Sitta leucopsis*) under various RCPs i.e. RCP 2.6, RCP 4.5, 6.0 and 8.5 by 2050, and 2070.	Developed species distribution maps for habitat suitability of the selected Himalayan range restricted bird species in current and future climate change scenario	NA
4	Capacity building development		Strengthen capacity and skill for further species distribution modelling	NA

(*) As stated in the Sanction Letter issued by the NMHS-PMU.

2.4. Strategic Steps with respect to Outcomes (in bullets)

S. No.	Particulars	Number/ Brief Details	Remarks/ Enclosures
1.	New Methodology developed:	-	-
2.	New Models/ Process/ Strategy developed:	Developed models for the habitats suitability of three Himalayan range-restricted bird species selected bird species in current and future climatic conditions	-
3.	New Species identified:	-	
4.	New Database established:	✓ Database generated on the shift of Himalayan range restricted bird species in response to future climate change. ✓ Reported bioclimatic and other variables contributing toward habitat suitability of the selected range restricted bird species in the Himalayan states (Uttarakhand, Himachal Pradesh, and Jammu and Kashmir).	
5.	New Patent, if any:	-	
	I. Filed (Indian/ International)	-	
	II. Granted (Indian/ International)	-	
	III. Technology Transfer (if any)	-	

S. No.	Particulars	Number/ Brief Details	Remarks/ Enclosures
6.	Others, if any:	✓ Used species distribution modeling to predict distribution of suitable future habitat of Western tragopan (*Tragopan melanocephalus*) and Cheer Pheasant (*Catreus wallichii*) and white-cheeked nuthatch (*Sitta leucopsis*) in the state of Uttarakhand, Himachal Pradesh, and Jammu and Kashmir under the climate change scenario developed by IPCC in the form of Representative Concentration Pathways (RCPs) viz. RCP 2.6, RCP 4.5, 6.0 and 8.5 by 2050, and 2070.	

3. Technological Intervention

S. No.	Type of Intervention	Brief Narration on the interventions	Unit Details (No. of villagers benefited / Area Developed)
1.	Development and deployment of indigenous technology		
2.	Diffusion of High-end Technology in the region		

3.	Induction of New Technology in the region	Used species distribution modelling approach for the prediction and species range shift of Himalayan range restricted bird species under future climate change. This is very first initiative in the Indian western Himalayas where modelling for range restricted bird species was undertaken to conserve and manage Himalayan biodiversity	
4.	Publication of Technological / Process Manuals		
	Others (if any)		

4. New Data Generated over the Baseline Data

S. No.	New Data Details	Existing Baseline	Additionality and Utilisation of New data (*attach supplementary documents*)

1.	✓ Database generated on the shift of Himalayan range restricted bird species in response to future climate change.	✓ No data existing on the habitat shift of selected species in the Himalayan region.	
2.	✓ Reported bioclimatic and other variables contributing toward habitat suitability of the selected range restricted bird species in the Himalayan states (Uttarakhand, Himachal Pradesh, and Jammu and Kashmir).	✓ No data existing on the contribution of bioclimatic and associated variables to habitat suitability.	

5. Linkages with Regional & National Priorities (SDGs, INDC, etc.)/ Collaborations

S. No.	Linkages /collaborations	Details	No. of Publications/ Events Held	Beneficiaries

1.	Sustainable Development Goals (SDGs)	• The study will fulfil the action required under SDG 13 on "Climate Change" which focuses on urgent action to combat climate change and its impacts on various ecosystems/ sectors.	1	Policymakers, biodiversity conservator, climate change scientists and academician, students, state forest departments etc.
2.	Climate Change/INDC targets	• The findings of this study will assist various climate actions in understanding climate change impacts on the ecosystem for developing plans and strategies for conserving and managing Himalayan biodiversity in the wake of climate change.	1	Policymakers, biodiversity conservator, climate change scientists and academician, students, state forest departments etc.

3.	International Commitments	• The results of the present study would be inputs to the reports on climate change developed by the IPCC, UNFCC, etc.		
4.	National Policies	• The present study's findings will be aids various plans/policies for the conservation and management of Himalayan biodiversity.		
5.	Others collaborations			

6. Financial Summary (Cumulative)*

*Please attach the **consolidated and audited Utilization Certificate (UC) and Consolidated and *Year-wise* Statement of Expenditure (SE)** separately, *ref.* **Annexure I.**

These documents are attached alonwith this report.

7. Quantification of Overall Research Progress

S. No.	Parameters	Total (Numeric)	Remarks/ Attachments/ Soft copies of documents
1.	IHR States Covered	3	NA
2.	Project Site/ Field Stations Developed	-	
3.	New Methods/ Modeling Developed	3	NA
4.	No. of Trainings arranged	-	
5.	No of beneficiaries attended trainings	-	
6.	Scientific Manpower Developed	1 (RA)	NA

	(Phd/M.Sc./JRF/SRF/ RA):		
7.	SC stakeholders benefited	-	
8.	ST stakeholders benefited	-	
9.	Women Empowered	-	
10.	No of Workshops Arranged along with level of participation	-	
11.	On field Demonstration Models initiated	-	
12.	Livelihood Options promoted	-	
13.	Technical/ Training Manuals prepared	-	
14.	Processing Units established	-	
15.	No of Species Collected	-	
16.	New Species identified	-	
17.	New Database generated (Types):	-	
	Others (if any)	-	

***** Please attach the soft copies of supporting documents word files and data files in excel.

8. Knowledge Products and Publications*

S. No.	Publication/ Knowledge Products	*Number*		*Total Impact Factor*	*Remarks/* Enclosures **
		National	International		
1.	Journal Research Articles/ Special Issue (Peer-reviewed/ Google Scholar)	-	1	5.27	Enclosed
2.	Book Chapter(s)/ Books:	-	-	-	-
3.	Technical Reports/ Popular Articles	-	-	-	-
4.	Training Manual (Skill Development/ Capacity Building)	-	-	-	-
5.	Papers presented in Conferences/ Seminars	-	1	-	Enclosed
6.	Policy Drafts (if any)	-	-	-	-

S. No.	Publication/ Knowledge Products	*Number*		*Total Impact Factor*	*Remarks/* Enclosures **
		National	International		
7.	Others (specify)	-	1	-	enclosed (communication)

*Please append the list of KPs/ publications (with impact factor and URL link details) with due Acknowledgement to NMHS.
**Please provide supporting copies of the published documents.

9. Recommendation on Utility of Research Findings, Replicability and Exit Strategy

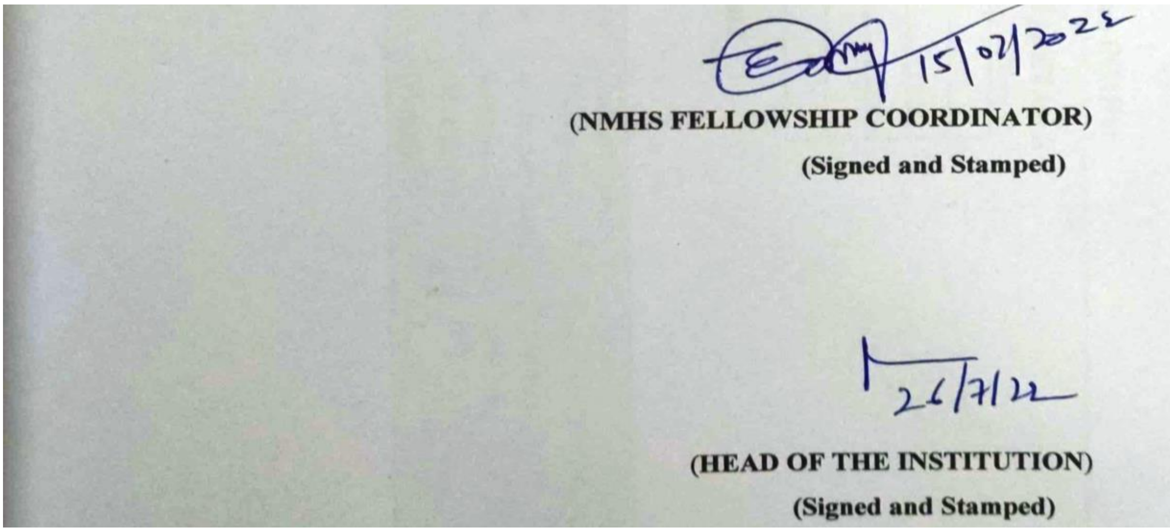
9.1 Utility of the Fellowship Findings

S. No.	*Research Questions Addressed*	*Succinct Answers (within 150–200 words)*
1.	Whether changing climate and land use would modify the distribution ranges of the restricted range Himalayan birds in future?	The findings revealed that future changing climatic scenarios and land use would significantly modify the habitat distribution range of the Himalayan range-restricted bird species. Further, there will be an upward shift in the habitat distribution of the selected range of restricted bird species in the Himalayan ecosystem.

9.2 Recommendations on Replicability and Exit Strategy:

Particulars	**Recommendations**

Replicability of Fellowship, if any	Similar study may be replicated for other vulnerable and endangered avifauna of the Himalayan region to assess the impact of climate change and land use on the habitat shift/habitat distribution to develop effective biodiversity conservation and management plans. Besides, species and environment/land-use change interactions may be understood to develop appropriate strategies for conserving and managing biodiversity in the Himalayan region.
Exit Strategy:	The projects' findings will help various stakeholders such as forest departments, the Union Ministry of Environment, Forest and Climate Change, policymakers and planners, scientists, academicians, biodiversity conservators, etc., to understand the climate change and land use impacts on the Himalayan ecosystem. This study also suggested that a participatory approach may be taken to conserve and manage the Himalayan biodiversity, especially avifauna of the Himalayan states, which is very sensitive and vulnerable to climate change and land-use interventions.


15/07/2022

(NMHS FELLOWSHIP COORDINATOR)

(Signed and Stamped)

26/7/22

(HEAD OF THE INSTITUTION)

(Signed and Stamped)

PART B: COMPREHENSIVE REPORT (including all sanctioned positions of Researchers)

Based on the Fellowship Proposal submitted/approved at the time of sanction, the co-ordinating Principal Investigator shall submit a comprehensive report including report of all individual researchers.

The comprehensive report shall include an **Executive Summary** and it should have separate chapters on (1) **Introduction** (2) **Methodologies, Strategy and Approach** (3) **Key Findings and Results** (4) **Overall Achievements** (5) **Impacts of Fellowship in IHR** (6) **Exit Strategy and Sustainability** (7) **References/ Bibliography** and (8) **Acknowledgements** (It should have a mention of financial grant from the NMHS, MoEF&CC).

Further, description of Technical Activities, List of Trainings/ Workshops/ Seminars with details of trained resources, list of New Products developed under the fellowship, Manual of Standard Operating Procedures (SOPs) developed, Technology developed/Transferred etc should be enclosed as Appendix.

Report (hard copy) should be submitted to:

Er. Kireet Kumar
Scientist 'G' and Nodal Officer, NMHS-PMU
National Mission on Himalayan Studies (NMHS)
G.B. Pant National Institute of Himalayan Environment (GBP NIHE)
Kosi-Katarmal, Almora 263643, Uttarakhand

Report (soft copy) should be submitted at:

E-mail: nmhspmu2016@gmail.com; kireet@gbpihed.nic.in; gupta.dharmendra@gov.in

PART B: COMPREHENSIVE REPORT

EXECUTIVE SUMMARY

The Executive Summary of the fellowship should not be more than 3–5 pages, covering all essential features in precise and concise manner as stated in Part A (Cumulative Fellowship Summary Report) and Part B (Comprehensive Report).

Fellowship Report No.: ***1 of 1*** *(n = Sequential number; N= Total no. of fellowships granted to the Institute/ University)*

Researchers Details

Type of Fellowship (HRA/HJRF/HJPF)	Name of Himalayan Researcher	Date of Joining	Date of Resignation **	Research Title	Name of the PI & Designation
1	Dr. Narendra Kumar	10/12/2018	30/06/2021	Predicting climatically suitable future habitats for the range restricted Himalayan bird using species distribution modelling approach	Dr. Hukum Singh, Scientist

*If the appointed researcher resigned in the mid of the fellowship duration, then also mention the name of the Himalayan researcher who carried forward the fellowship.

1 INTRODUCTION

1.1 Background/ Summary of the Associateship / Fellowship Study undertaken (max. 500 words)

The Indian Himalayan region is rich in biological and socio-cultural diversity and is considered one of the 34 biological hotspots of India. The Indian Himalayan region is most vulnerable and sensitive to climate change (IPCC, 2007). This region is forced by the changing climatic conditions and anthropogenic activities. The average global temperature has risen by 0.6°C in the past 100 years. If the current rate of greenhouse emissions is continued, the global temperature is expected to increase by 1.5 to 4.5 °C by the end of this century (IPCC 2014). The climate change and associated variables have impacted IHR resulting in changes in the ecosystem's structure, function, and composition, including species habitat and range shift.

Minimal studies are available on the climate change impacts on flora and fauna of the Indian Himalayan Region flora and fauna using modeling approach. The avifauna, i.e., range-restricted and vulnerable bird species of this region, is more vulnerable and habitats are likely to be impacted by climate change and other related variability. Climate change impact studies on range-restricted bird species are required for developing policies for conserving and managing biodiversity under the influence of climate change to maintain ecological balance.

This region is vastly lacking such studies, particularly species-level studies in terms of observations related to impacts of climate change on the ecosystem as well as biodiversity (Gautam et al. 2013). But now a day's, researchers are very enthusiastic about understanding how climate change adversely affects the Himalayan ecosystem and developing conservation and management strategies.

Climate change in the last few decades has drastically affected the Himalayan biodiversity, particularly significant changes in biological diversity (viz. flora and fauna). Changes in adaptive behavior in changing climatic conditions will determine the distribution of species in the Indian Himalayan ecosystem in the future. With climate change patterns and global warming, several species of animals can try to (a) Build adaptations to new environmental conditions (b) shift their distribution from their native places towards higher elevations and (c) they may die or become extinct if they are unable to move. Variation in temperature, notably higher temperature, alters their habitat and breeding strategies for adaptation to the drastic changes. It has been reported that many bird species (viz. snow pigeon, white-winged redstart, blood pheasant and rusty-bellied shortwing etc.), moths, and butterflies are shifted, and the range of occurrence is from 1500 to 4000 masl (Acharya and Chettri, 2012). Nevertheless, endemic species of the north-eastern Himalayan region such as takin (*Budorcas taxicolor*), Namdapha flying squirrel (*Biswamoyopterus biswasi*), Sclater's monal (*Tragopan temminckii*), white-winged, black-necked crane, wood duck, etc. are on the verge of extinction.

Recent extreme events in terms of climate change have frequently caused large-scale shifts in plant and animal ecosystems. Single large-scale extinction events happened at least five times in the history of Earth, with the sixth mass extinction assumed to be underway. Climate regimes and groups that were not analogous triggered both the extinction of existing species and the emergence of new ones (Packert et al. 2012). Extreme climate change causes genetic, phenologic, biogeographic, and population-level differences in a bird species in the arena of the Himalayan ecosystem. These changes threaten the persistence of several species and lead to shifts in community composition and function.

Genetic changes due to climate change result in smaller body sizes, coloration change and changes in the bird species' routes of migration or migratory activity (Oliver and Morecroft 2014; Plummer et al. 2015). Bird phenology alters with climatic change, which might be the arrival and departure time of migratory birds, the distance of the migratory route, the breeding behaviour, and the declining migratory activities in the region (Smallegange et al. 2010; Moller et al. 2010). Likewise, spatial and areal shift, colonization events, and local extinction happened in birds of the Indian Himalayan region; these changes are considered in biogeographic changes. Predicting the species distribution of Himalayan range-restricted bird species is a major area of research to develop management options for adapting to changes in climatic conditions (Hitch and Leberg 2007). In addition, population changes depend upon the species' adaptability and happen through the changes in the bird species' surrounding biotic and abiotic conditions with respect to climate change and land use (Huang et al. 2017). The need for the hours is to predict suitable habitats for the range of restricted bird’s species in the Indian Himalayan region. Species Distribution Modelling (SDM) is an approach used by ecologists worldwide to predict future suitable habitats of various floral and faunal species based on correlations between known occurrence records and the environmental conditions at occurrence localities. It is also used to predict the effects of climate change on species ranges, select conservation areas, and determine the risk of species invasions. Although predictions have been made for other regions of the world by using SDM, the Indian Himalayan Region (IHR) has been given less attention. Therefore, the present study aims to predict climatically suitable future habitats for the range-restricted Himalayan birds using Species Distribution Modelling (SDM). We have selected eleven bird species based on critically endangered (CR), Vulnerable (VU), least concern (LC), Near Threatened (NT), which are restricted to Indian Himalayan Region. In the present study, we selected three birds (viz. *Catreus wallichii*, *Tragopan melanocephalus* and *Sitta leucopsis*) to predict climate change and land-use change on habitat suitability.

This study was carried out in two states (Uttarakahnd & Himachal Pradesh) and one Union territory (J&K). The region is characterized by four distinct physiographic zones i.e. Shivalik zone, middle Himalaya, upper Himalaya, and Trans- Himalaya zone, and the data were collected from the different zone of selected sites. The collected data were processed with the Arc GIS and prepared model by using the MaxEnt model and ensemble modelling approach. The model was run for each species with current and future scenarios. The MaxEnt model predicts the potential habitat based on considering the entropy of different variables associated with present location data. This model is based on the species distribution modelling (SDM) projection and java-based geographical information system (GIS) toolkit as well. The model was run with the different representative concentration pathway (RCP), which is related to climate change. These pathways are RCP2.6, RCP4.5, RCP6.0, and RCP8.5, which were climatic scenarios according to radiative forcing values in the year 2100 relative to pre-industrial values (+2.6, +4.5, +6.0, and+8.5 W m^{-2}, respectively) (IPCC, 2014). With the help of these pathways, we can predict the future distribution of the species.

The habitat distribution of maps of the three important Himalayan range restricted bird species were developed which showed suitable potential occurrence and distribution on selected species in Himalayan states. In this study, for evaluation of model performance, two indicators were used a) threshold depended on test which includes a fraction of the predicted area and extrinsic omission rate, and another b) threshold independent test included area under the receiver operating characteristic (ROC) curve or AUC. In case of western tragopan species the fractional predicted area, training omission rate, test omission rate were 0.543, 0.991, 0.984, respectively in the current scenario. Besides, the training omission rate and test rate were varying i.e. 0.987 and 0.983 and the random prediction was 0.5 in the different RCPs for the year 2050 and 2070. These were recorded for the statistical performance of the model. The AUC value was found to be 0.97 and TSS (0.98) and Kappa (0.71) value was measured for the suitable habitat distribution. From the result it was concluded that there is huge change with onset of the climate change or in future RCPs as compared to the current distribution. The results revealed that the habitat of concern species will shift towards the higher altitude from the present location during 2050 and 2070. It means the present habitat area of western tragopan would decrease in the future.

Based on the analysis and results, it was revealed that the selected species would migrate towards the higher altitude for their survival in future climatic conditions as compared to current climatic conditions. It was concluded that the suitable habitat of *Catreus wallichii*, *Tragopan melanocephalus* and *Sitta leucopsis* would shift their habitats towards higher altitudes with different RCPs of climate change for the years 2050 and 2070.

This study will help policymakers to develop and formulate policies/strategies for conserving and managing biological diversity in the Himalayan region under future climate change. Besides, this study will allow policymakers to identify priority species for conservation and protection, especially those on the verge of extinction. It is further suggested that similar research would be implemented for other Himalayan range-restricted species to predict future suitable habitats to conserve and manage Himalayan bird species in the wake of climate change.

1.2 Baseline and Scope of the Associateship / Fellowship (max. 1000 words)

Changing climatic condition in future, changes the natural habitat and distribution of the bird species which directly loss the concern species in an ecosystem. To predict the future habitat suitability and distribution in the natural ecosystem, we can effectively target the modeling approach such as MaxEnt approach which is a species distributions modeling approach. For the accuracy of the model we should have detailed and reliable information about the spatial distribution of species. The present work encompassed in the two states (Uttarakahnd and Himachal Pradesh) and one Union territory (Jammu & Kashmir). Data were collected on the probability of maximum occurrence. Occurrence data were collected by different approaches such as call count (Gaston, 1980), line transects (Bumham et al., 1980) and point count (Sutherland 1996) by trekking over long distances and large range of altitudes in these selected areas. The results provide significant and ecologically meaningful correlates with the distribution of these range restricted bird's species. The presence data of these birds was recorded in the early in the morning (07.00±11.00) or late afternoon (15.00± 18.00) using 8X or 10X binoculars from the surveys areas. The data were assorted for western tragopan (167 point), cheer pheasant (215 point) and *sitta leucopsis* (132 point) from the selected regions. Besides, data on the occurrence of selected bird species were retrieved from the ebird platform, secondary sources such as published documents, forest departments, etc.

A significant observation of bird species in the context of potential climate change is of interest for several reasons. Firstly, since birds are fairly easy to recognize and measure and their response to environmental disturbance is reasonably well known, they are useful as bio-indicators of environmental change. In fact, birds have an interest in biodiversity on their own right. Bird populations are facing global conservation threats, with 1 out of 10 species at high risk of extinction in the near future according to a recent study. Finally, birds perform significant ecosystem services that have consequences for human health and well-being including control of pests, sanitation, seed dispersal and pollination (Sekercioglu et al., 2004).

Bird distribution is closely related to both winter and summer temperatures and rising temperatures due to climate change would have a direct effect on birds by requiring them to use more energy for thermoregulation. This can interfere with their maintenance (the energy required to maintain their condition and activity), breeding and migration times, reproduction, and decrease survival. Birds can respond to these costs by changing their ranges over time to areas with more suitable thermal conditions, but habitat and other resources may not be adequate or suitable for their needs. Generally, global atmospheric temperatures are declining with increased latitude and elevation, thus, a future prediction is that species will shift towards higher elevation (Devictor et al., 2008).

Climate-related changes in the distribution of bird species along latitudinal and elevation gradients have significant consequences for conservation. If temperature changes occur at a faster pace than vegetation responses or beyond the limits of acceptable potential vegetation, bird populations may be pushed into marginal habitat areas where they are likely to experience reduced survival and reproduction. With elevation changes, the area available for colonizing species as ranges migrate upwards often decreases with elevation. Montane species are therefore deemed particularly vulnerable to climate change (Sekercioglu et al., 2008). Even soil type, forest cover and type also responsible for the changes in the habitat of the range restricted bird species.

The findings revealed that under RCP 4.5, the habitat area for western tragopan would increase with high suitability area of 2779.75 km^2. Likewise, under RCP 6.0, the area for the suitable habitat would decrease by 24509.25 km^2 compared to the suitable area observed under the current climate, while no change would be observed for a total area of 4825.81 km^2. In the prevailing scenario of RCP 8.5, the suitability area would decrease by 1434.19 km2 compared to the current climate for 2050. Similarly, for the year 2070, it was observed that under RCP 4.5, the bird's distribution area and habitat would shift 1365.31 km^2 compared to the current habitat distribution. Besides, that decrease in habitat suitability distribution would be 1933.38 km^2 than the present climatic scenario. Likewise, suitable habitat distribution of western tragopan shifted 23714.94 km^2 under RCP 6.0 while the distribution area would decrease by 107.06 km^2 compared to the current climatic condition. Similarly, in RCP 8.5 the distribution of suitable habitat would also increase by 10469.06 km^2 and reduce by 72.31 km^2, while about 4764.56 km^2 area would not change compared to the current distribution of the species.

The results revealed that the cheer pheasant would shift towards the higher elevation under the changing climatic scenarios. The results showed for the different RCPs that areas less desirable for range-restricted vulnerable birds would increase with respect to the current potential distribution map. By 2050, under RCP 4.5, the distribution of suitable habitats of the species would increase by 88.36 km2, and a decrease in the suitability of the area was recorded by 12.50 km2 while there would be no change in suitability classes for an area of 2805.23 km^2 as compared to the current distribution map. Under the RCP 6.0, the suitable habitat distribution of the species would shift by 80.75 km^2, and the area would decrease by 14.75 km^2 compared to the suitable area observed under the current climate, while no change would be observed for a total area of 2810.60 km^2. In the prevailing scenario of RCP 8.5, it is predicted that habitat suitability area would increase by 115.05 km^2 and 12.05 km^2 area of the species distribution decreases and no change is predicted in the area of 2778.99 km^2 in contrast to the current climate. Similarly, the prediction is also made for the year 2070, and it was observed that the species would shift from their current habitat under RCP 4.5. The future shifting area would be 93.52 km^2 and the decreased suitable distribution area would be 12.87 km^2 compared to the current climate. It was also predicted that an area of about 2799.69 km^2 has no change in future climatic conditions. Besides, under RCP 6.0, the area of suitable habitat for their survival and reproduction would shift by 163.02 km^2 and decrease in area of suitability by 14.14 km^2 while no changes occur in the area of 2728.93 km^2 at the onset of changing climatic conditions.

In case of *Sitta leucopsis,* the new database is generated over baseline. It is predicted that under RCP 4.5 increased distribution of the habitat suitability area would record 26.86 km^2, and decreased area of suitability for their survival would 42.96 km^2. These are the database generated for predicting climatically suitable future habitats for the range of restricted Himalayan bird species. In contrast, no change in the habitat suitability would be recorded 2836.26 km^2 compared to the habitat suitability of the current climate condition. Likewise, under the RCP 6.0 the area would increase by about 227.76 km^2 and decreased habitat suitability would record 9.14 km^2, whereas in an area of 2669.19 km^2, there is no change. In the case of RCP 8.5, the increased suitability area would be 116.43 km^2 and 29.47 km^2 areas would decrease, while 2760.18 km^2areas have no change in this scenario for the period 2050. Notwithstanding this, for 2070, under RCP 4.5 and RCP 6.0, the area which would increase is 457.47 km^2, the decreased area would be 2.91 km^2 and area in which no change would be observed is 2650.71 km^2. Likewise, under RCP 8.5, the increased area would be 125.36 km^2 and the decreased area would be 30.61 km^2 while no change would occur in 2750.11 km^2.

Project Scope:

1. Projecting potential habitat distribution of avifauna in current climatic conditions.
2. Assessing the impacts of land cover change on species distributions

3. Predict suitable habitat and distribution of these species in future climatic conditions.

1.3 Overview of the major issues to be addressed (max. 1000 words)

Climate change is predicted to result in significant changes to Himalayan ecosystems, including changed temperatures, rainfall patterns, increased seasonality and extreme events. Species faced with changing climates shifted towards the higher elevations. Evidences of range shift in trees (Kelly and Goulden 2008), birds (Freeman and Freeman 2014), moths (Chen et al. 2009) and butterflies (Konvicka et al. 2003) have already emerged. These changes threaten the persistence of several species, and lead to shifts in community composition and function. Predicting these changes in species distribution is a major area of research in order to develop management options to adapt to ongoing climate change (Mokany et al. 2014; 2017). The main approach to predicting future species distributions is through climate matching, where a species' current climate requirements are identified and future distributions of this climate envelope are determined under different climate-change scenarios (Mokany et al. 2014, 2017). Although such predictions have been developed for other regions of the world (Hilbert et al. 2004), we lack predictions for the Indian Himalayan region. It has been suggested that massive deforestation leading to habitat loss threatens endemic biodiversity in Indian Himalayan region (Pandit et al. 2007). However, we have a very limited understanding of how Himalayan biodiversity will respond to changing climatic conditions. Birds present a suitable taxon group to address the research gaps for the Indian Himalayan region. In the last decade, we have had extensive research on bird community composition in the Indian Himalayan region (Ghosh-Harihar and Price 2014).

This project aims to develop a climate- envelop models for the contemporary bird distribution for the Western Himalayan region, one of bird diverse areas. Project addresses the gaps in the dataset with field sampling of bird communities using standardized techniques. It has been suggested that birds with restricted ranges and those with lower mobility such as ground birds would be at considerable risk from climatic changes in mountain regions (Şekercioğlu et al. 2012). In this study, we projected distributions of birds under potential climate change scenarios to identify range shifts along altitudinal gradients. Besides, we identified range restricted bird species which would be badly hit by climate change, critical connecting habitats and habitat restoration scenarios that enhance bird species movement in changing Himalayan landscapes.

1.4 Brief summary of the activities under taken by the researcher

2 METHODOLOGIES, STARTEGY AND APPROACH

2.1 Methodologies used for the study

2.1.1 Development of map of study sites

The map for selected two states (Uttarakhand & Himachal Pradesh) and one union territory (Jammu & Kashmir) was prepared using ArcGIS software for the study of future habitat distribution of selected birds of the Himalayan region under different RCPs (Fig. 1).

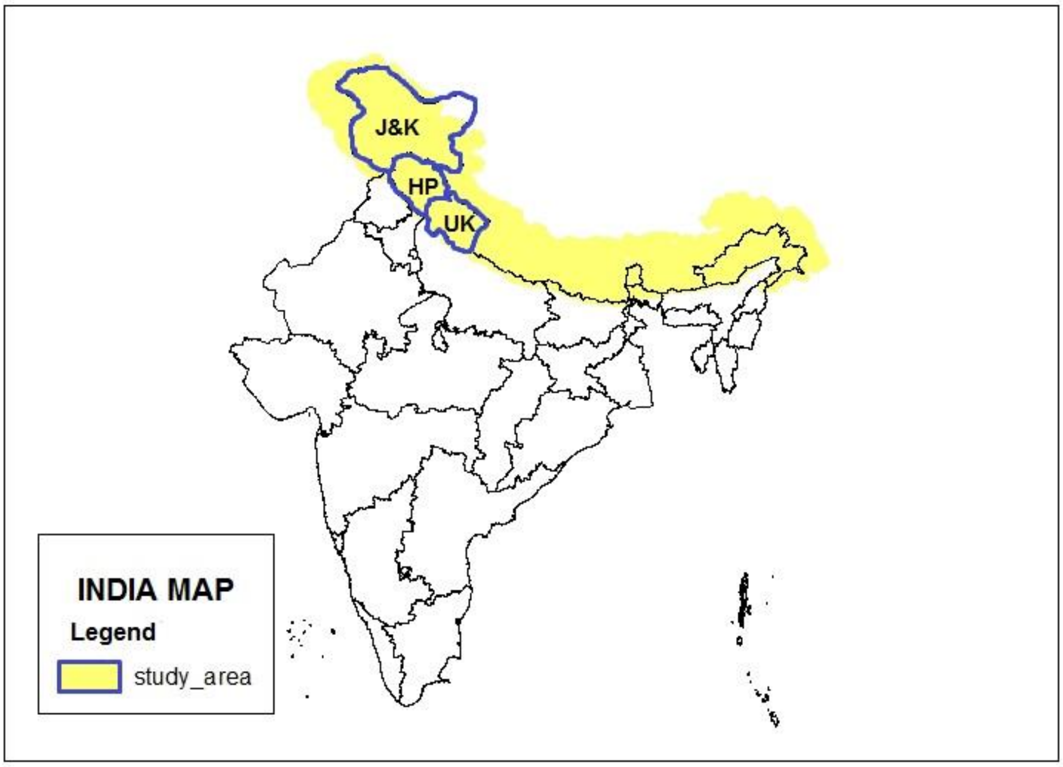


Fig. 1 Map of selected study sites (Uttarakhand, Himachal Pradesh, and Jammu and Kashmir)

2.1.2 Assortment of presence data of the Himalayan birds species

For this study, presence data since the 1990s on these bird species were requested from Ebird (an open-source database domain). Additionally, researchers and scientists from the various organizations who were previously or currently involved in carrying out studies on birds in the Indian Himalayan region were contacted for additional data on the selected bird presence. Moreover, the literature on the selected bird species was reviewed, and occurrence data from the different studies were collected. The state forest departments were also contacted to obtain data on bird species. All the collected secondary presence data was validated by personal communications and field visits in the presence sites (except Pak-occupied Kashmir). The bird species presence data was used for modelling suitable habitats with the help of MaxEnt software. The sampling was done in the study area by following the line transect (Burnham et al., 1980) and point count (Sutherland 1996) approaches for gathering information on the presence or absence of selected bird species. On average 240 points were collected from the areas chosen for these bird species and did further cleaning to remove the repetition of data. The data on birds seen and calls were recorded for the presence of bird species, and accordingly, geo-coordinates were taken. The observations were made between 05:30 am to 17:00 pm during breeding and off-breeding seasons.

2.1.3 **Data assortment on climatic and habitat covariate**

Various factors affect species distribution, such as temperature, geographical barriers, rainfall, and other ecological factors, such as underlying geological formations. To determine which environmental variables most influence the distribution of these bird species, we included in our model 19 bioclimatic variables (www.worldclim.org), five topographic variables derived from the digital elevation model (SRTM) (elevation, aspect, and slope, heat load index and topographic wetness index), soil parameters (soil texture, bulk density, soil taxonomy class, etc.) and land use land cover data (Table 1 & 2). High correlated variables (P>0.75) reduce multicollinearity among these variables. (Pearson correlation coefficient) were used and selected 12 variables for the development of models **(Fig 2.)** (Graham, 2003). These variables include aspect, slope, heat load index, topographic, bulk density, sand percentage, soil order, Bio2 (Mean Diurnal range), Bio3 (isothermality), Bio 14 (Precipitation of Driest Month), Bio15(Precipitation Seasonality), and land-use class. These environmental parameters were re-sampled at 250-meter resolution and converted into Ascii format using ArcGis 10.5. The future climate data for two representative concentration pathways (RCPs) for carbon dioxide for 2050 (average of predictions for 2041–2060) and 2070 (average of predictions for 2061–2080) were also included. These are the most recent GCM climate projections used in the Fifth Assessment IPCC reports.

Table 1. Environmental variables and their units.

Code	Environmental variables	Unit
Bio1	Annual mean temperature	°C
Bio2	Mean diurnal range (mean of monthly (max temp–min temp))	°C
Bio3	Isothermality (Bio2/Bio7) (×100)	–
Bio4	Temperature seasonality (standard deviation ×100)	C of V
Bio5	Max temperature of warmest month	°C
Bio6	Min temperature of coldest month	°C
Bio7	Temperature annual range (Bio5–Bio6)	°C
Bio8	Mean temperature of wettest quarter	°C
Bio9	Mean temperature of driest quarter	°C
Bio10	Mean temperature of warmest quarter	°C
Bio11	Mean temperature of coldest quarter	°C
Bio12	Annual precipitation	mm
Bio13	Precipitation of wettest month	mm
Bio14	Precipitation of driest month	mm
Bio15	Precipitation seasonality (coefficient of variation)	
Bio16	Precipitation of wettest quarter	mm
Bio17	Precipitation of driest quarter	mm
Bio18	Precipitation of warmest quarter	mm
Bio19	Precipitation of coldest quarter	
LULC	Land use and land cover	
ELE	Elevation	m
SLO	Slope	º

ASP	Aspect	0
HLI	Heat load index	
TWI	Topographic wetness index	
BD	Bulk density	
ADB	Absolute depth to bedrock	
SP	Sand percentage	
SO	Soil order	
LU	Land use	

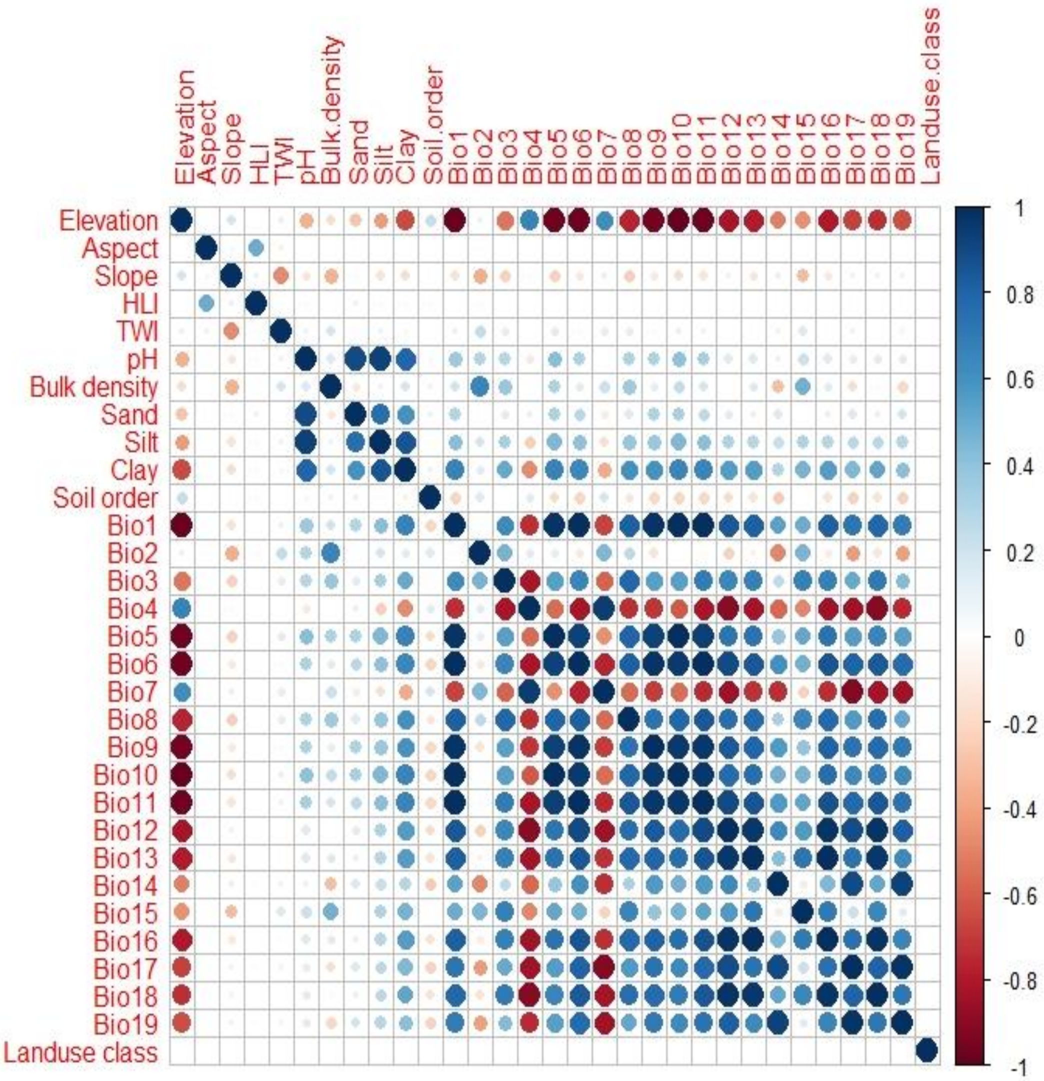


Fig 2. Pearson's correlation between different environmental variables

Table 2: Sources for obtaining the SRTM dataset, soil data set and land use and cover data, bioclimatic parameters, and Species location data.

Data	Resolution	Source
Elevation (SRTM)	30 m	https://earthexplorer.usgs.gov (United States Geological Survey)
Soil parameters	250 m	https://soilgrids.org (International Soil Reference and Information Centre)
Land Use and Land Cover Map	23.4 m	FSI India
BioClimatic parameters	1000 m	http://www.worldclim.org (University of California, Berkeley)
Species location data	Point data	http://www.gbif.org (Global biodiversity information facility)

2.1.4 Habitat distribution modelling of chosen bird species

We used the maximum entropy model (MaxEnt version 3.3.3) for the western tragopan range-restricted bird species, which is one of the best performing. We adopted software for preparing the species distribution model (SDM) to predict the future habitat distribution of selected bird species (Phillips et al., 2006). This model has better accuracy and is used for small sample sizes compared to other methods (Phillips et al., 2006). MaxEnt uses presence-only data to predict the distribution of a species based on the theory of maximum entropy. The program attempts to estimate a probability distribution of species occurrence closest to uniform while still subject to environmental constraints. About 70% of occurrence data was used to prepare the model, and the rest, 30%, was used for model validation. Further, the Jackknife method was used to measure variable importance in the development of the model. The model was iterated 500 times with 20 replications using the bootstrap method and further projected for present and future climate scenarios.

The model's results were validated using Area under the curve (AUC), TSS, and Kappa coefficient that show the ability of the developed model to discriminate between presence and absence data and the model's performance. The values of AUC, TSS, and kappa lie between 0 to 1, which indicates the model performance. The low value (AUC is <0.50) describes the poor discrimination between the presence and absence of data, whereas the model with a value of 1 indicates perfect discrimination. The model with the highest AUC value was considered the best performer. In our models, we selected 75% data for model training and 25% for model testing (Phillips, 2008), keeping other values as default. Jackknife analyses were performed to determine variables that reduce the model reliability when omitted. Similarly, for other bird species, Cheer pheasant and *Sitta leucopsis*, ensemble modelling was used for species distributions. The presence or absence of species was modelled using eight statistical methods (Heikkinen et al. 2006).

These methods included MaxEnt, Generalized boosted model (GBM), Support vector machine (SVM), three regression methods (generalized linear models, GLM; multivariate adaptive regression splines, MARS), three machine-learning methods (artificial neural networks, ANN; random forest, RF) and one classification methods (Classification tree analysis, CTA). All the different models were calibrated using different packages of the R environment software (R Development Core Team 2009). For each two range-restricted bird species, the two Species Distribution Models were built using a random subset of data containing 70% of the sites. The remaining 30% of the data was used to evaluate the predictive performance of the models. The prediction of these two species was made on different RCPs, i.e., RCP 4.5, RCP 6.0, and RCP 8.5 (Table 2) for the future changing climatic conditions (2050 and 2070).

Table 2. Different representative concentration pathways (RCPs)

S.N.	Radiative Forcing	Atmospheric CO_2 equivalent (ppm)	Description	References
1.	RCP 8.5	(~1370 ppm)	Rising radiative forcing pathway leading to 8.5 W/m^2	Riahi et al. 2007
2.	RCP 6.0	(~850 ppm)	Stabilization without overshoot pathway to 6 W/m^2	Hijioka et al. 2008; Fujino et al. 2006
3.	RCP 4.5	(~650 ppm)	Stabilization without overshoot pathway to 4.5 W/m^2	Smith and Wigley 2006; Wise et al. 2009

4.	RCP 2.5	(~490 ppm)	Peak in radiative forcing at ~3 W/m^2	Van Vuuren et al. 2006; Van Vuuren et al., 2007

2.2. Details of Scientific data collected and Equipments Used (max 500 words)

The data were retrieved from various sources (eBird, BirdLife International etc) on the occurrence/absence, since 1990, of the selected bird's species in Uttarakhand, Himachal Pradesh, and Jammu & Kashmir. The data were also collected from the researchers who are already engaged in or currently conducting studies on the birds of the Indian Himalayan Region through personal meets and emails. Besides that, we collected through the forest staff, volunteer bird watchers, and photographers in the selected area during our field visits to observe the population of birds chosen species in Uttarakhand, Himachal Pradesh and Jammu & Kashmir through the field survey during the month of April-Jun when they are breeding and tend to be most vocal. However, cheer pheasants are frequently seen during October−November in these areas. Both male and female, these birds give loud calls from 05:30 am to 17:00 pm during these months. We collected data using a call count (Gaston, 1980), line transect (Burnham et al, 1980), and point count techniques (Sutherland 1996). Totally across three selected sites, 167 points, >215 points and 132 points, Including secondary source data, were collected for the species Western tragopan, Cheer pheasant and *Sitta leucopsis*, respectively. In this study, we have used camera and GPS for data collection. The camera was used to click the pictures in the study area, GPS was used to record species occurrence in the selected area, and coordinates were recorded.

2.3 Primary Data Collection

The occurrence locations of selected three bird species in Indian Himalayan region were collected during a 3-year field survey across the chosen area. Field visits were done from April- Jun for three successive years during the breeding season. The sampling was done in the study area by following the line transect (Bumham et al, 1980) and point count (Sutherland 1996), and call count (Gaston, 1980) approaches for gathering information on the presence or absence of selected bird species. We have also used GPS for the coordinates of the chosen species and verified the data collected from secondary sources. In addition, we have communicated with local people and forest staff in the nearby area to collect the data. Primary data was collected through field visits, local NGOs, forest staff, volunteer bird watchers, and photographers in the selected areas. Secondary data were assorted from various sources viz. eBird, BirdLife International etc. A total of 350 points were collected from the chosen sites then cleaning was done to remove the repetition of data. The data on birds seen and calls were recorded for the presence of bird species, and accordingly, geo-coordinates were taken. The observations were made between 05:30 am to 17:00 pm during breeding and off-breading season.

2.4 Details of Field Survey

The field survey was conducted in April- Jun every year from 2018-2021 for data collection of different species such as western tragopan, cheer pheasant, and *sitta leucopsis*. In the project's first year (2018-2019), we collected data for the bird species, i.e., western tragopan, from Uttarakhand, Himachal Pradesh, and Jammu & Kashmir. We have collected data from Himachal Pradesh (Sainj, Jivanal, Thirthan, Chamba, etc.), Uttarkhand (Almora, Bageshwar, Chamoli, Dehradun, Nainital, Pithoragarh, etc.), and Jammu and Kashmir **(Fig. 3).**

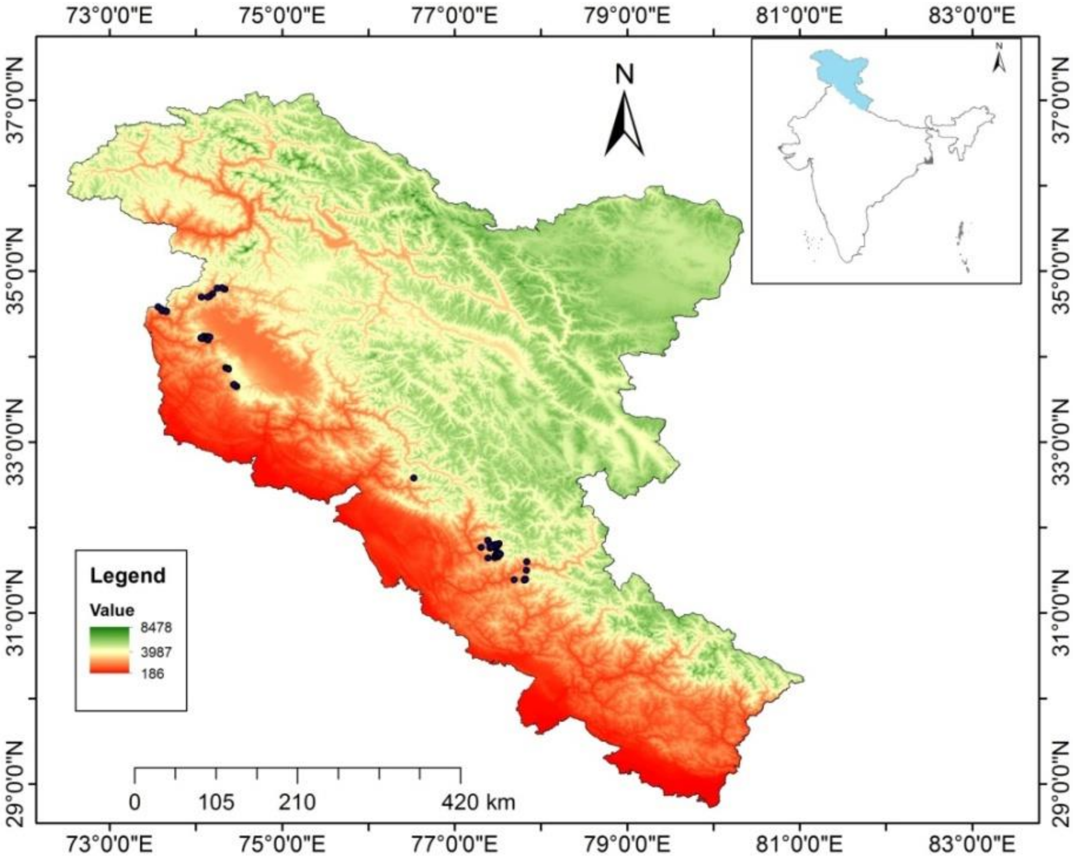


Fig 3. Location map of the study area. The black point shows the species occurrence of western tragopan.

Next year (2019-2020), we collected data for cheer pheasant species and surveyed the higher altitudinal area of Uttarakhand, Himachal, and Jammu & Kashmir. The survey in Uttarakhand is done from Jun- July, and in Himachal and Jammu & Kashmir, we surveyed from October –November. The maximum frequency of occurrence was in Himachal Pradesh >Uttarakhnad > Jammu & Kashmir. We visited Chamba, Kullu, Mandi, Shimla, Solan, and the Great Himalayan National Park (GHNP) in Himachal Pradesh. Similarly, in Uttarakhand, we have visited Almora, Bageshwar, Chamoli, Dehradun, Nainital, Pithoragarh, Uttarkashi, Rudraprayag, and Chamoli. Furthermore, in the Jammu and Kashmir regions, we visited Baramula and Kathua to collect data on the species of cheer pheasant **(Fig. 4).**

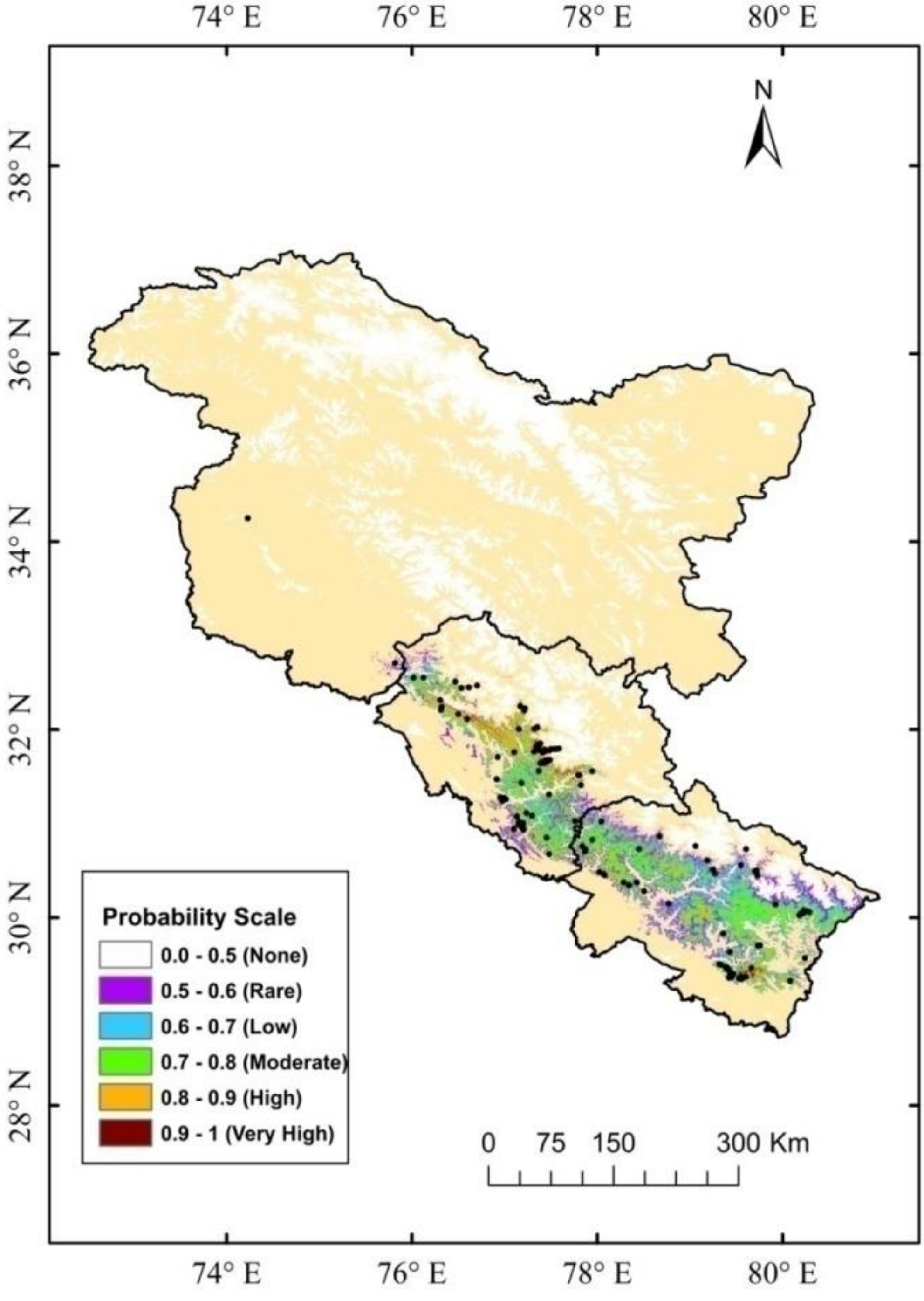


Fig. 4. Location map of the study area. The black point shows the species occurrence of cheer pheasant

The last survey was done in April- Jun 2021 for the *Sitta leucopsis*. The survey was done in the selected area of Uttarakhand, such as Uttarkashi, Dehradun, Bageshwar, Nainital, Pithoragarh, and Chamoli; in Himachal Pradesh, such as Chamba, Shimla, Kullu, Kinnaur, Lahul and Spiti, Kangra and in Jammu & Kashmir the area we visited for the collection of data for the selected species are Rajouri, Srinagar, Kishtwar, Badgam, Doda, Baramula, Ganderbal, Anantnag with the help of local people, forest staff, or by using binocular and GPS (Fig 5.).

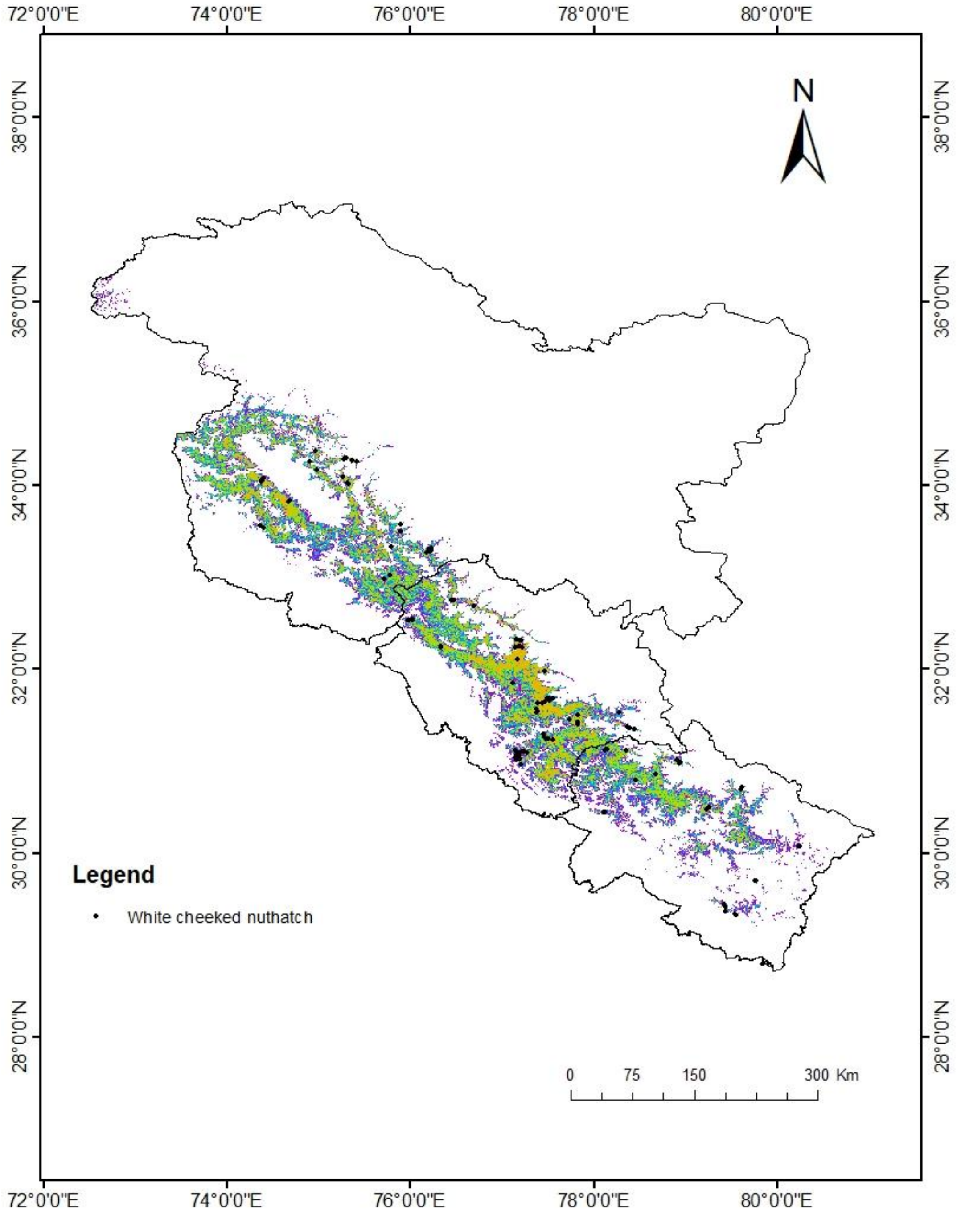


Fig. 5. Location map of the study area. The black point shows the species occurrence of *Sitta leucopsis.*

2.5 Strategic Planning for each Activities

The present study was restricted to three Himalayan states of Indian Western Himalayas (IWH) namely Himachal Pradesh, Uttarakhand, and Jammu and Kashmir. From 2018 to 2019, we performed a detailed field survey to gather information on the presence locations in the states of Jammu & Kashmir, Himachal Pradesh, and Uttarakhand. We used a handheld GPS (Garmin Etrex 20X) with a precision of ±3 m to identify the location of the occurrence of the chosen species. We recorded observations from 05:30 am to 07:00 pm during field surveys. A total of 120 presence locations were identified during the field survey. Besides, we gathered 95 occurrence data from the ebirdopen access (https:/ebird.org/) and the forest department officials, etc. Hence, we used 225 presence locations for developing the species distribution model.

We used nineteen bioclimatic variables retrieved from www.worldclim.org at a resolution of 1000 m. We generated topographic variables from the digital elevation model (https://earthexplorer.usgs.gov) at 30 m resolution. The soil variables (soil texture defined by the percentage of sand, silt, and clay, bulk density, soil taxonomy order, and soil pH) were obtained from the https://earthexplorer.usgs.gov at 250 m resolution. Land use/land cover data were retrieved from the Forestry Survey of India at 23.4 m resolution. For this purpose, we used the caret package function in R-language to remove pair-wise correlation with a cutoff value of 70%. With a correlation coefficient >70%, only one variable was used for selecting the correct variables in the model by logical inference. We converted all variables into ASCII format for the model preparation using the ArcGIS program. The variables used for model development were four bioclimatic (mean diurnal range, isothermality, precipitation of driest month, precipitation seasonality), four physiographic (slope, aspect, heat load index, topographic wetness index), four soil (bulk density, absolute depth to bedrock, sand percentage, soil order) and land-use/ land-cover data.

We used the future climate change scenario in the form of Representative Concentration Pathways (RCPs) for further modeling in the present study. RCPs expound on four multiple pathways associated with greenhouse gas emissions that might increase greenhouse gas atmospheric concentrations. These RCPs pathways are utilized by the global scientific community in long-term and near-term modeling experiments. The pathways are characterized by the radiative forcing generated by the late 21st century. Radiative forcing defines the change in the net, downward minus upward, the radiative flux in W m^{-2} at the top of the atmosphere owing to greenhouse gas emissions. Further, RCPs provide a mitigation scenario resulting in a very low level of forcing (RCP2.6), two medium stabilization scenarios (RCP4.5 and RCP6), and a very high baseline emission scenario (RCP8.5). In this present study, we used climate data version 5 (MIROC5) of global climate models for RCPs for the years 2050 and 2070. It has been proven that MIROC5 best reflects the South Asian region and Himalayan climatic variability (Sharmila et al., 2015; Jena et al., 2016).

Habitat modelling was performed using the stacked species distribution models (SSDM) package (Schmitt et al., 2017) in the R package (Phillips et al., 2006; Phillips and Dudik, 2008). The Jackknife test was used to calculate the significance of variables in the habitat suitability mapping. We selected the models based on AUC> 0.75, and weighted AUC was used to ensemble different chosen models. Furthermore, the ensemble model was used to project the habitat suitability map for potential habitats under current and future scenarios. To determine model stability, AUC and the kappa coefficient were used to assess model stability and accuracy, which often signify the ability to distinguish the model's presence and absence of data and model performance (Allouche et al., 2006).

2.6 Activity-wise Timeframe followed using Gantt/ PERT Chart

Activities	Project Duration (three years and three months)						
	Ist Years		IInd year		IIrd Year		IV^{rth} Year
	Ist HY*	IInd HY	Ist HY	IInd HY	Ist HY	IInd HY	Ist Q**
Review of literature on the related aspects of the study							
Digitalization of study area							
Retrieval of bioclimatic and associated variables							
Cleaning and post processing of the							

retrieved bioclimatic and associated variables							
Generation of database encompassing restricted range bird species sighting records.							
Assortment of species occurrence data through filed survey and secondary sources							
Generation of modeling protocol for further use for other birds of the Indian Himalayan region.							
Habitat distribution map of selected species in current climate							
Modeling habitat shift of selected species under future climate change							
Submission of abstract to the conference for disseminating the findings							

Preparation and submission of manuscript based on the results							

*HY denotes half year and ** denotes quarter year for which extension was accorded

3 KEY FINDINGS AND RESULTS

3.1 Major Research Findings

3.1.1 Model validation and influencing bioclimatic variables

For western tragopan, the model performance was evaluated using the area under the curve (AUC) (Fig. 6). The AUC value was obtained as 0.983 for the test data, which suggests the excellent performance of the model. This indicates that the MaxEnt-derived distributions closely approximated real-world distribution probabilities. The estimated values of TSS and Kappa were 0.98 and 0.71, respectively, which further suggest the robustness of the model in predicting suitable habitats. Besides that, twelve variables such as bioclimatic, topographic, physiographic, land use, etc., with six models (CTA, MARS, MaxEnt, RF, GBM, SVM, ANN) were chosen to prepare an ensemble model for habitat suitability of cheer pheasant and *Sitta leucopsis* (Table). All models have their AUC value which is > 0.7, indicating the study efficiency of the selected model. The maximum area under the curve was recorded for the MaxEnt and RF, whereas the minimum was recorded for the CTA model for the species cheer pheasant. Similarly, MaxEnt and RF were registered as a maximum while GBM was recorded minimum for the species *sitta leucopsis* . Such AUC values from different models showed distribution was a near approximation of the likelihood of real-world distribution. In addition, the Kappa value for MaxEnt (0.798) and RF (0.773) was also calculated and reported as maximum for cheer pheasant. In contrast, the kappa value for MaxEnt and RF was 0.745 and 0.657 for the species *sitta leucopsis*. The Kappa values even indicate the model's reliability in predicting suitable habitats.

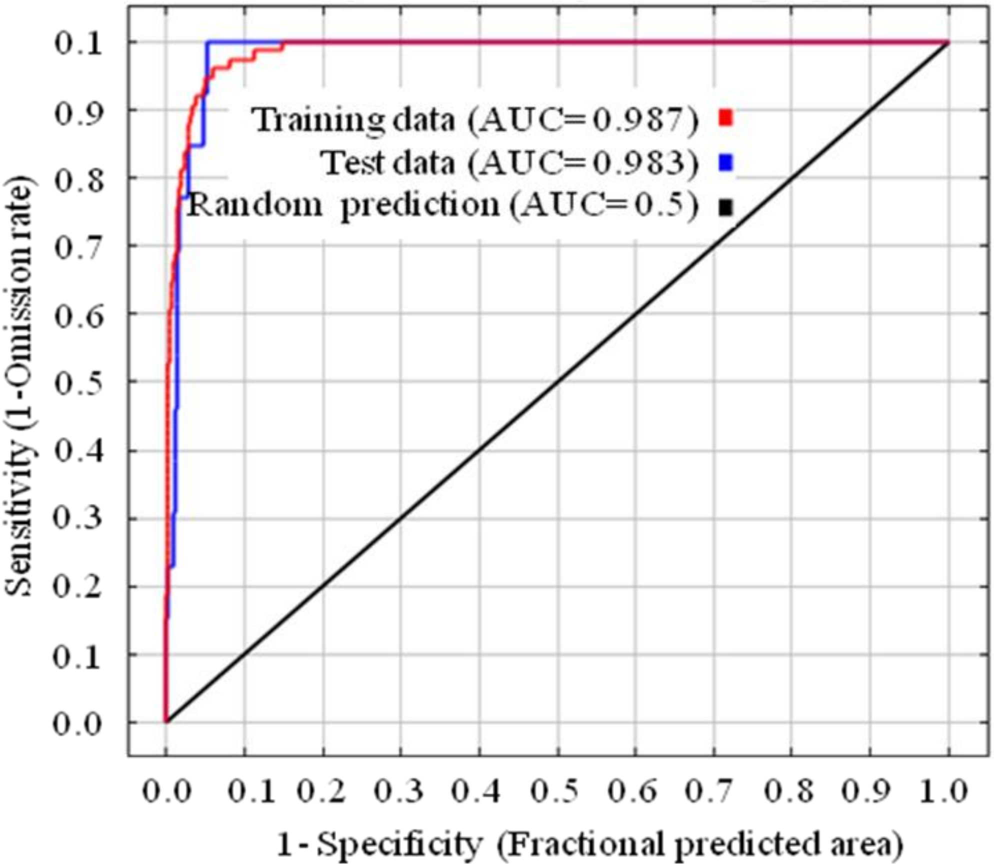


Fig 6. ROC curve and AUC value for MaxEnt model.

3.1.2 Contributions of environmental variables

The jack-knife test results for western tragopan showed the importance of different bioclimatic, topographic, soil, and land-use class variable while mapping habitat suitability (Fig. 7).

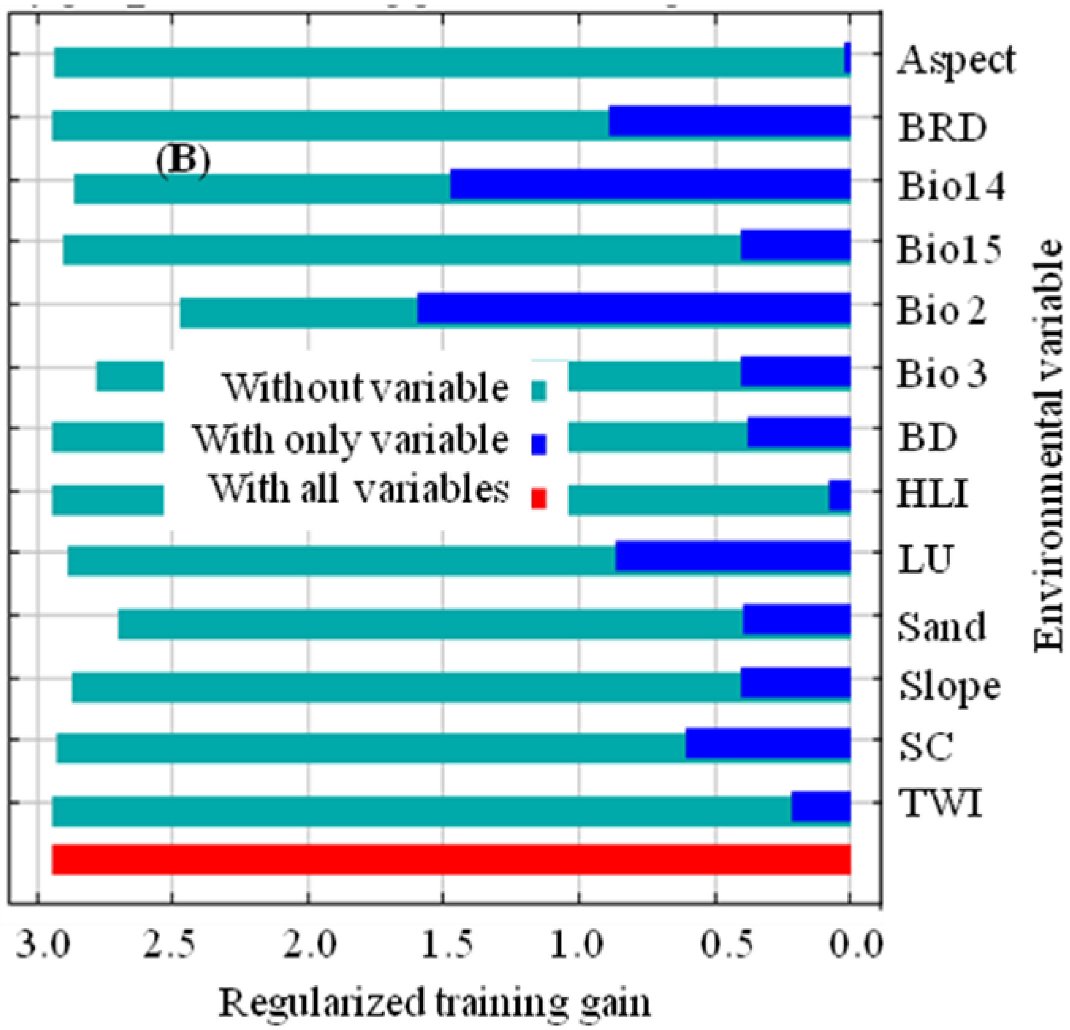


Fig 7. The Jackknife test indicates the contribution of the different variables in the current distribution of the species.

The test results indicated the relative contribution of climatic variables for current distribution and are presented as a mean value of 20 replicate model runs. The results revealed that precipitation of driest month (Bio14), mean diurnal range of temperature (Bio2), land use classes and sand proportion in the soil contribute by more than 70% in the model to predict the habitat (Fig. 8).

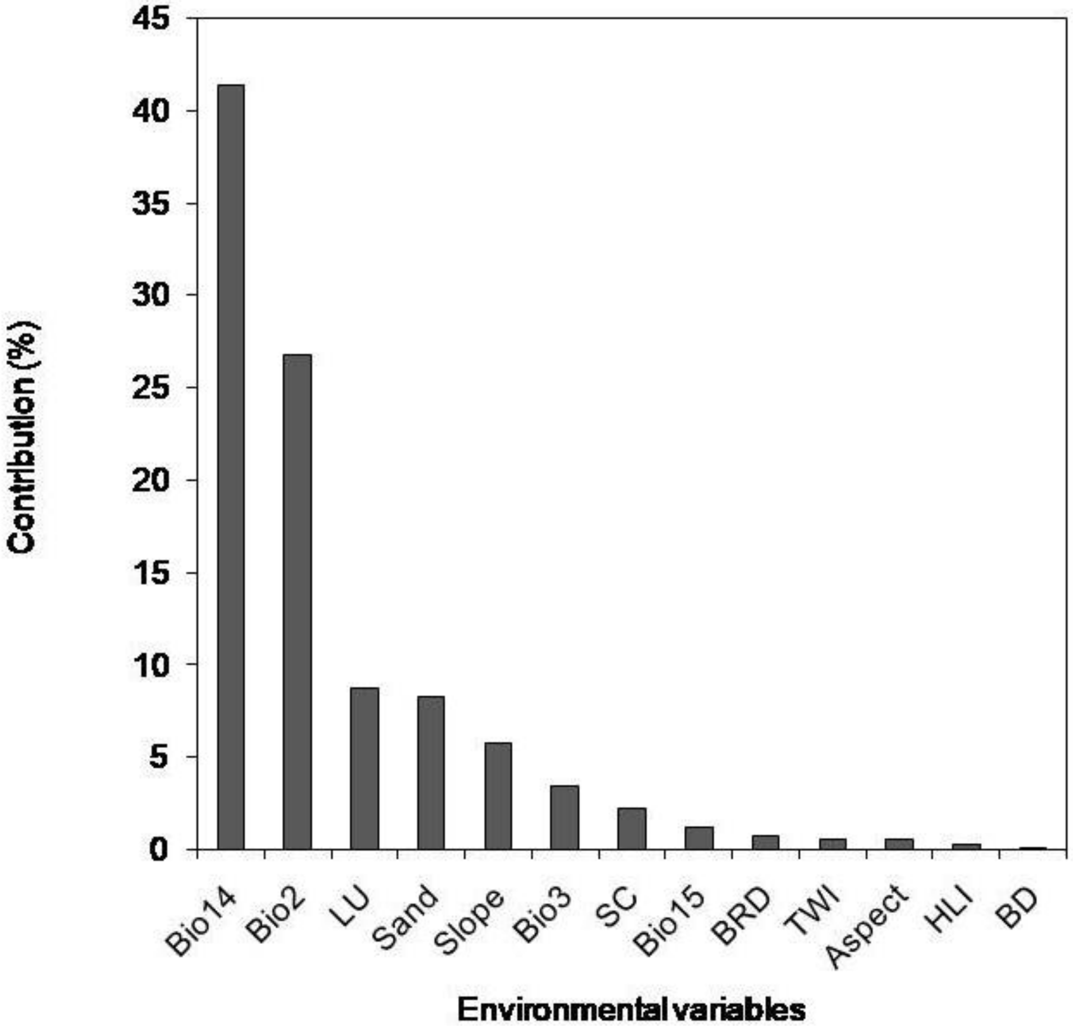


Fig 8. Contributions of environmental variables to MaxEnt model performance of western tragopan

The response curves showing the effect of individual variables for model prediction are presented in Fig 7. Whereas in case of cheer pheasant the findings showed that mean diurnal temperature range (Bio2), Precipitation Seasonality (Bio 15), Isothermality (Bio 3), land use classes, and soil sand proportion contribute to habitat prediction by on an average more than 75 percent in the ensemble modeling (Fig. 9).

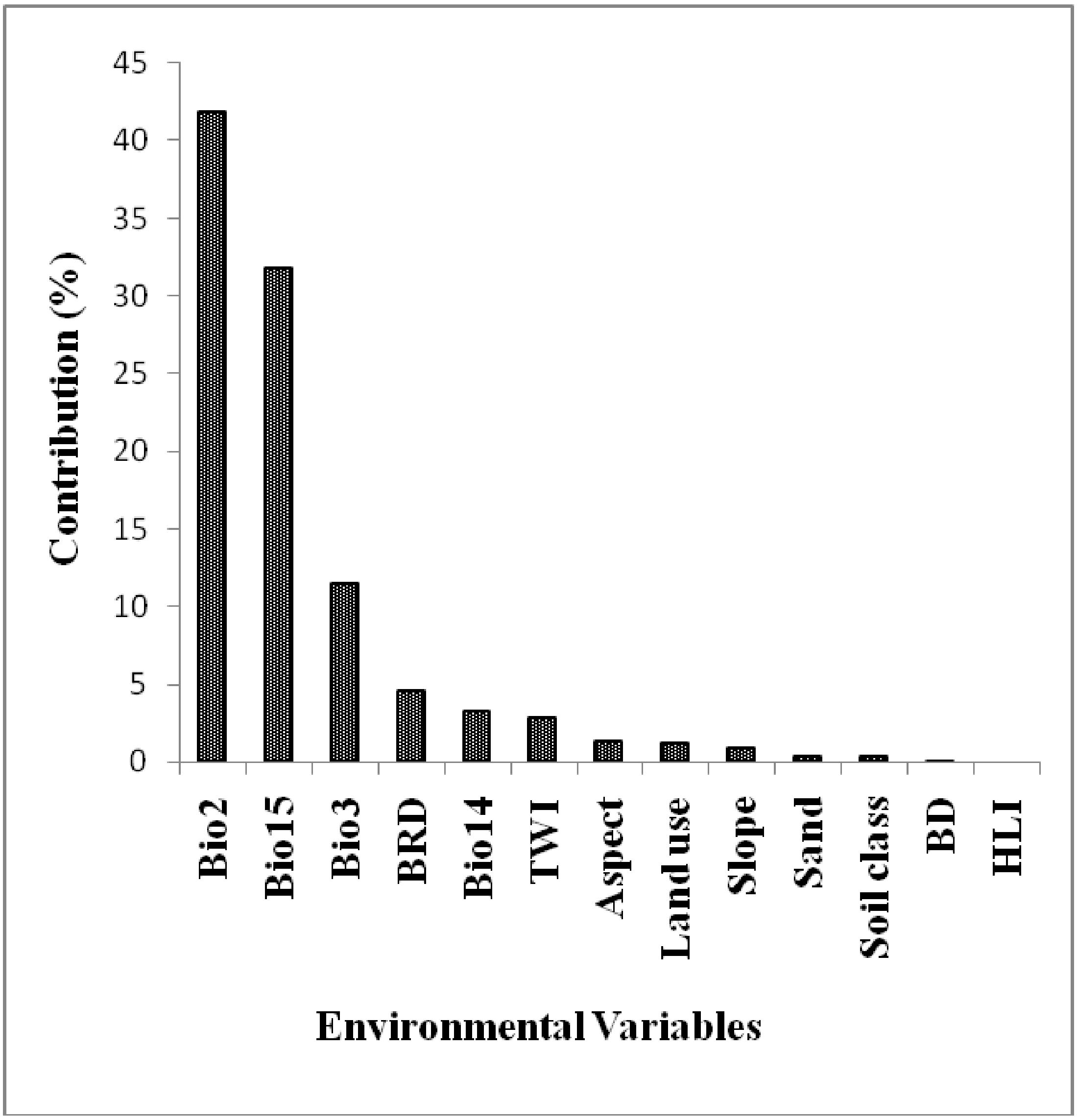


Fig 9. Contributions of environmental variables to ensemble model performance of Cheer pheasant

The results revealed that the model's response to different variables was positively nonlinear. These curves elaborated the response of different variables for habitat suitability mapping. Similarly, in *Sitta leucopsis*, mean diurnal temperature range (Bio2), precipitation of driest month (Bio14) and isothermality (Bio3), bulk density, Taxonomic class, and land use contribute ~75% to the prediction of the habitat suitability of the species using ensemble modeling approach **(Fig. 10).**

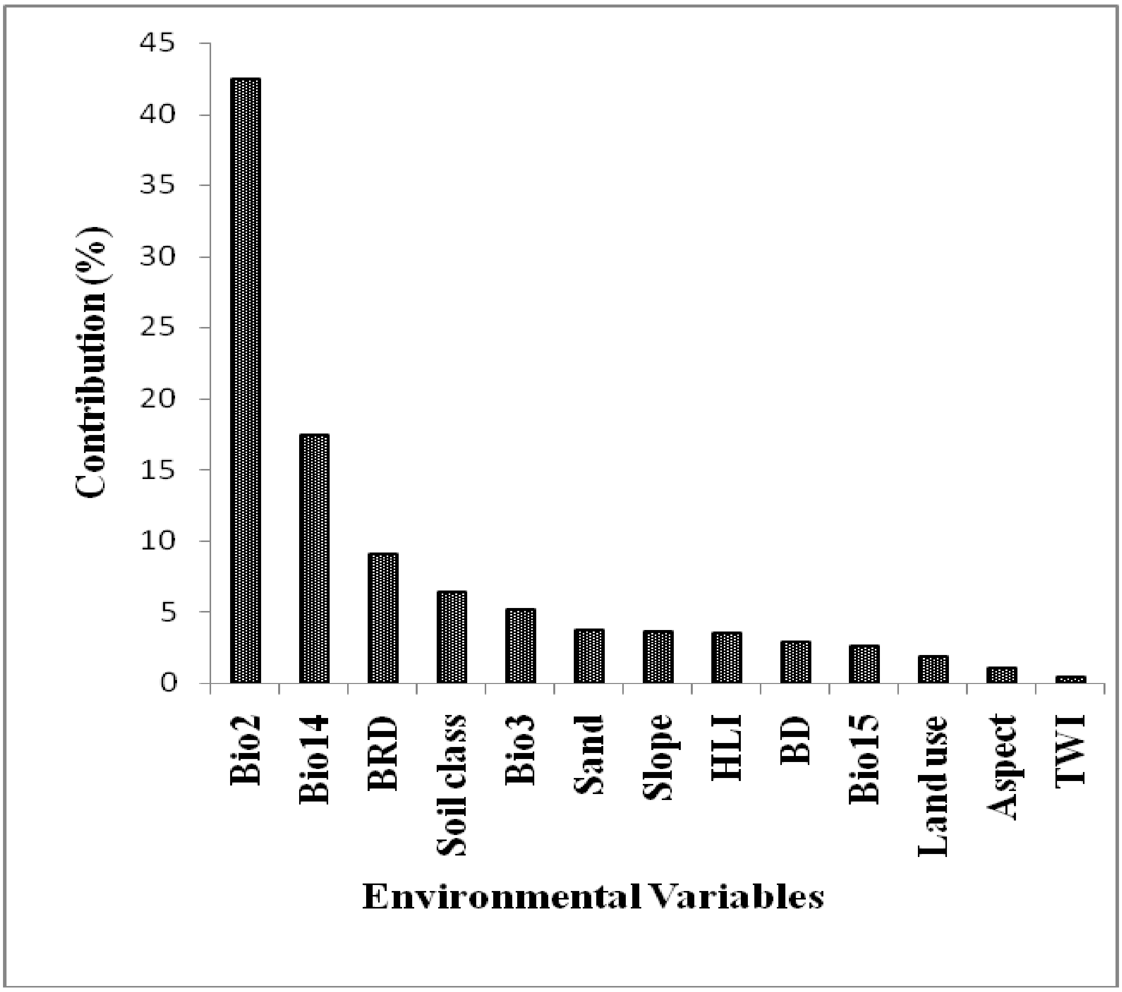


Fig 10. Contributions of environmental variables to ensemble model performance of *Sitta leucopsis*

3.1.3 Suitable habitat under current climate for the selected species

The suitable habitat for the Tragopan based on current environmental factors is shown in Fig. 11. The probability distribution output was divided into three categories i.e. highly suitable (> 85%), moderately suitable (71–85%), low suitable (51–70%). Under current climatic conditions, the model identified an area of 297.06 km^2 as highly suitable and 1883.38 km^2 as moderately suitable while 358423.75 km^2 of the area observed as low suitable for the current habitat of the species.

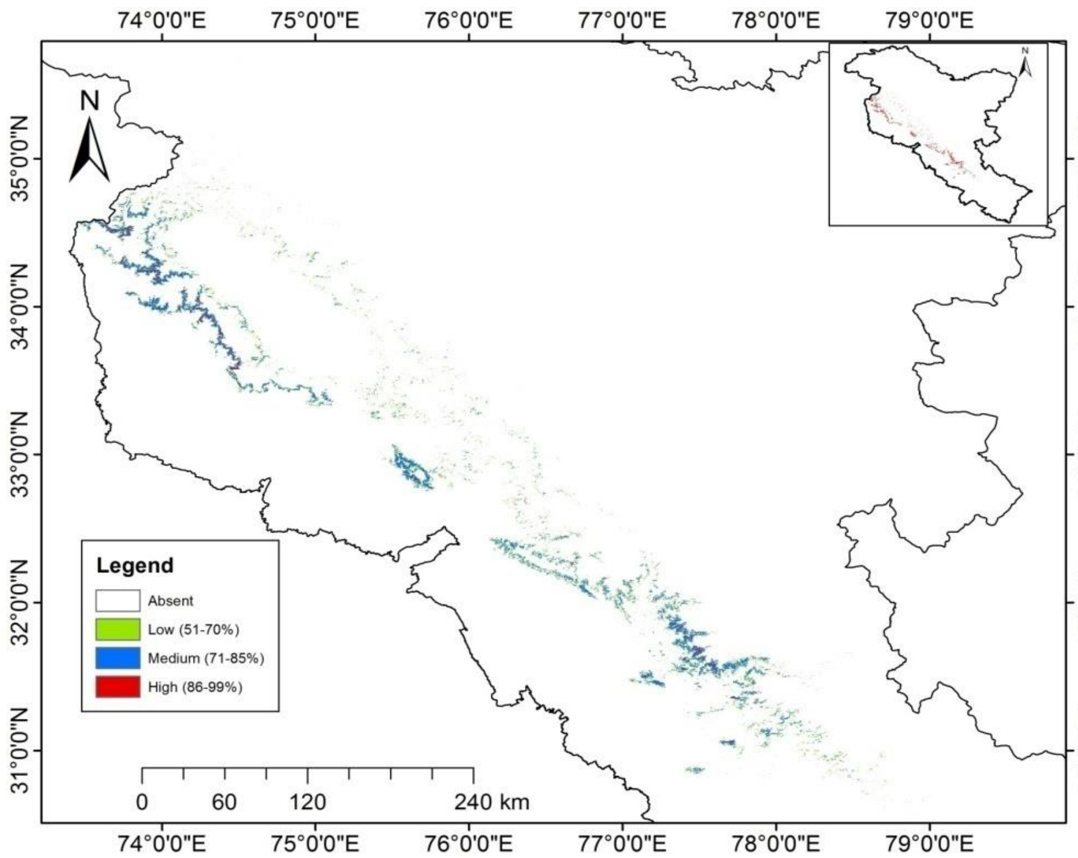


Fig 11. Potential habitat suitability distribution of Western Tragopan in current climatic conditions.

For cheer pheasant, the probability distribution output was classified into five categories i.e. very highly suitable (>90 %), highly suitable (80-90%), moderately suitable (70–80%), low suitable (60–70%), and rarely suitable (50-60 %). Under current climatic conditions, the model identified an area of 4.24 km^2 as very highly suitable, 50.35 km^2 as highly suitable, 109.29 km^2 as moderately suitable, and 91.03 km^2 as low suitable while 88.89 km^2 of the area observed as rarely suitable for the current habitat of the cheer pheasant (Fig. 12).

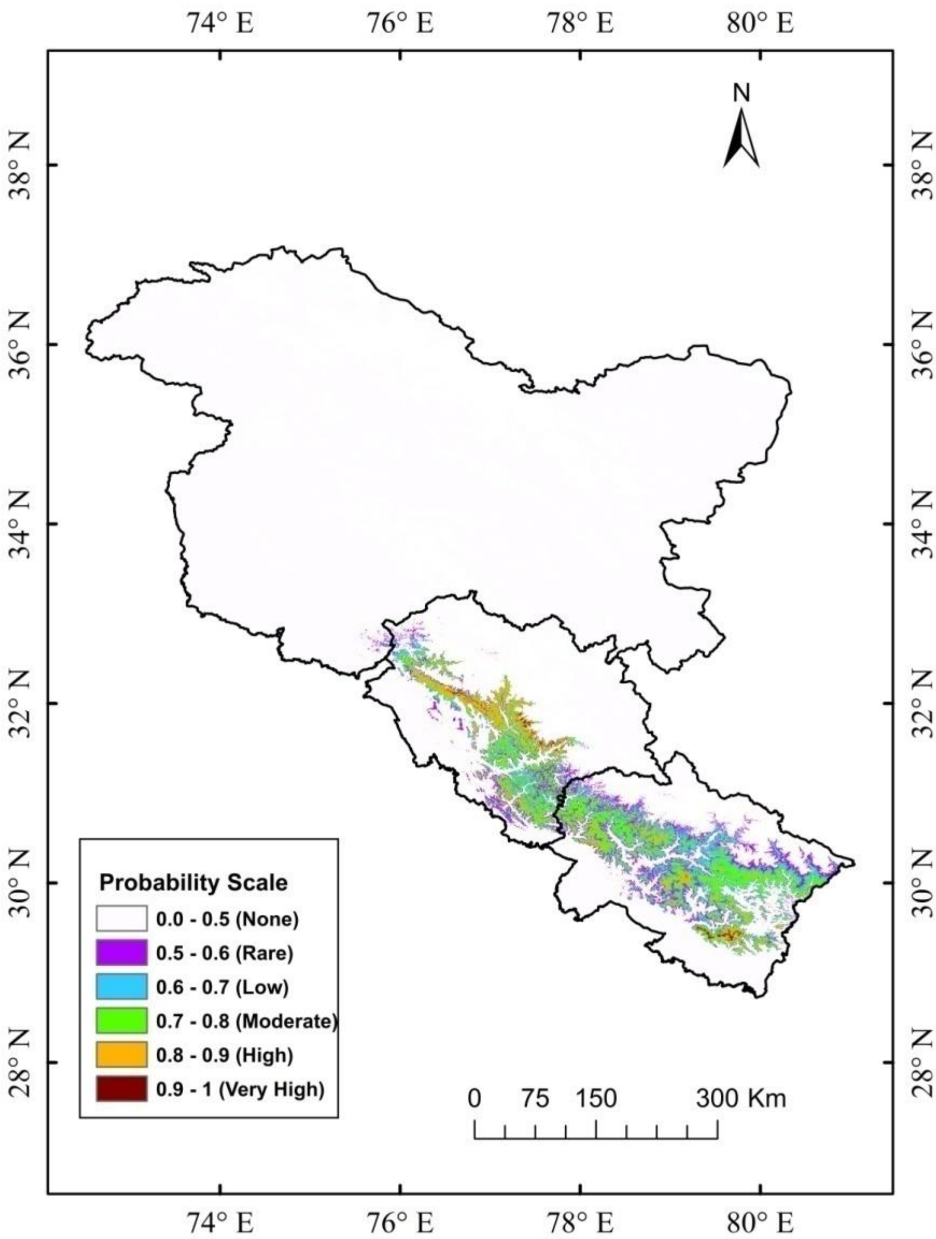


Fig 12. Potential habitat suitability distribution of Cheer pheasant (*Catreus wallichii*) in current climatic conditions.

Similarly for *Sitta leucopsis* the probability distribution was also classified into the five categories as cheer pheasant i.e. very highly suitable (>90 %), highly suitable (80-90%), moderately suitable (70–80%), low suitable (60–70%), and rarely suitable (50-60 %). Under current changing climatic condition, the model identified an area for white cheeked nuthatch and the probability distribution output was classified into five categories as cheer pheasant i.e. very highly suitable (>90 %), highly suitable (80-90%), moderately suitable (70–80%), low suitable (60–70%), and rarely suitable (50-60 %). Under current climatic conditions, the model identified an area of 4.26 km^2 as very highly suitable, 51.97 km^2 as highly suitable, 150.37 km^2 as moderately suitable, and 173.83 km^2 as low suitable while 141.54 km^2 of the area observed as rarely suitable for the current habitat of the white cheeked nuthatch (Fig 13).

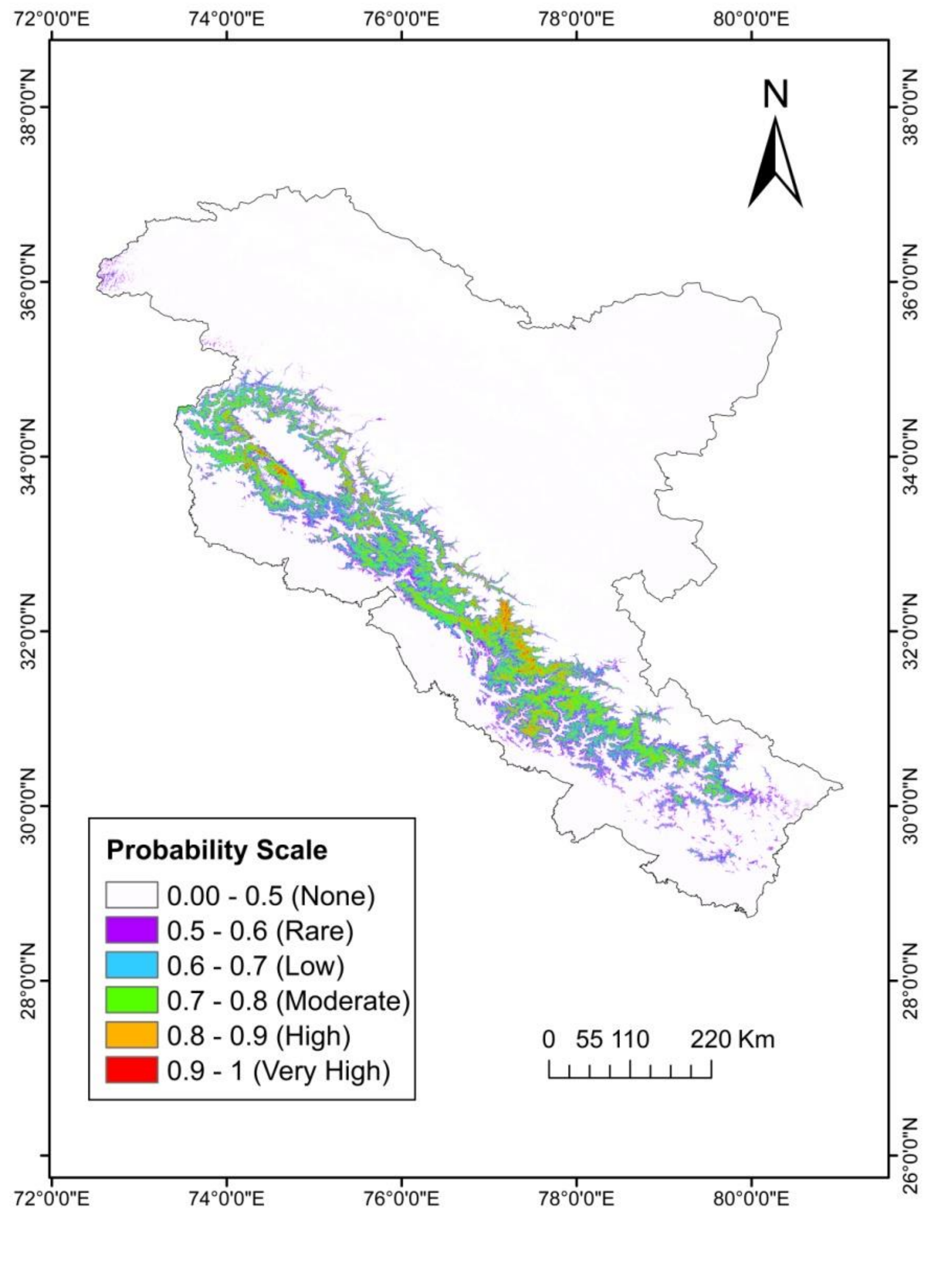


Fig 13. Potential habitat suitability distribution of white cheeked nuthatch (*Sitta leucopsis*)

3.1.4. Suitable habitat for selected species under future climate

The outcome of future habitat suitability for the species under different RCPs predicted by the MaxEnt model showed that the changing climatic condition alters the distribution of future suitable habitat of Tragopan.

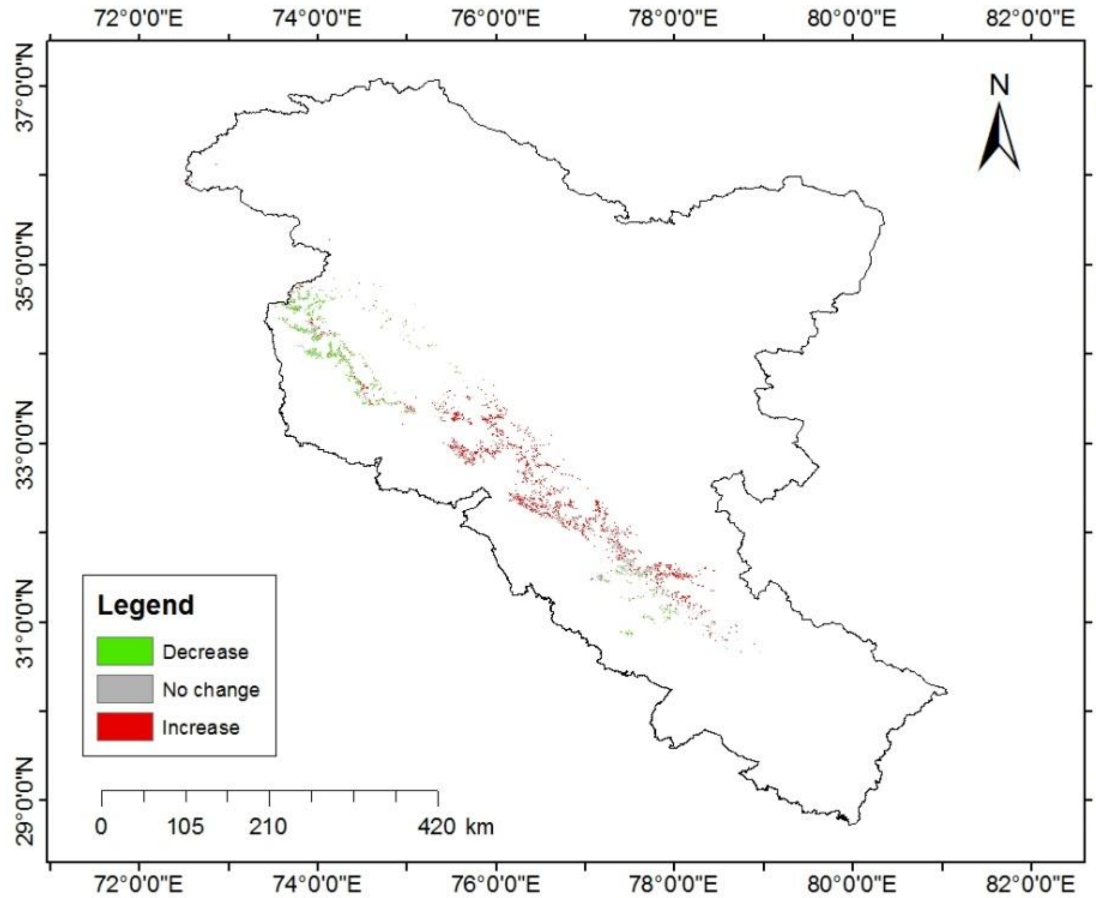


Fig. 14. Prediction of suitable future habitat of Western Tragopan (*Tragopan melanocephalus*) in RCP 4.5 for the period 2050.

The species distribution model was developed for three RCPs i.e. 4.5, 6.0 and 8.5 for the year 2050 (Fig. 14,15,16) and 2070 (Fig. 17, 18, 19) and it showed that areas that are less suitable for the range restricted birds would increase with respect to the current potential distribution. For the period of 2050, under RCP 4.5 the increase in area for high suitability was found by 2779.75 km^2 and a decrease in suitable area was recorded by 1301.06 km^2 while there would be no change in suitability classes for an area of 3535.81 km^2. Similarly, under RCP 6.0 an area for the suitable habitat would decrease by 24509.25 km^2 compared to the suitable area observed under current climate while no change would be observed for a total area of 4825.81 km^2. In the prevailing scenario of RCP 8.5, the decrease in area of suitability would be by 1434.19 km^2 compared to current climate. Similarly the observations were compared for the year 2070 and it was observed that under RCP 4.5 suitable area would decrease by 1365.31 km^2 compared to current climate. A detailed representation of changing suitability under different scenarios for the year 2050 and 2070 is shown in Table 3. It was observed that the suitable habitat of western tragopan would shift towards eastern regions with decrease in the suitable habitat with respect to present scenario by 5 to 35% under different RCPs for the years 2050 and 2070.

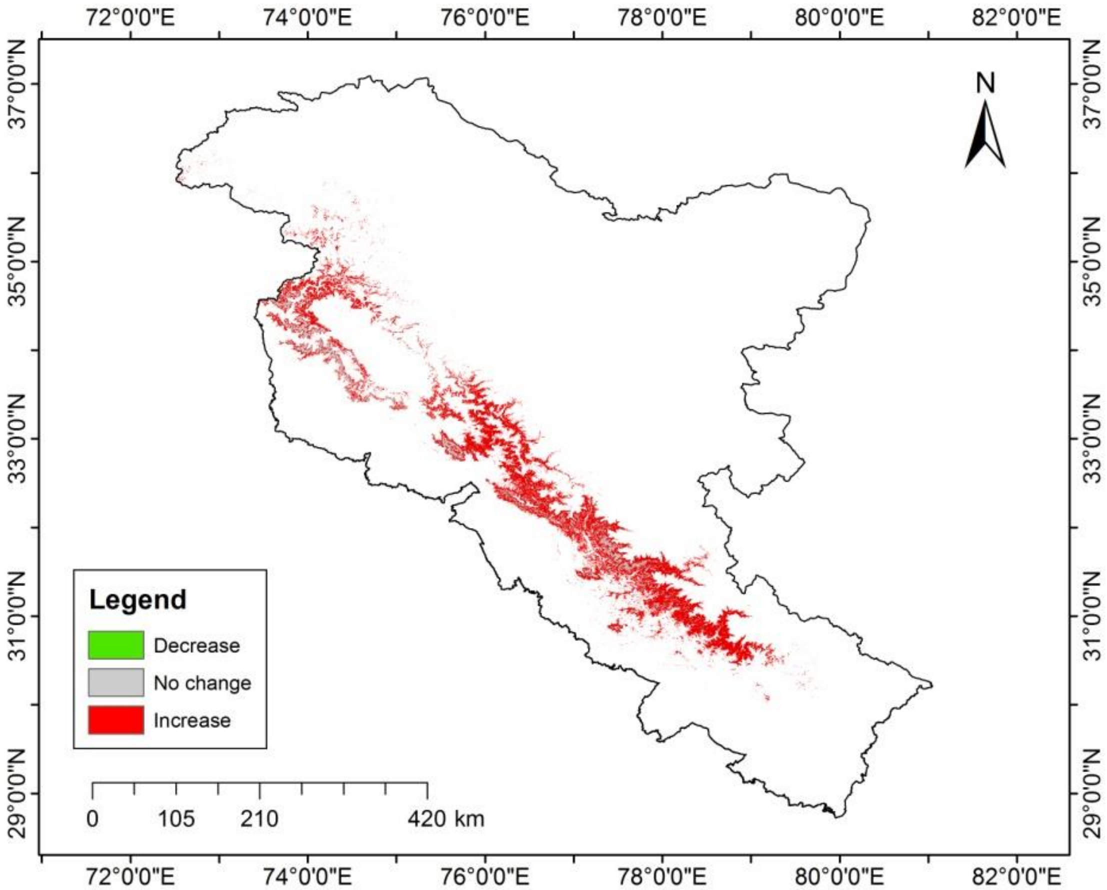


Fig. 15. Prediction of suitable future habitat of Western Tragopan (*Tragopan melanocephalus*) in RCP 6.0 for the period 2050.

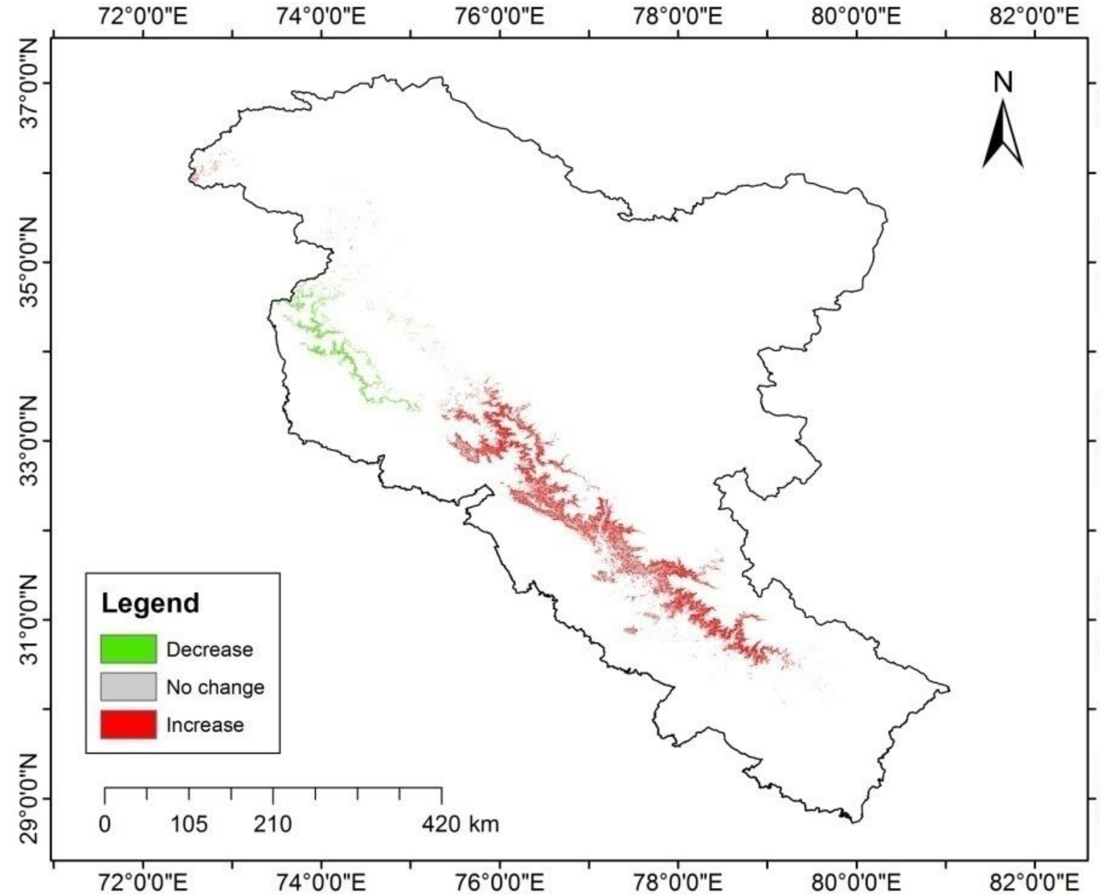


Fig. 16. Prediction of suitable future habitat of Western Tragopan (*Tragopan melanocephalus*) in RCP 8.5 for the period 2050.

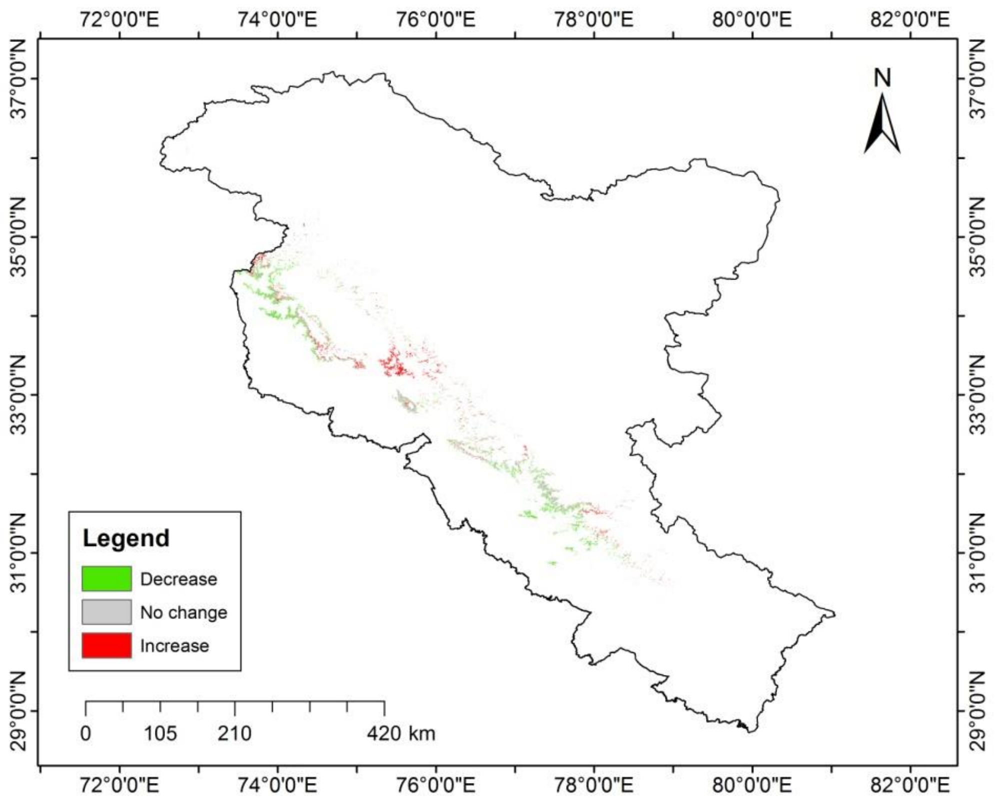


Fig. 17. Prediction of suitable future habitat of Western Tragopan (*Tragopan melanocephalus*) in RCP 4.5 for the period 2070.

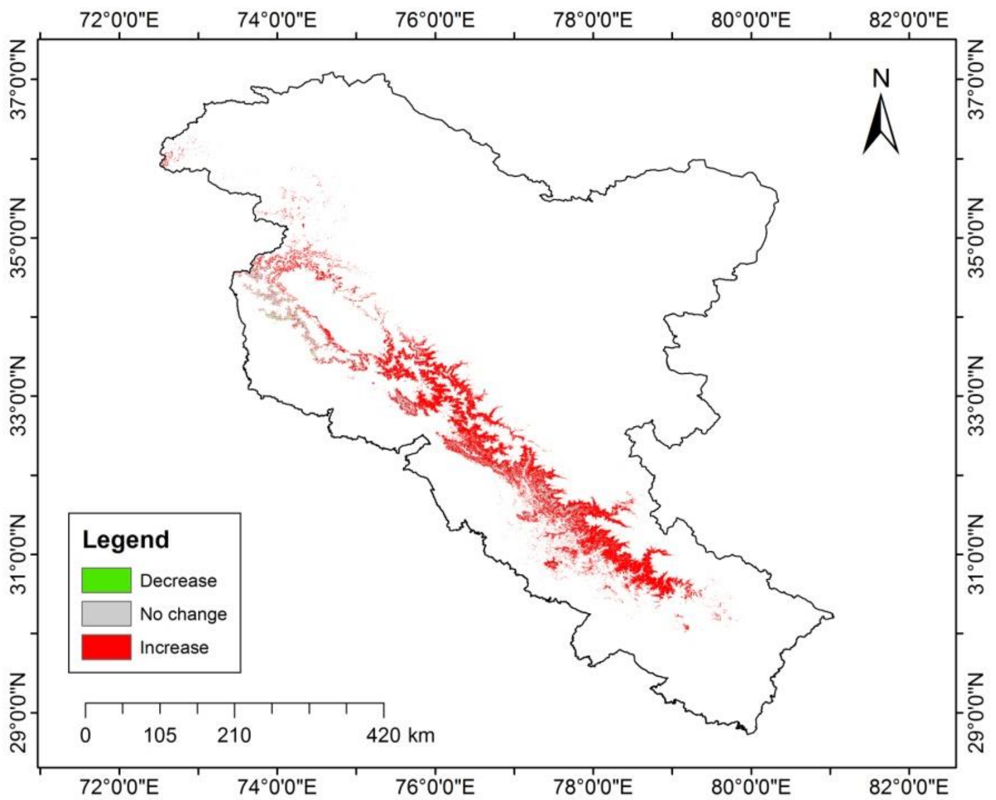


Fig. 18. Prediction of suitable future habitat of Western Tragopan (*Tragopan melanocephalus*) in RCP 6.0 for the period 2070.

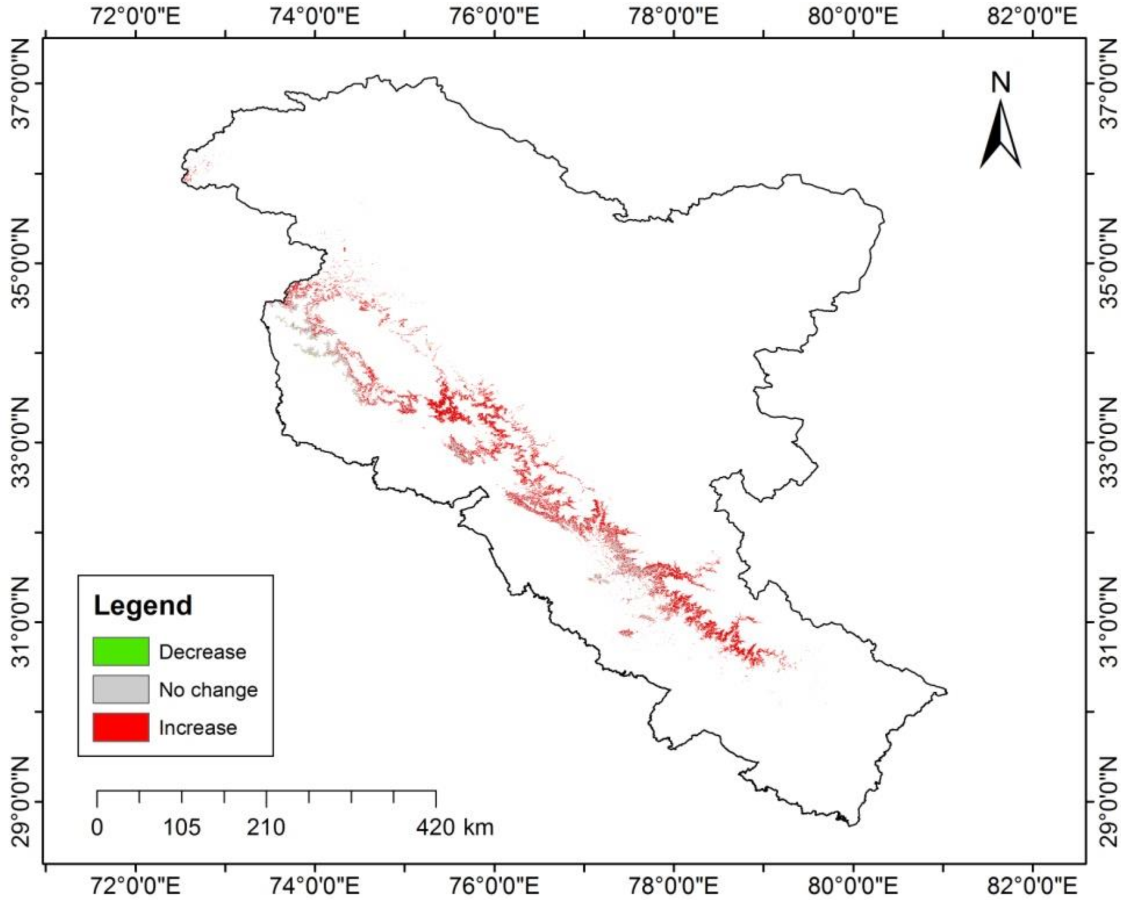


Fig. 19. Prediction of suitable future habitat of Western Tragopan (*Tragopan melanocephalus*) in RCP 8.5 for the period 2070.

The consequence of the future habitat suitability expected by the ensemble modelling approach for the selected species under different RCPs showed that the potential future effects of global climate change have significantly altered the area of suitable habitats for cheer pheasant. The species distribution model of the selected species was constructed as per three RCPs, i.e. 4.5, 6.0, and 8.5 for the years 2050 (Fig. 20, 21, 22) and 2070 (Fig. 23, 24, 25), and showed that area that is less desirable for range-restricted vulnerable birds would increase with respect to the current potential distribution map. For the period of 2050, under RCP 4.5 the increase in area for high suitability was found by 88.36 km^2 and a decrease in the suitable area was recorded by 12.50 km^2 while there would be no change in suitability classes for an area of 2805.23 km^2. Similarly, under the RCP 6.0 area for the suitable habitat would decrease by 14.75 km^2 compared to the suitable area observed under the current climate while no change would be observed for a total area of 2810.60 km^2. In the prevailing scenario of RCP 8.5, the suitability area would decrease by

12.05 km2 compared to the current climate. Similarly, the observations were compared for the year 2070 and it was observed that under RCP 4.5 suitable area would decrease by 12.87 km^2 compared to the current climate.

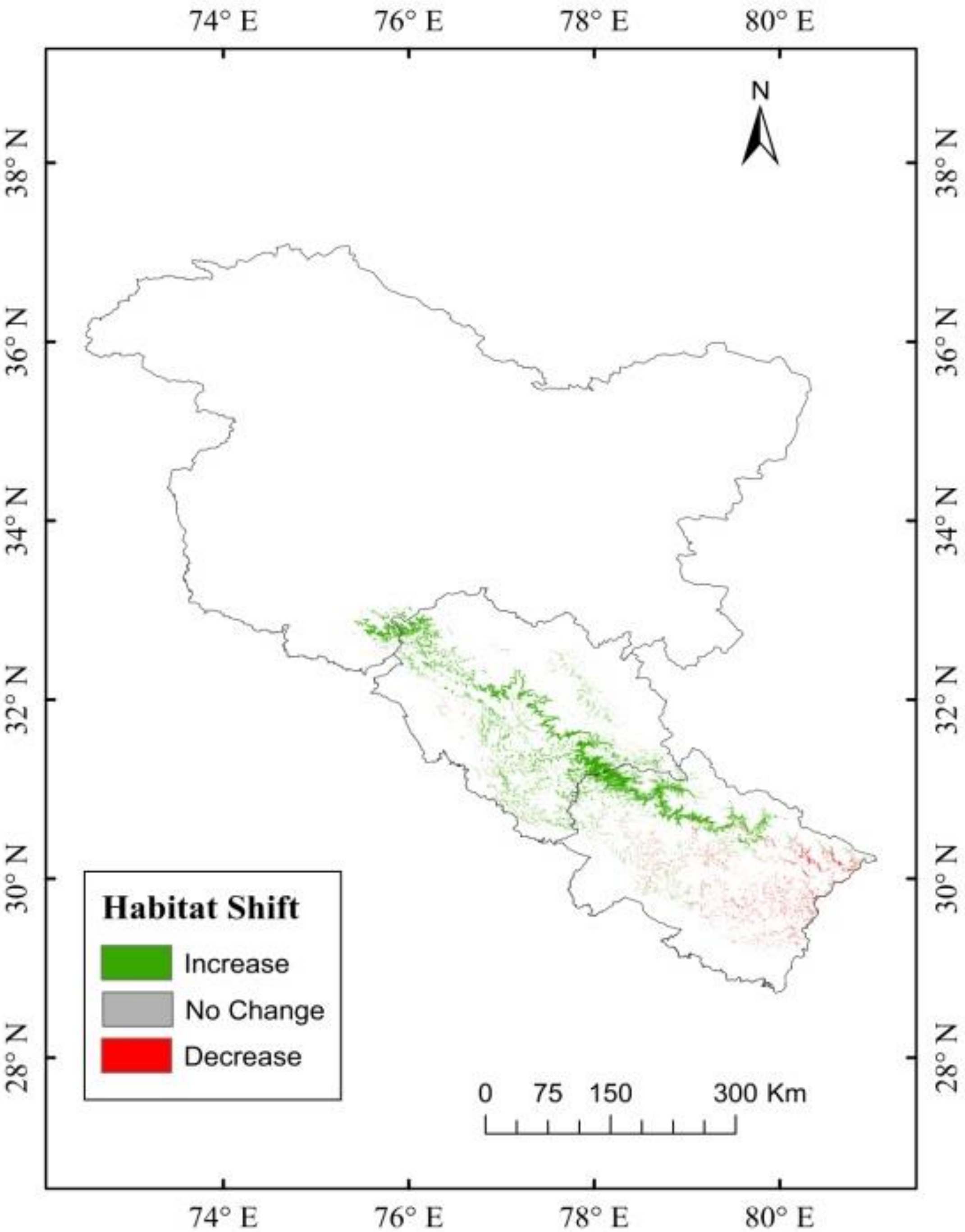


Fig 20. Prediction of suitable future habitat of Cheer Pheasant (*Catreus wallichii*) in RCP 4.5 for the period 2050.

A detailed representation of changing habitat suitability under different scenarios for the years 2050 and 2070 is shown in table 3. It was observed that habitat loss of cheer pheasant results in upwards elevation shifts of the suitable habitat with respect to the present scenario under the future changing climatic condition.

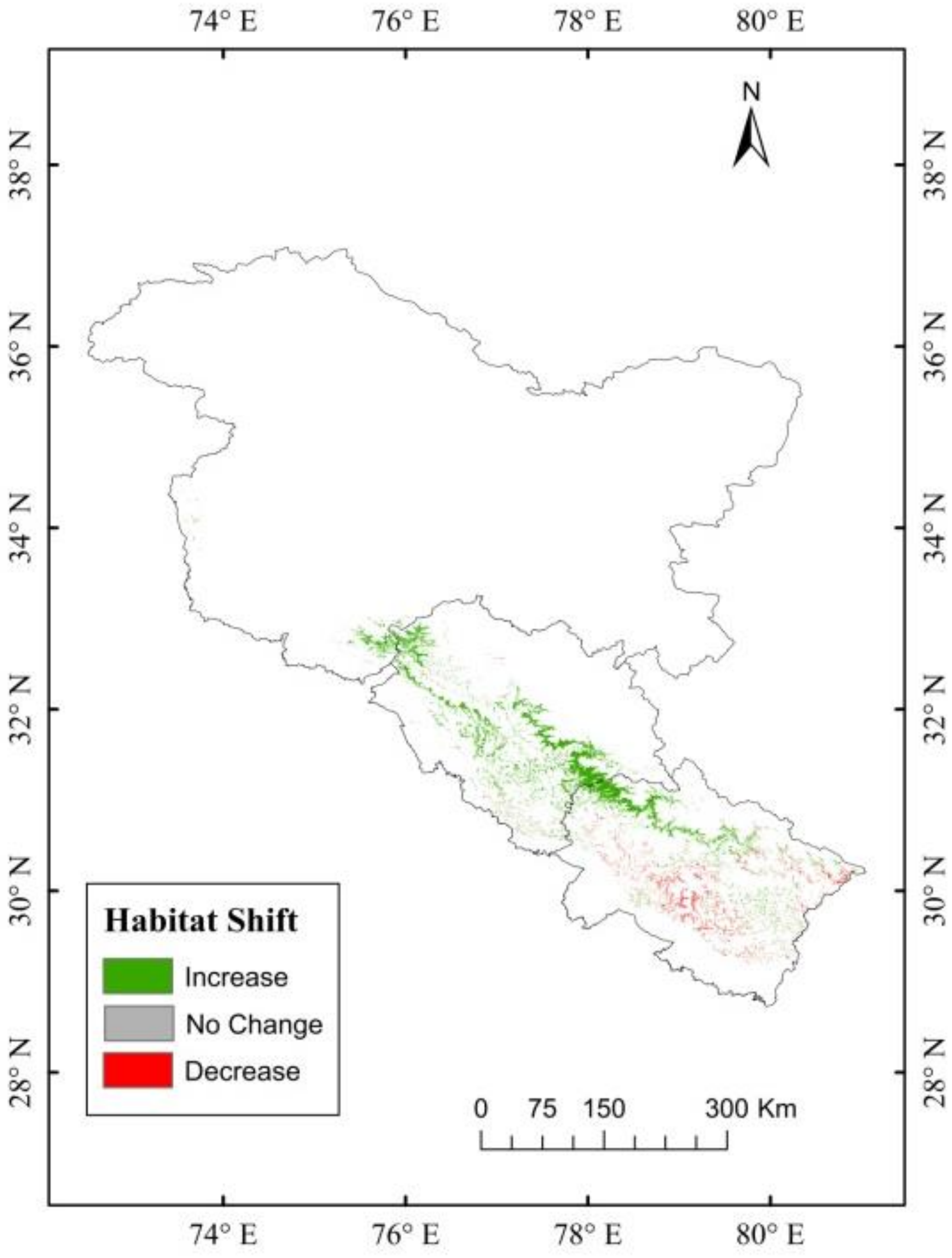


Fig 21. Prediction of suitable future habitat of Cheer Pheasant (*Catreus wallichii*) in RCP 6.0 for the period 2050.

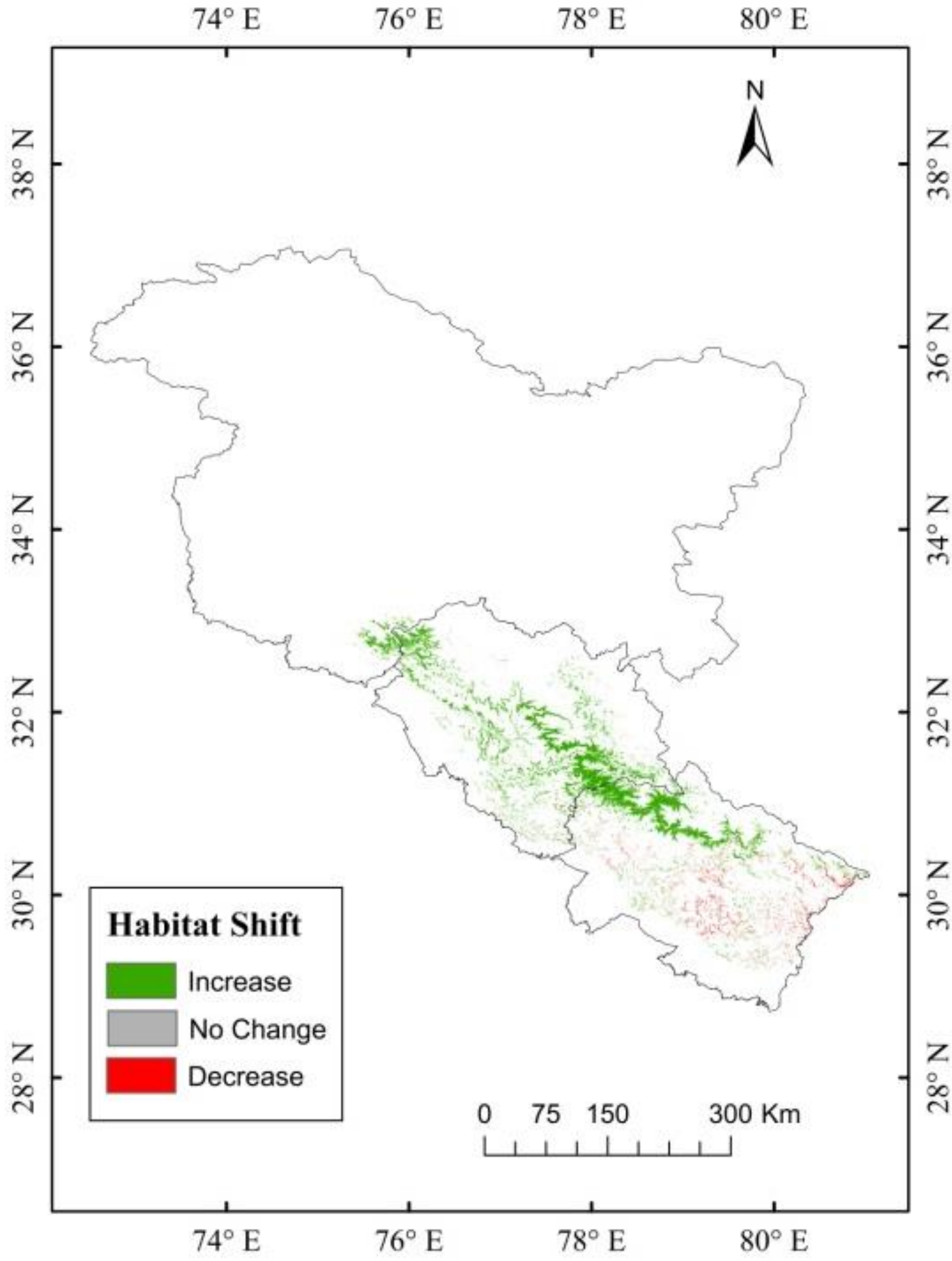


Fig 22. Prediction of suitable future habitat of Cheer Pheasant (*Catreus wallichii*) in RCP 8.5 for the period 2050.

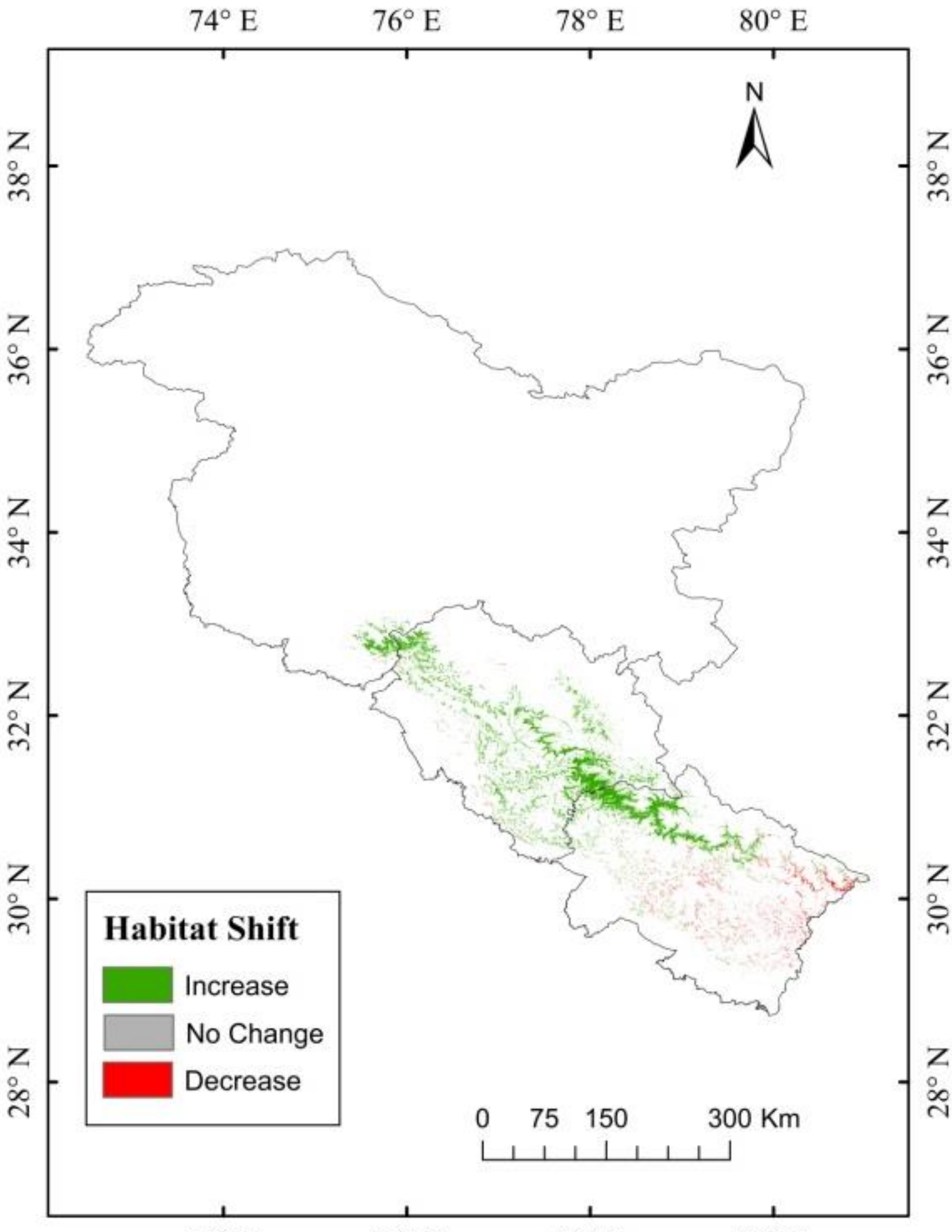


Fig 23. Prediction of suitable future habitat of Cheer Pheasant (*Catreus wallichii*) in RCP 4.5 for the period 2070.

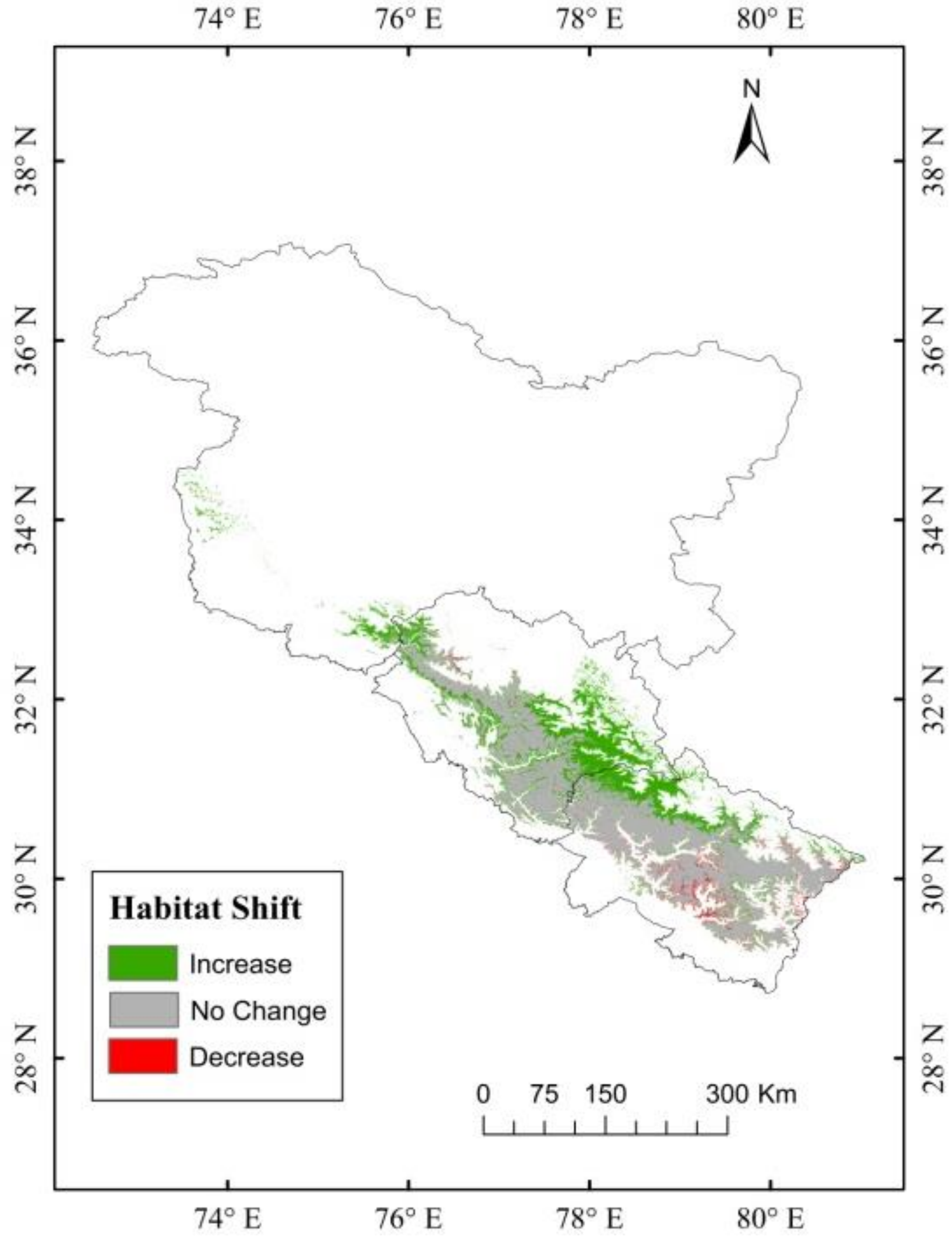


Fig 24. Prediction of suitable future habitat of Cheer Pheasant (*Catreus wallichii*) in RCP 6.0 for the period 2070.

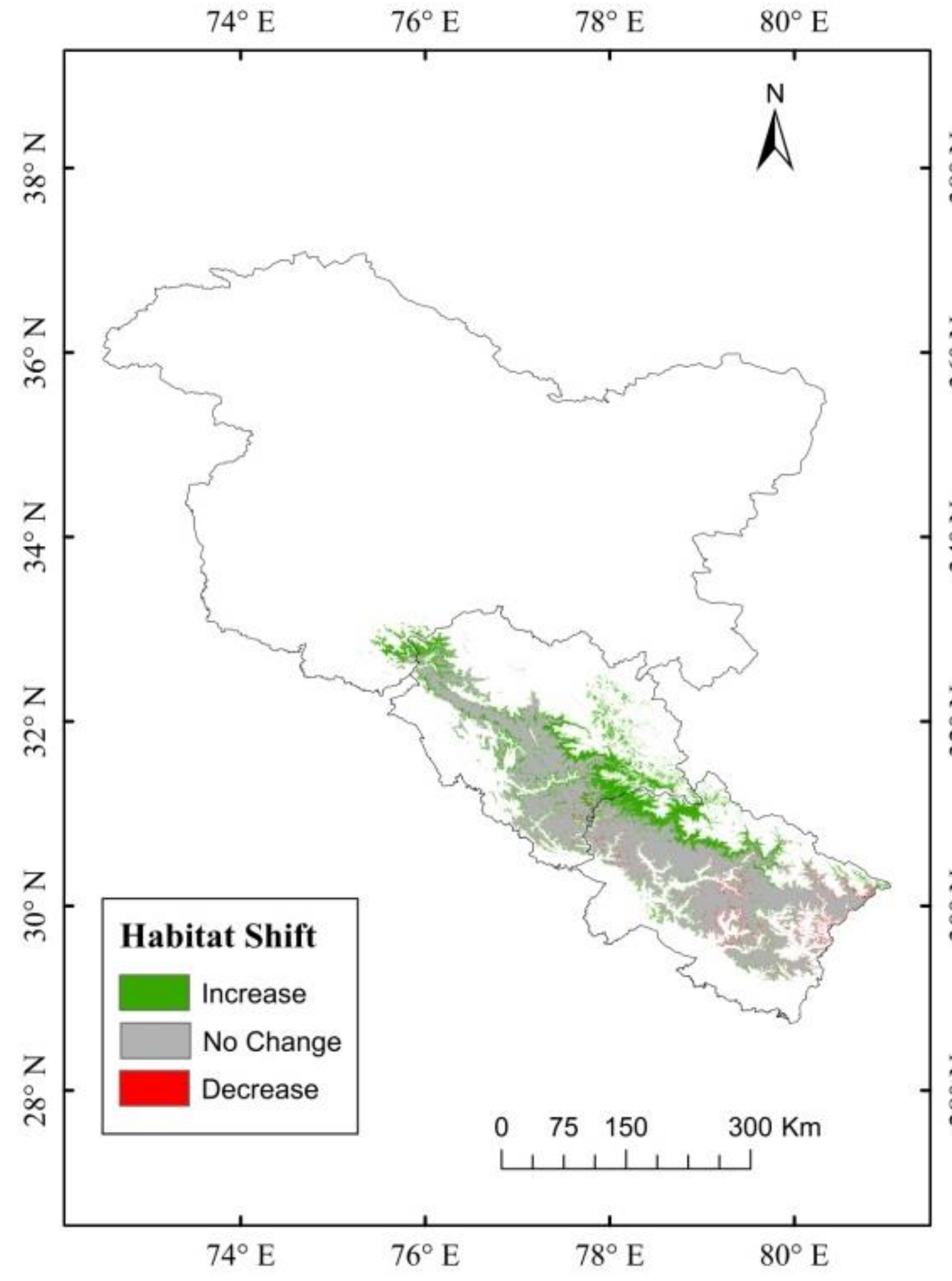


Fig 25. Prediction of suitable future habitat of Cheer Pheasant (*Catreus wallichii*) in RCP 8.5 for the period 2070.

The models were developed in case of range restricted Himalayan bird i.e. *Sitta leucopsis,* for the period 2050 (Fig. 26, 27, 28) and 2070 (Fig. 29, 30, 31) under different RCPs 4.5, 6.0, 8.5. It was observed that under RCP 4.5 increased distribution of the habitat suitability area would be recorded 26.86 km^2 and decreased areas would be 42.96 km^2 whereas no change in the habitat suitability would be recorded 2836.26 km^2 compared to the habitat suitability of the current climate condition.

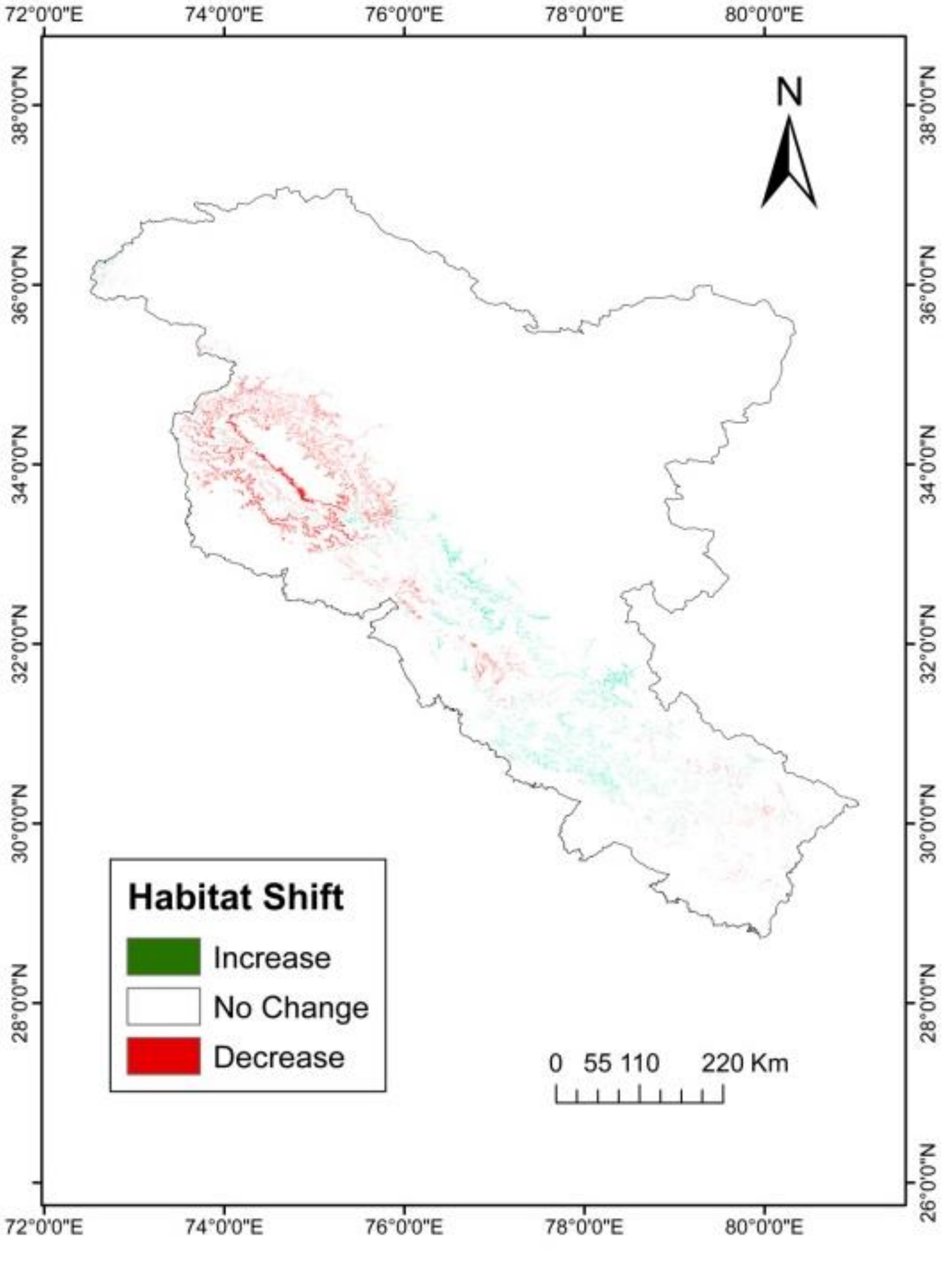


Fig. 26. Prediction of suitable future habitat of white cheeked nuthatch (*Sitta leucopsis*) in RCP 4.5 for the period 2050.

Likewise under the RCP 6.0, the area would increase about 227.76 km^2 and decreased habitat suitability would be 9.14 km^2 whereas there will be no change in the area about 2669.19 km^2. In case of RCP 8.5, increased area of suitability would be 116.43 km^2 and 29.47 km^2 areas would be decreased while 2760.18 km^2 areas has no change in this scenario for the period 2050.

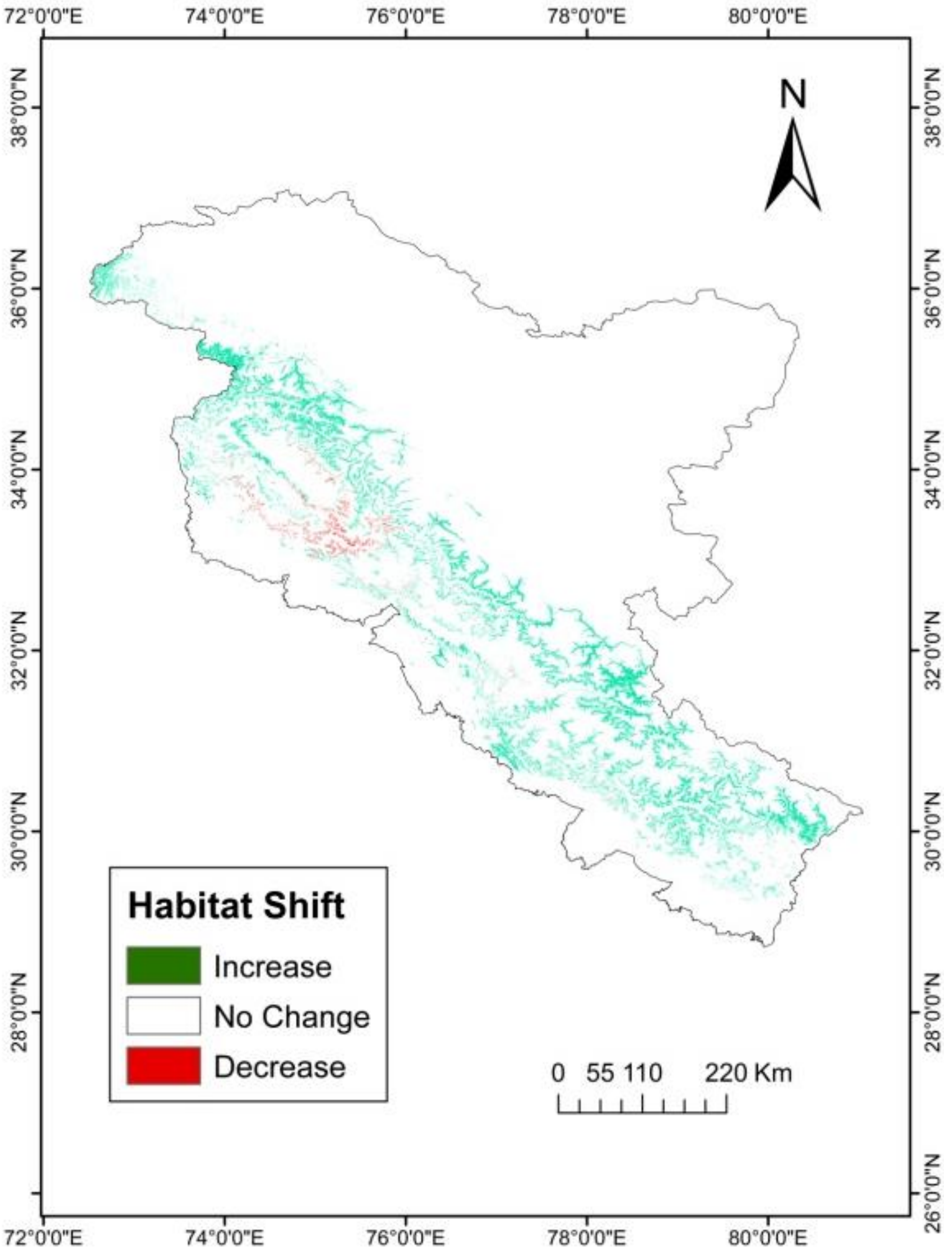


Fig. 27. Prediction of suitable future habitat of white cheeked nuthatch (*Sitta leucopsis*) in RCP 6.0 for the period 2050.

Notwithstanding this, for the period 2070, under RCP 4.5 & RCP 6.0, the area which would be increase is 457.47 km^2, decreased area would be 2.91 km^2 and area in which no change would be observed is 2650.71 km^2. Likewise under RCP 8.5, the increased area would be 125.36 km^2 and decreased area would be 30.61 km^2 while no change would be occur in the areas of 2750.11 km^2.

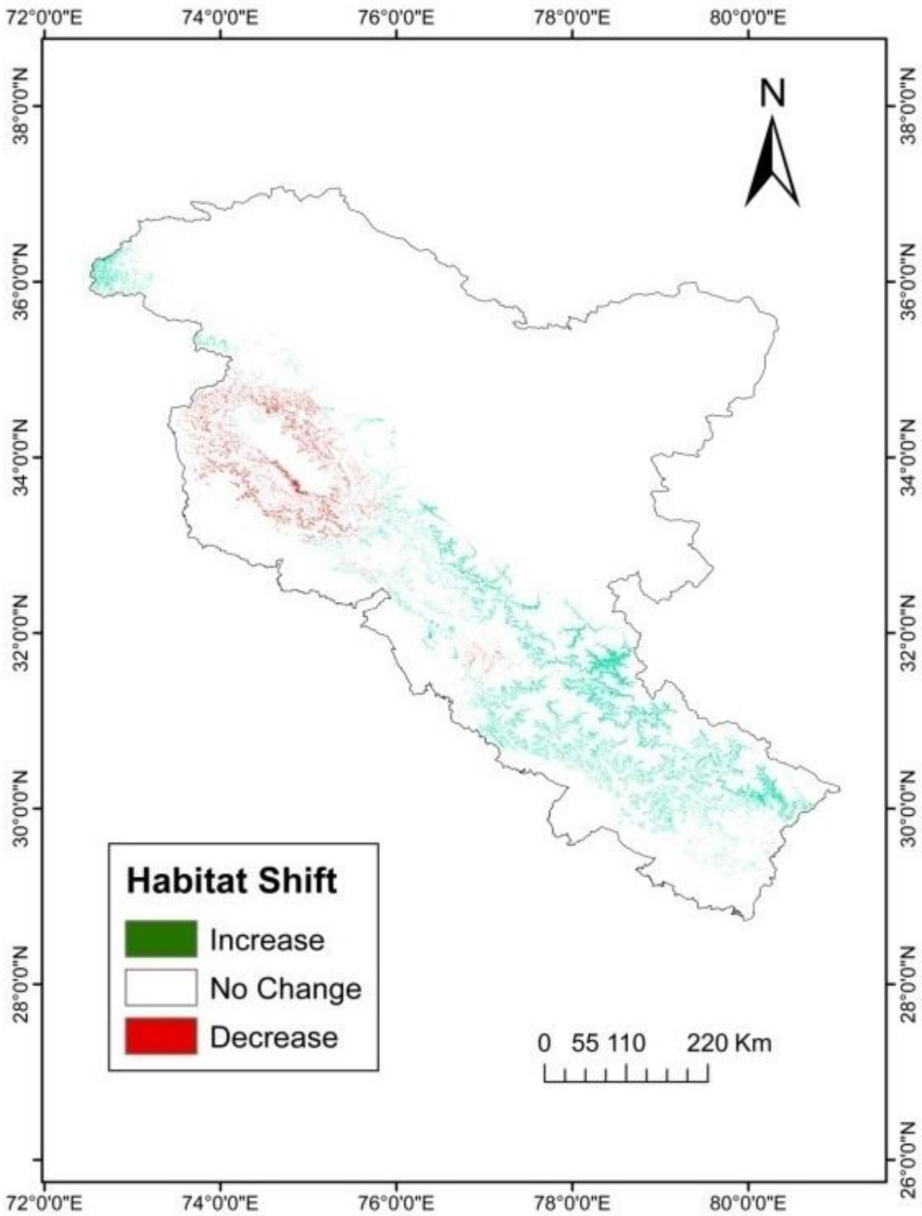


Fig. 28. Prediction of suitable future habitat of white cheeked nuthatch (*Sitta leucopsis*) in RCP 8.5 for the period 2050.

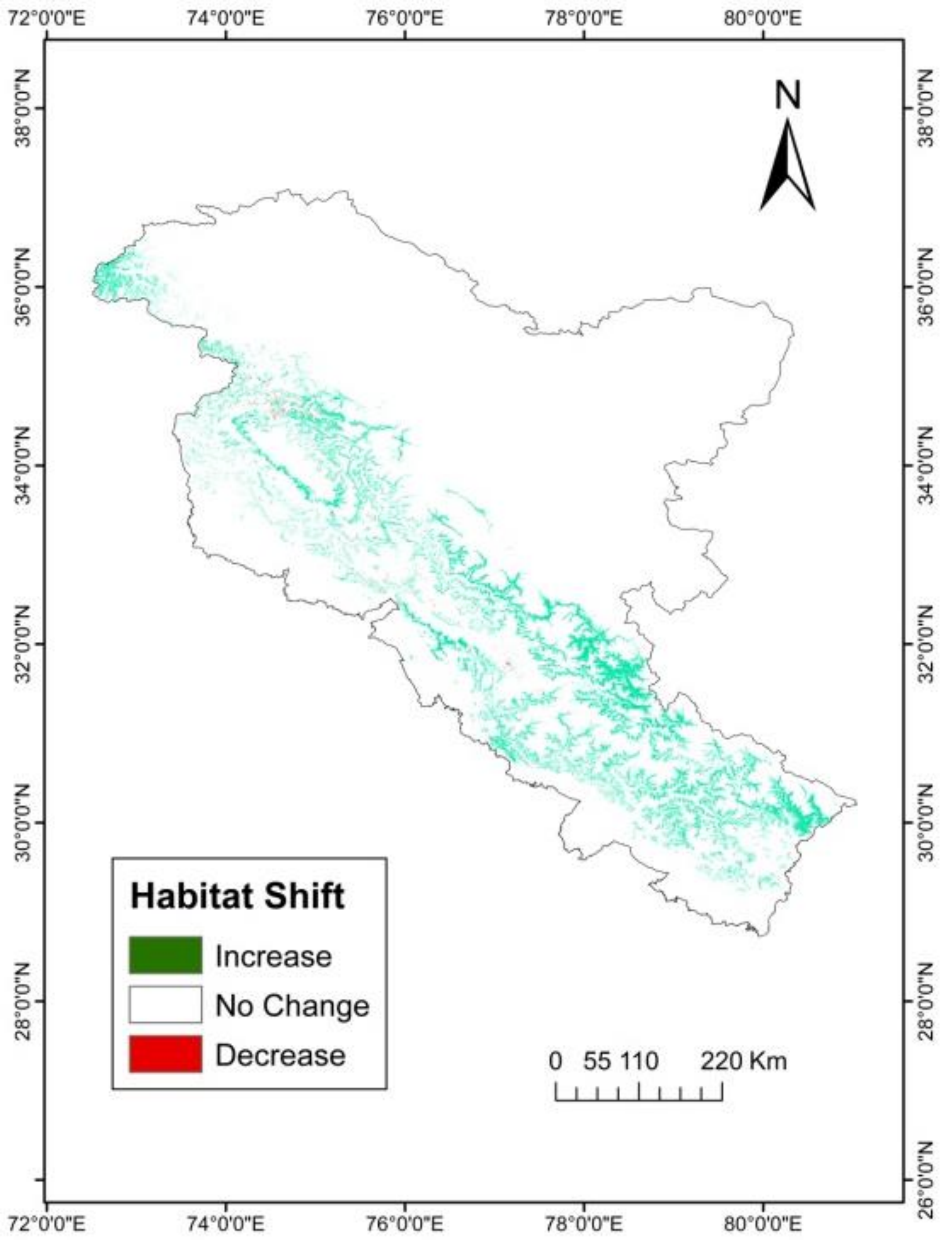


Fig. 29. Prediction of suitable future habitat of white cheeked nuthatch (*Sitta leucopsis*) in RCP 4.5 for the period 2070.

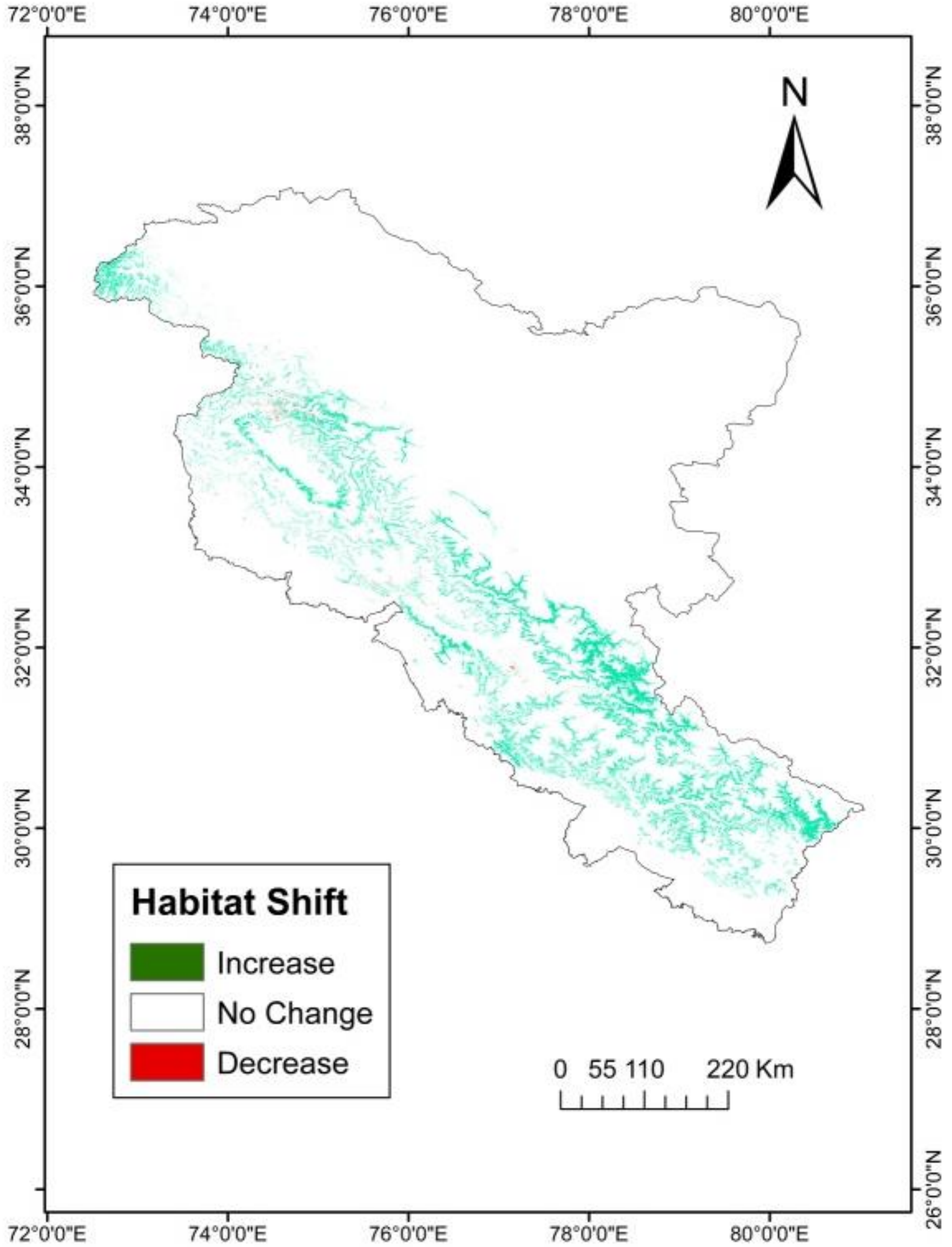


Fig. 30. Prediction of suitable future habitat of white cheeked nuthatch (*Sitta leucopsis*) in RCP 6.0 for the period 2070.

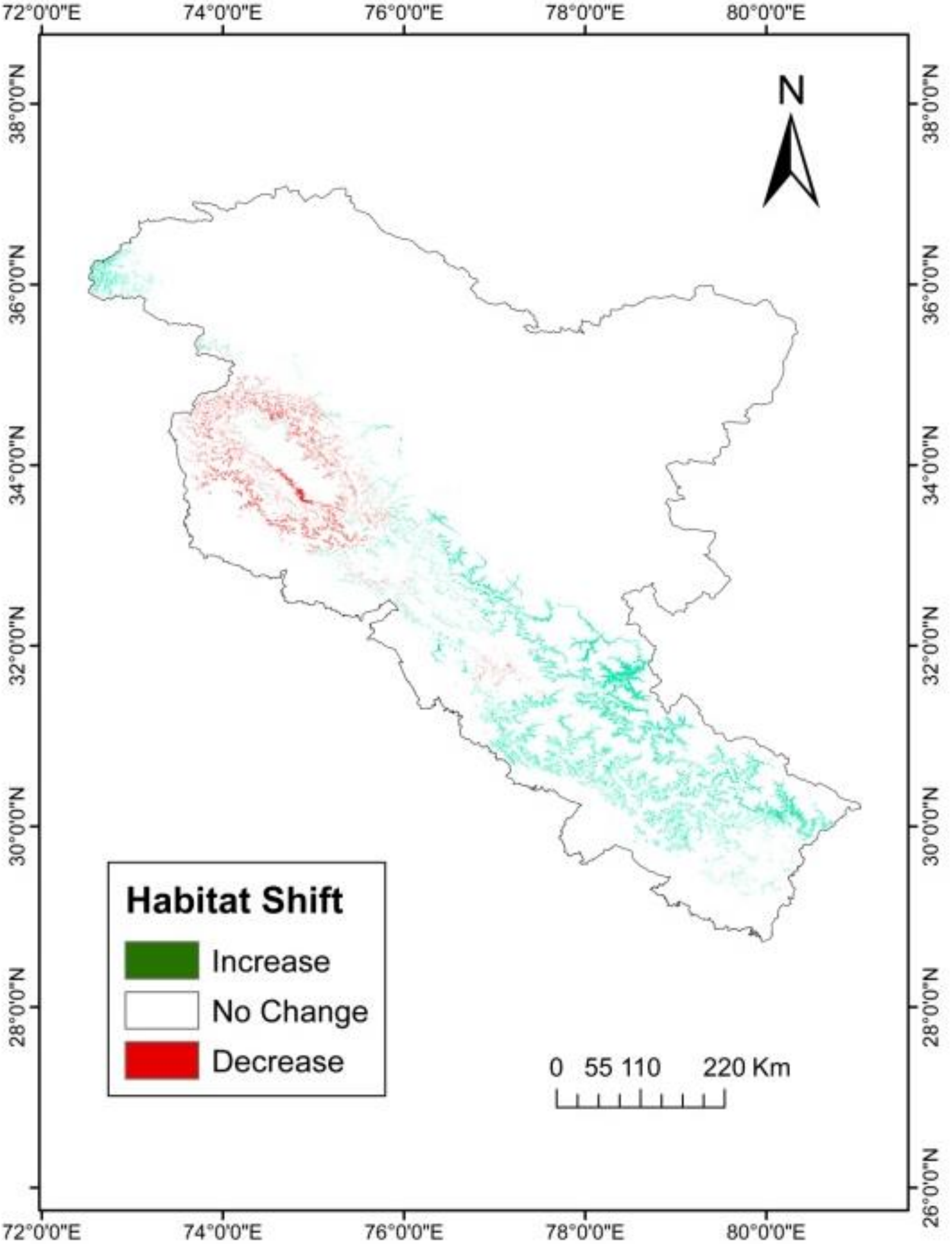


Fig. 31. Prediction of suitable future habitat of white cheeked nuthatch (*Sitta leucopsis*) in RCP 8.5 for the period 2070.

3.2 Key Results (max. 1000 words in bullets covering all activities)

- MaxEnt modelling approach for model preparation was used for the species western tragopan and ensemble modeling approach (including six model such as classification tree analysis (CTA), Multivariate adaptive regression spline (MARS), Maximum entropy (MaxEnt), Random forest (RF), Generalized boosted model (GBM), Support vector machine (SVM), Artificial neural networks (ANN) was used for the two range restricted Himalayan bird species such as cheer pheasant and s*itta leucopsis.*

- Current suitable habitat distribution map was developed for the three selected bird species (viz. Western tragopan (*Tragopan melanocephalus*), Cheer pheasant (*Catereus wallichi*), White cheeked nuthatch (*Sitta leucopsis*).

- Future habitat suitability prediction of the selected range restricted Himalayan bird species showed that the habitat of these species would shift towards eastern regions by expending ~25 to 55% habitat area under different representative concentration pathways (RCPs) for the years 2050 and 2070.

- Developed model for the current and future changing climatic condition by using species distribution modelling approach through MaxEnt modelling for western tragopan suggested a significant (AUC >0.97), shifting of suitable future habitat distribution of western tragopan towards the higher altitude in future climates under different representative concentration pathways for the years 2050 and 2070. Similarly, we have prepared a model for other range restricted bird species i.e. cheer pheasant (*Caterus wallichi*). In this we also prepared the model for the current as well as the future changing climatic conditions i.e. under different RCPs by using ensemble modelling approach and found that area under curve (AUC) for the cheer pheasant was 0.927 which indicates the best performance of the model. Based on the model it was observed that in future changing climatic condition under different RCPs the species is shifted towards the higher elevation for the year 2050 and 2070. Likewise for the species i.e. *sitta leucopsis* we have also done ensemble modelling and prepared model for the current and in different RCPs i.e. 4.5, 6.0 and 8.5 and found that the area under curve (AUC) was 0.875, indicating that the best performance of the model and also observed that the species are shifting their habitat towards the higher elevations in 2050 and 2070 under different RCPs.

- The estimated values of TSS and Kappa were 0.98 and 0.71, respectively which further suggested the robustness of the model to predict suitable habitat of western tragopan. Apart from that the Kappa value for MaxEnt (0.798) & RF (0.773) was also calculated and reported as maximum for cheer pheasant whereas kappa value for MaxEnt and RF was 0.745 & 0.657 for the species *sitta leucopsis*. The Kappa values even indicate the model's reliability in predicting suitable habitat.

- The jack-knife test results for western tragopan showed the importance of different bioclimatic, topographic, soil, and land use class variable while mapping habitat suitability. The test results indicated the relative contribution of climatic variables for current distribution and are presented as a mean value of 20 replicate model runs.

- The results revealed that precipitation of driest month (Bio14), mean diurnal range of temperature (Bio2), land use classes and sand proportion in the soil contribute by more than 70% in the model to predict the habitat.

- In case of cheer pheasant the findings showed that mean diurnal temperature range (Bio2), Precipitation Seasonality (Bio 15), Isothermality (Bio 3), land use classes, and soil sand proportion contribute to habitat prediction by on an average more than 75 percent in the ensemble modelling. The results revealed that the response of different variables in the model was positively nonlinear. These curves elaborated response of different variables for the mapping of habitat suitability.

- Similarly in case of *Sitta leucopsis* the results revealed that mean diurnal temperature range (Bio2), precipitation of driest month (Bio14) and isothermality (Bio3), bulk density, taxonomic class and land use contribute ~75% to the prediction of the habitat suitability of the species using ensemble modeling approach.

- The probability distribution output of western tragopan was divided into three categories i.e. highly suitable (> 85%), moderately suitable (71–85%), low suitable (51–70%). Under current climatic conditions and the model identified an area of 297.06 km^2 as highly suitable and 1883.38 km^2 as moderately suitable while 358423.75 km^2 of the area observed as low suitable for the current habitat of the species.

- For cheer pheasant, the probability distribution outcome was categorize into five categories i.e. very highly suitable (>90 %), highly suitable (80-90%), moderately suitable (70–80%), low suitable (60–70%), and rarely suitable (50-60 %). Under current climatic conditions, the model identified an area of 4.24 km^2 as highly suitable, 50.35 km^2 as highly suitable, 109.29 km^2 as moderately suitable, and 91.03 km^2 as low suitable while 88.89 km^2 of the area observed as rarely suitable for the current habitat of the cheer pheasant. Similarly for *Sitta leucopsis* the probability distribution is also categorize into the same categories as cheer pheasant.

- The outcome of future habitat suitability for the species under different RCPs predicted by the MaxEnt model showed that the changing climatic condition alters the distribution of future suitable habitat of Tragopan. The species distribution model was developed for three RCPs i.e. 4.5, 6.0 and 8.5 for the year 2050 and 2070 and it showed that areas that are less suitable for the range restricted birds would increase with respect to the current potential distribution. It was observed that the suitable habitat of western tragopan would shift towards eastern regions with decrease in the suitable habitat with respect to present scenario under different RCPs for the years 2050 and 2070.

- The consequence of the future habitat suitability expected by the ensemble modelling approach for cheer pheasant under different RCPs showed that the potential future effects of global climate change have significantly altered the species distribution area. The species distribution model of the selected species was constructed as per three RCPs, i.e. 4.5, 6.0, and 8.5 for the years 2050 and 2070, and showed that area that is less desirable for range-restricted vulnerable birds would increase with respect to the current potential distribution map. It was observed that through the ensemble modeling due to habitat loss of cheer pheasant results upwards elevation shifts of the suitable habitat with respect to the present scenario under the future changing climatic condition. Similarly in case of *Sitta leucopsis*, the habitat would be shifting from their native place towards the higher elevation under different future changing climatic scenario for the year 2050 and 2070.

3.3 Conclusion of the study undertaken (maximum 500 words in bullets)

- The modeling approach could be adopted for mapping the suitable habitats of bird species under the influence of changing climatic conditions and land-use change. The study revealed that habitat suitability is determined by climatic factors, land-use changes, and anthropogenic activities.

- It was reported that bioclimatic variables, i.e., temperature contributed more toward habitat suitability of bird species in the current and future climate change scenario.

- The study revealed the locality and extent of the distribution of western tragopan, cheer pheasant, and *Sitta leucopsis,* and the areas identified through the modelling approach as suitable habitats can be protected to ensure the conservation of western tragopan, cheer pheasant, and *Sitta leucopsis* for the current as well as future changing climatic scenarios.

- It is observed that the habitat of these selected bird species will shift towards the higher altitude in an eastward direction under prevailing climate change scenarios for the years 2050 and 2070.

- It is also examined that a total decrease in the area of suitable habitat would further restrict the range of selected bird species under prevailing scenarios of climate change for the assessment the years.

- Though there can be certain limitations in mapping habitat suitability and species distributions under climate change scenarios, we highlight that the Indian Himalayan Region reserves the habitat of these bird species. Thus, it must have a focused conservation approach to protect the viable number of these species. The Himalayan region is the habitat of many other important species. Thus, there is a need to identify the suitable habitat of selected priority species for conservation and protection, especially those on the verge of extinction.

- This integrated approach will also be the most effective in developing robust conservation strategies for species and ecosystems in the face of the environmental stressors of climate change, land-use change, habitat destruction, invasive species, and other anthropogenic influences.

- Besides that, the predictions will be helpful to policymakers in developing strategies for conservation and management plans of range-restricted Himalayan bird species in future climate change.

4 OVERALL ACHIEVEMENTS

Project objective: Predicting climatically suitable future habitats for the range-restricted Himalayan bird using species distribution modelling approach

Deliverables:

- **Generation of database encompassing restricted range bird species sighting records**

We generated the database for the selected range restricted bird species such as *Tragopan melanocephalus, Caterus wallichi* and *Sitta leucopsis*. In case of tragopan the species distribution map under three RCPs i.e. 4.5, 6.0 and 8.5 for the year 2050 and 2070 showed that areas that are less suitable for the range restricted birds would increase with respect to the current potential distribution.

Table 1: Changes in suitability of western tragopan species under different RCP scenarios.

Climate Model	Suitable class	Species Distribution area (km^2)		
		RCP 4.5	RCP 6.0	RCP 8.5
2050	No change	3535.813	4825.813	3402.688
	Decreased	1301.063	11.0625	1434.188
	Increased	2779.75	24509.25	11686.5

2070	No change	2903.5	4729.813	4764.563
	Decreased	1933.375	107.0625	72.3125
	Increased	1365.313	23714.94	10469.06

For the period of 2050, under RCP 4.5 the increase in area for high suitability was found by 2779.75 km^2 and a decrease in suitable area was recorded by 1301.06 km^2 while there would be no change in suitability classes for an area of 3535.81 km^2. Similarly, under RCP 6.0 an area for the suitable habitat would decrease by 24509.25 km^2 compared to the suitable area observed under current climate while no change would be observed for a total area of 4825.81 km^2. In the prevailing scenario of RCP 8.5, the decrease in area of suitability would be by 1434.19 km^2 compared to current climate. Similarly the observations were compared for the year 2070 and it was observed that under RCP 4.5 suitable area would decrease by 1365.31 km^2 compared to current climate (Table 1).

Table 2. Changes in suitability of Cheer Pheasant under different RCP scenarios

Climate Model	**Suitable Class**	**Species distribution area (Km^2)**			
		RCP 4.5		**RCP 6.0**	**RCP 8.5**
2050	No Change	2805.234		2810.594	2778.989
	Increase	88.3555		80.7465	115.0495
	Decrease	12.496		14.7445	12.0465
2070	No Change	2799.689		2728.93	2762.677
	Increase	93.524		163.0155	133.335
	Decrease	12.8725		14.14	10.073

Similarly for the species cheer pheasant it was also observed that the species was shifted towards the higher elevation under the future changing climatic condition. For this we developed distribution model of the selected species under three RCPs, i.e. 4.5, 6.0, and

8.5 for the years 2050 and 2070, and showed that area that is less desirable for range-restricted vulnerable birds would increase with respect to the current potential distribution map. For the period of 2050, under RCP 4.5 the increase in area for high suitability was found by 88.36 km^2 and a decrease in the suitable area was recorded by 12.50 km^2 while there would be no change in suitability classes for an area of 2805.23 km^2. Similarly, under the RCP 6.0 area for the suitable habitat would decrease by 14.75 km^2 compared to the suitable area observed under the current climate while no change would be observed for a total area of 2810.60 km^2. In the prevailing scenario of RCP 8.5, the decrease in the area of suitability would be by 12.05 km^2 compared to the current climate. Similarly, the observations were compared for the year 2070 and it was observed that under RCP 4.5 suitable area would decrease by 12.87 km^2 compared to the current climate. It was observed that through the ensemble modeling due to habitat loss of cheer pheasant results upwards elevation shifts of the suitable habitat with respect to the present scenario under the future changing climatic condition (Table 2).

Table 3. Changes in suitability of *Sitta leucopsis* under different RCP scenarios

Climate Model	**Suitable Class**	**Species distribution area (Km^2)**			
		RCP 4.5		**RCP 6.0**	**RCP 8.5**
2050	No Change	2836.257		2669.186	2760.183
	Increase	26.8625		227.7605	116.433
	Decrease	42.966		9.1385	29.469
2070	No Change	2650.708		2650.708	2750.11
	Increase	252.467		252.467	125.3645
	Decrease	2.91		2.91	30.6105

Likewise, in case of range restricted Himalayan bird i.e. *Sitta leucopsis*, under RCP 4.5 increased distribution of the habitat suitability area would be recorded 26.86 km^2 and decreased areas would be 42.96 km^2 whereas no change in the habitat suitability would be recorded 2836.26 km^2 compared to the habitat suitability of the current climate condition. Likewise under the RCP 6.0 the area would increase about 227.76 km^2 and decreased habitat suitability would be recorded 9.14 km^2 whereas there is no change in the area about 2669.19 km^2. In case of RCP 8.5, increased area of suitability would be 116.43 km^2 and 29.47 km2 areas would be decreased while 2760.18 km^2 areas has no change in this scenario for the period 2050. Notwithstanding this, for the period 2070, under RCP 4.5 & RCP 6.0, the area which would be increase is 457.47 km^2, decreased area would be 2.91 km^2 and area in which no change would be observed is 2650.71 km2. Likewise under RCP 8.5, the increased area would be 125.36 km^2 and decreased area would be 30.61 km^2 while no change would be occur in the areas of 2750.11 km^2. These are the database generated for predicting climatically suitable future habitats for the range restricted Himalayan bird species (Table 3).

4.1 Establishing New Database/Appending new data over the Baseline Data (max. 1500 words, in bullet points).

- We generated the new database for the selected range restricted bird species such as *Tragopan melanocephalus*, *Caterus wallichi* and *Sitta leucopsis*. For these range restricted bird species we have developed model under three RCPs i.e. 4.5, 6.0 and 8.5 for the year 2050 and 2070.

- In case of western tragopan, under RCP 4.5 the increased in area for high suitability was found by 2779.75 km^2. Likewise, under RCP 6.0, area for the suitable habitat would decrease by 24509.25 km^2 compared to the suitable area observed under current climate while no change would be observed for a total area of 4825.81 km^2. In the prevailing scenario of RCP 8.5, the decrease in area of suitability would be by 1434.19 km^2 compared to current climate for the period of 2050. Similarly for the year 2070 it was observed that under RCP 4.5, distribution area and the habitat of the bird would shift 1365.31 km^2 as compared to the current habitat distribution besides that decrease in the area of habitat suitability distribution would be 1933.38 km^2 than the current climatic scenario. Likewise, suitable habitat distribution of western tragopan shifted 23714.94 km^2 under RCP 6.0 while the area of distribution would decrease by 107.06 km^2 compared to the current climatic condition. Similarly in case of RCP 8.5 the distribution of suitable habitat would also increase by 10469.06 km^2 and decrease by 72.31 km^2 while about 4764.56 km^2 area would no change compared to the current distribution of the species.

- Cheer pheasant species are also range-restricted bird species affected by the changing climatic conditions. From the result, it was observed that there is also a new database generated for the species which will help in the conservation and management of the species in the future changing climatic condition. According to the results, it was revealed that the species would shift towards the higher elevation under the changing climatic scenarios. The results showed for the different RCPs that area less desirable for range-restricted vulnerable birds would increase for the current potential distribution map. By 2050, under RCP 4.5, the distribution of suitable habitats of the species would increase by 88.36 km^2, and a decrease in the suitability of the area was recorded by 12.50 km^2 while there would be no change in suitability classes for an area of 2805.23 km^2 as compared to the current distribution map. Under the RCP 6.0 the suitable habitat distribution of the species would shift by 80.75 km^2, and the area would decrease by 14.75 km^2 compared to the suitable area observed under the current climate. In comparison, no change would be observed for a total area of 2810.60 km^2. In the prevailing scenario of RCP 8.5, it is predicted that habitat suitability area would increase by 115.05 km^2 and 12.05 km^2 area of the species distribution decreases and no change is predicted in the area of 2778.99 km^2 in contrast to the current climate.

- Similarly, the prediction is also made for the year 2070, and it was observed that the species would shift from their current habitat under RCP 4.5. The area of shifting in the future would 93.52 km^2 and decrease suitable distribution area would 12.87 km^2 compared to the current climate. It was also predicted that an area of about 2799.69 km^2 has no change in future climatic conditions. Similarly, under RCP 6.0, the area of suitable habitat for their survival and reproduction would shift by 163.02 km^2 and decrease in area of suitability by 14.14 km^2 while there is no changes occurring in the area of 2728.93 km^2 at the onset of changing climatic condition.

- In case of *Sitta leucopsis*, new database is generated over baseline and it is predicted that under RCP 4.5 increased distribution of the habitat suitability area would recorded 26.86 km^2 and decreased area of suitability for their survival would 42.96 km^2 whereas no change in the habitat suitability would be recorded 2836.26 km^2 compared to the habitat suitability of the current climate condition. Likewise under the RCP 6.0 the area would increase about 227.76 km^2 and decreased habitat suitability would record 9.14 km^2 whereas in area 2669.19 km^2 there is no change. In case of RCP 8.5, increased area of suitability would 116.43 km^2 and 29.47 km^2 areas would decreased while 2760.18 km^2 areas has no change in this scenario for the period 2050. Notwithstanding this, for the period 2070, under RCP 4.5 & RCP 6.0, the area which would increase is 457.47 km^2, decreased area would be 2.91 km^2 and area in which no change would observed is 2650.71 km^2. Likewise under RCP 8.5, the increased area would 125.36 km^2 and decreased area would 30.61 km^2 while no change would occur in the areas of 2750.11 km^2. These are the database generated for predicting climatically suitable future habitats for the range restricted Himalayan bird species.

4.2 Generating Model Predictions for different variables (if any) (max 1000 words in bullets)

- Yes, we have generated model for the three range restricted bird species i.e Western tragopan, Cheer pheasant, *Sitta leucopsis* under different RCPs i.e. 4.5, 6.0, 8.5. Species distribution models (SDMs) have been recognized as a useful tool for assessing the impact of environmental change on the distribution of organisms, and for selecting natural ecosystems important for preservation and management. Based on the model it was revealed that the habitat distribution of all the selected species would shift towards the higher altitude during the period of 2050 and 2070.

4.3 Technological Intervention (max. 1000 words): **No**

4.4 On-field Demonstration and Value-addition of Products (max. 1000 words, in bullet points): **NA**

4.5 Developing Green Skills in IHR : **NA**

4.6 Addressing Cross-cutting Issues (max. 500 words, in bullet points):

- Global climate change is a worldwide phenomenon impacting various ecosystems significantly. It has significant impacts on biodiversity, including Himalayan biodiversity. Hence, the study addressed climate change issues and focused on the future impacts of climate change on Himalayan range-restricted bird species. This study will help develop conserving and managing biodiversity especially Himalayan range-restricted bird species, in the wake of climate change.

5 IMPACTS OF FELLOWSHIP IN IHR

5.1 Socio-Economic Development (max. 500 words, in bullet points)

5.2 Scientific Management of Natural Resources In IHR (max. 500 words, in bullet points)

- This study projected the climate change impacts on habitat range shift of Himalayan range-restricted bird species of Uttarakhand, Himachal Pradesh, and Jammu and Kashmir. The finding reported that the habitat of selected range-restricted bird species would shift toward higher elevations to adapt the future climatic conditions. Hence, it is further suggested that policymakers may formulate effective conservation and management policies/strategies to protect these species under the influence of climate change.

5.3 Conservation of Biodiversity in IHR (max. 500 words, in bullet points)

- Considering the effects of threats and identifying conservation regions are critical for the conservation and management of threatened species. Climate change is a significant threat to biodiversity, which puts pressure on species to move to new climatically suitable areas. This study examined the distribution of suitable habitats for vulnerable bird species such as Western tragopan, Cheer Pheasant, and *Sitta leucopsis* in the Indian Himalayan region, as classified by the International Union for Conservation of Nature (IUCN). The Major causes of depletion of vulnerable species were anthropogenic activities such as habitat loss, overgrazing, deforestation, temperature, rainfall pattern, etc. Notwithstanding this, Climate influences the species distribution and often acts as a limiting factor in the extent and location of species margins. Due to unexpected changes in climatic conditions, biodiversity hotspots are at high risk of species extinction. The consequences for range-restricted species would be more severe as they have limited habitats for sustenance. Within the last two decades, range shifts have increasingly been debated as proof of measurable climate change impact on bird species and communities. Researchers reported the geographical distribution of bird species is shifting from their native habitat.

- In northern temperate regions, the species shift has been reported towards the northeast or northwest, whereas evidence for corresponding southern shifts is very scarce. It was due to increased temperature and species shifting towards cooler regions. The Himalayan ecosystems are one of the most fragile and vulnerable to climate change. The bird species in the Himalayan biodiversity hotspot face several threats due to the degradation and fragmentation of forested landscapes.

- The most adjacent effect of climate change is on the distribution of species. A rise in global temperature may result in bird species shifting to higher elevations. Any alterations in climatic variables might negatively influence some species with limited suitable habitats, such as the range-restricted species. The survival of the species under the influence of climate change would depend upon the adaptive capacity of the species. If the climate change is beyond the adaptive capacity, species may shift to a suitable habitat to match their climatic niche; else, they may face extinction. These changes threaten the persistence of several species and alterations in community structure and function, which may affect biological diversity.

- Therefore, conservation and management of habitat loss are necessary at their earliest. Thus the future habitat suitability distribution maps would benefit biodiversity conservators and policymakers in formulating future strategies and planning for conservation and management of the selected Himalayan range-restricted bird species.

5.4 Protection of Environment (max. 500 words, in bullet points)

- Anthropogenic climate change is a severe threat to the range-restricted bird species and global biodiversity. Changes in the geographic distribution of species, decrease in species population sizes, changes in ecological interactions, and the extinction of various species are some of the predicted impacts of climate change. Modeling studies in particular of Himalayan range-restricted bird species indicated that climate change is a crucial extinction driver in the Indian Himalayan region.

- The average global temperature has increased by 0.74 °C over the last century and is projected to increase by a further 1.8–4.0 °C by 2090–2099. If a significant cut in global greenhouse gas emissions is achieved, the temperature rise may stabilize at approximately 2 °C; however, even with this limit, a certain amount of damage is unavoidable. It is thus necessary to assess the impact of climate change on species distributions to determine the extent of potential ecological risk and to design appropriate conservation strategies for adaptive management.

- Climate change is a significant threat to the range-restricted bird species in the IHR. To cope with these changes, the network of protected areas is one of the most important means of enhancing species survival. However, novel challenges to the efficiency of the reserve network are evident because the changing climate may drive species outside the protected areas they currently occupy.

- The efficiency of the protected area network in preserving bird species is the main point for the conservation of range-restricted bird communities, i.e., identifying sites with the highest conservation value, establishing and managing protected areas, and implementing suitable conservation measures.

- In the present study, the models are developed under different projections, which revealed the range shifts of species under climate change scenarios towards higher altitudes which needs conservation planning for the present and potential future distributions.

5.5 Developing Mountain Infrastructures: NA
5.6 Strengthening Networking in IHR: NA

6 EXIT STRATEGY AND SUSTAINABILITY

6.1 How effectively the fellowship findings could be utilized for the sustainable development of IHR (max. 1000 words):

- The loss of species results in the loss of natural processes that influence the flow of ecosystem services. Species loss will affect trophic systems and their interactions on a larger scale than only spatiotemporal scales. It has already been established that the influence of climate variability will significantly impact species distribution and extinction, resulting in a reduction in ecosystem services flow. According to the regional reports of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (Diaz et al., 2018) and the Millennium Ecosystem Assessment (2005), more than half of the world's biodiversity is facing extinction.

- The Himalayas are well-known biodiversity hotspots, where ecological and evolutionary processes have aided in preserving species richness and diversity.

Climate change will profoundly impact Himalayan ecosystems and the flow of ecosystem services, affecting people living both upstream and downstream. The India Himalayan Region's (IHR) fragile landscapes and undulating terrains are especially vulnerable to natural hazards and disasters. Many portions of IHR are constantly deteriorating as a result of climate-related vulnerability. Predicting the likely distribution of species in the face of climate change and ongoing anthropogenic intervention will be a helpful tool for developing effective conservation measures.

6.2 Efficient ways to replicate the outcomes of the fellowship in other parts of IHR

- The approach used in the present study may be suggested to replicate in the remaining Himalayan states to predict the climate change impacts on the endangered and vulnerable species. Besides, the study could be replicated for the Himalayan range-restricted species, which are not studied in the present project. The replication of this study will provide the database on the habitat shifting of bird species under climate change and land-use scenarios for developing and implementing strategies for conservation and management of the Himalayan biodiversity.

6.3 Identify other important areas not covered under this study, but needs further attention

- The following areas need to be studied
    1. Species environment relationship in the Himalayan ecosystem in reference to climate change and land-use change.
    2. Species' evolutionary relationship with the climate and environments
    3. Adaptive nature of bird species towards climate change and other biotic factors.

6.4 Major recommendations for sustaining the outcomes of the fellowship in future

- The present study predicted the climate change impacts on habitat suitability and habitat shift in Himalayan range-restricted bird species in three Himalayan states using the species distribution modeling approach. The study revealed that the habitat of chosen species would shift toward higher elevations to adapt the future climate change and maintain the Himalayan biodiversity under the influence of climate change. Such studies are replicated for other species as well as states to understand climate change impacts on the species and how these species will adapt the climate change. Hence, it is recommended that such fellowship may be encouraged in the future to strengthen the skill and knowledge of the young researchers and academicians so that data could be generated for other species and states in the similar dimensions studied in the present project.

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8 Acknowledgements

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I would like to thank the Group Coordinator of Research, Forest Research Institute, for his support and coordination during the project.

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The family is the second home to God, and nothing could be ever achieved without their support, faith, and constant boosting in every stage of life. Thus, I am wholeheartedly thankful to my family members for their continued support as lifejacket and endurance.

(Hukum Singh)
Principal Investigator/
Project Coordinator

Appendices

Appendix 1	-	Details of Technical Activities	: Yes
Appendix 2	-	Copies of Publications duly Acknowledging the Grant/ Fund Support of NMHS	: Yes
Appendix 3	-	List of Trainings/ Workshops/ Seminars with details of trained resources and dissemination material and Proceedings	: NA
Appendix 4	-	List of New Products (utilizing the local produce like NTFPs, wild edibles, bamboo, etc.)	: NA
Appendix 5	-	Copies of the Manual of Standard Operating Procedures (SOPs) developed	: NA
Appendix 6	-	Details of Technology Developed/ Patents filed	: NA
Appendix 7	-	Any other (specify)	: NA

******

N Kumar

(Signature of HRA/HJRF/HPF)

15/07/2022

(NMHS FELLOWSHIP COORDINATOR)

(Signed and Stamped)

26/7/22

(HEAD OF THE INSTITUTION)

(Signed and Stamped)

Place: Dehradun

Date: 15/07/2022

Annexure-I

Consolidated
Utilization Certificate (UC) and Statement of Expenditure (SE)

For the Period: 1st April 2018 to 30th June 2021

1.	Title of the fellowship/Scheme:	Predicting climatically suitable future habitats for the range restricted Himalayan bird using species distribution modelling approach
2.	Name of the Principal Investigator & Organization:	Dr. Hukum Singh Forest Research Institute, Dehradun.
3.	NMHS-PMU, G.B. Pant National Institute of Himalayan Environment, Kosi-Katarmal, Almora, Uttarakhand Letter No. and Sanction Date of the Fellowship:	GBPNI/NMHS-2017-18/HSF-05/607 Dated: 30/03/2018
4.	Amount received from NMHS-PMU, G.B. Pant National Institute of Himalayan Environment, Kosi-Katarmal, Almora, Uttarakhand during the fellowship period (Please give number and dates of Sanction Letter showing the amount paid):	Rs. 2285375/- (total fund received) Rs. 42312/ (total bank interest) Total = Rs. 2327687.00
5.	Total amount that was available for expenditure (including commitments) incurred during the fellowship period:	Rs. 2327687.00/- (including bank interest)
6.	Actual expenditure (excluding commitments) incurred during the fellowship period:	Rs. 2065184.40/-
7.	Unspent Balance amount refunded, if any (Please give details of Cheque no. etc.):	Rs. 262502.60/- (including bank interest upto July 2022)
8.	Balance amount available at the end of the fellowships:	Rs. 250062.60/- (including bank interest upto March 2021)
9.	Balance Amount:	Rs. 262502.60/- (including bank interest upto July 2022)
10.	Accrued bank Interest:	Rs. 42312/- (upto July 2022) This accrued bank interest included in the balance amount available on 31st July 2022.

Certified that the expenditure of **Rs.__ 2065184.40/-__ (Rupees Twenty lakh sixty five thousand one hundred eighty four and forty paisa only)** mentioned against Sr. No. 6 was actually incurred on the fellowship/scheme for the purpose it was sanctioned.

Date:

(Signature of the Principal Investigator)	लेखा अधिकारी Accounts Officer (Signature of Account Officer)	Director Forest Research Institute (Signature of Head of the Institution)

OUR REF. No.

ACCEPTED AND COUNTERSIGNED

Date:

COMPETENT AUTHORITY
NATIONAL MISSION ON HIMALAYAN STUDIES (GBP NIHE)

Statement of Consolidated Expenditure

[Forest Research Institution, Dehradun]

Statement showing the expenditure of the period from: April 2018 – June 2021
Sanction No. and Date : GBPNI/NMHS-2017-18/HSF-05/607
Dated: 30/03/2018

1. Total outlay of the Fellowship : Rs. 2327687.00

2. Date of Start of the Fellowship : 10/12/2018

3. Duration : Three years and three months

4. Date of Completion : 30th June 2021

a) Amount received during the fellowship period : Rs. 2285375/-

b) Total amount available for Expenditure : Rs. 2327687/- (including interest)

S. No.	Budget head (Rs.)	Amount received (Rs.)	Expenditure	Amount Balance/ excess expenditure
1	Salaries - RA	1640039	1514455	125489.6
2				
3				
4				
5				
6				
7				
8	Bank charge		94.40	
9	Contingency (including domestic travel)	450000	355299	94701
10	Institutional charges	195336	195336	
11	Accrued bank Interest	42312		42312
12	**Total**	**2327687**	**2065184.4**	**262502.60**

Certified that the expenditure of **Rs.__ 2065184.40/-__ (Rupees Twenty lakh sixty five thousand one hundred eighty four and forty paisa only)** mentioned against Sr. No. 6 was actually incurred on the fellowship/scheme for the purpose it was sanctioned.

Date: 26/9/22

लेखा अधिकारी
Accounts Officer
वन अनुसंधान संस्थान, देहरादून
Forest Research Institute, Dehradun

Director
Forest Research Institute
Dehra Dun-248 006

(Signature of the Principal Investigator)	(Signature of Account Officer)	(Signature of Head of the Institution)

OUR REF. No.

ACCEPTED AND COUNTERSIGNED

Date:

COMPETENT AUTHORITY
NATIONAL MISSION ON HIMALAYAN STUDIES (GBP NIHE)

Annexure-II

Consolidated Interest Earned Certificate

This is to certify that an amount of Rs. 42312/-only (Forty two thousand three hundred and twelve) was incurred under this project upto July 2022.

(Principal Investigator)

National Mission on Himalayan Studies (NMHS)

DIRECT BENEFIT TRANSFER (DBT) DETAILS

Scheme Name:	**National Mission on Himalayan Studies (NMHS)**
Scheme Type:	**Central Sector (CS) Grant-in-Aid Scheme**
Scheme Code:	**NMHS**
Category:	**Fellowship Grant**
Month-Year:	**10/01/2028 to 30/06/2021**

PRO FORMA FOR DBT DETAILS

University/Institution Name: Forest Research Institute Dehradun

S#	Position H-RA	Nam e	DoB*	DoI *	PI	Research title	Objectives	Study Area, IHR State	Contact details (Complete corresponding address), Mobile No., E-mail ID	Bank details (Account number, IFSC Code)	Emoluments /Fellowship	

1.	H-RA	Dr. Narendra Kumar	15-05-1988	10/12/2018	Dr. Hukum Singh	Predicting climatically suitable future habitats for the range restricted Himalayan bird using species distribution modelling approach	Predicting climatically suitable future habitats for the range-restricted Himalayan bird using species distribution modelling approach	Uttarakhand, Himachal Pradesh, Jammu and Kashmir	House No 66. Madhu vihar, dehradun Mob: 7579095458 Email: narendra.physiol@gmail.com	Bank: UBI Account No: 496902010089365 IFSC: UBIN0549690	47000+16% HRA	

Note: For each month, the DBT Details Pro forma dully filled and signed for each Himalayan Fellowship Grant under NMHS must be submitted at finance.nmhspmu2017@gmail.com; nmhspmu2016@gmail.com. *DoB (Date of Birth); DoJ (Date of Joining).

(Principal Investigator)

Latest Updated List of Himalayan Researchers or Fellows *(working in the current time)*

S#	Name	Fellowship (RA/JRF/JPF)
1.	**Nil**	**Nil**
2.		

Annexure-IV

Details and Declaration of Refund of Any Uunspent Balance

This is to certify that unspent balance of Rs. 262502.60/- (including bank interest upto July 2022) in this project is being refunded to the funding agency on the given bank A/c details.

Kindly note the further Bank A/c Details as follows:

Name of NMHS A/c:	NMHS GIA General
Bank Name & Branch:	Central Bank of India (CBI), Kosi Bazar, Almora, Uttarakhand 263643
IFSC Code:	CBIN0281528
Account No.:	3530505520 (Saving A/c)

In case of any queries/ clarifications, please contact the NMHS-PMU at e-mail: nmhspmu2016@gmail.com

(Principal Investigator)

Annexure-V

Technology Transfer and/ or Intellectual Property Rights Certificate

With a view to encourage the institutions to file patent applications on their innovations, motivate them to transfer their technologies for commercialization, and facilitate them to reward their inventions, the following instructions are issued.

1. In these instructions:

(a) **"Institution"** means any technical, scientific or academic establishment where research work is carried out through funding by the Central / State Government.

(b) **"Intellectual Property Rights"** include patents, registered designs, copyrights and layout design of integrated circuits.

(c) **"Inventor"** means an employee of the institution whose duties involve carrying out of scientific or technical research.

2. **Scope:** These instructions apply to those institutions receiving funds for research projects/ fellowships from NMHS, the Ministry of Environment, Forest and Climate Change (MoEF&CC).

3. **Inventions by institutions:** Institutions shall be encouraged to seek protection of Intellectual Property Rights (IPR) to the results of research through R&D projects/ fellowships. While the patent may be taken in the name(s) of inventor(s), the institutions shall ensure that the patent is assigned to it & DBT, GOI. The institution shall take necessary steps for commercial exploitation of the patent on non-exclusive basis. The institution is permitted to retain the benefits and earnings arising out of the IPR. However, the institution may determine the share of the inventor(s) and other persons from such actual earnings. Such share(s) shall be limited to 1/3rd of the actual earnings.

4. **Inventions by institutions and industrial concerns:** IPR generated through joint research by institution(s) and industrial concern(s) through joint efforts can be owned jointly by them as may be mutually agreed to by them and accepted by the Department through a written agreement. The institution and industrial concern may transfer the technology to a third party for commercialization on exclusive/non-exclusive basis. The third party, exclusively licensed to

market the innovation in India, must manufacture the product in India. The joint owners may share the benefits and earnings arising out of commercial exploitation of the IPR. The institution may determine the share of the inventor(s) and other persons from such actual earnings. Such share(s) shall not exceed 1/3rd of the actual earnings.

5. **Patent Facilitating Fund:** The institution shall set apart not less than 25 per cent of such earnings for crediting into a fund called Patent Facilitating Fund. This Fund shall be utilized by the institution for updating the innovation, for filing new patent applications, protecting their rights against infringements, for creating awareness and building competency on IPR and related issues.

6. **Information:** The institutions shall submit information relating to the details of the patents obtained the benefits and earnings arising out of IPR and the turnover of the products periodically to the Department/Ministry, which has provided funds.

7. **Royalty-free license:** The Government shall have a royalty-free license for the use of the intellectual property for the purposes of the Government of India.

26/7/22

(HEAD OF THE INSTITUTION)

(Signed and Stamped)

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Modelling habitat suitability of western tragopan (*Tragopan melanocephalus*) a range-restricted vulnerable bird species of the Himalayan region, in response to climate change

Hukum Singh[a,*], Narendra Kumar[a], Manoj Kumar[b], Ranjeet Singh[a]

[a] *Forest Ecology and Climate Change Division, Forest Research Institute, PO New Forest, Dehradun 248006, Uttarakhand, India*
[b] *Geographical Information System (GIS) Centre, Forest Research Institute, PO New Forest, Dehradun 248006, Uttarakhand, India*

A R T I C L E I N F O

Keywords:
MaxEnt
Himalayas
Climate change
Vulnerability
Species distribution modelling

A B S T R A C T

Climate change is expected to alter the structure and functions of an ecosystem including species composition and its geographical distribution. There is limited understanding on how the habitat of the Himalayan range-restricted species would be affected under the influence of climate change. In the present study, we model the climate change impacts on habitat suitability of western tragopan (*Tragopan melanocephalus*), a range-restricted and vulnerable bird species in the Indian western Himalayas. The climate change scenarios of IPCC represented by representative concentration pathways (RCPs) viz. RCP 4.5, RCP 6.0, and RCP 8.5 were considered for assessing the habitat suitability for the year 2050 and 2070. Most influencial variables that may be linked to habitat suitability of Tragopan, such as bioclimatic variables, land use (forest cover and forest type), soil characteristics, and topographic variables (elevation, slope, aspect, heat load index) were considered to develop a model using the Maximum Entropy (MaxEnt) algorithm. MaxEnt is a widely used and accepted tool for modeling species distribution. The model's performance for mapping habitat was evaluated by the Area Under Curve (AUC) (AUC > 90%). The measured TSS value 0.98 and Kappa value 0.71 were elaborated for the aptness of the model for suitable habitat mapping. It was observed that the suitable habitat of the western tragopan would shift towards higher elevations under all RCPs. The study would benefit to biodiversity conservators and policymaker for formulating future strategy and planning for conservation and management of the Himalayan range-restricted bird species. The approach of this study could be replicated with other range-restricted Himalayan bird species for future projections of suitable habitat.

1. Introduction

Climate change would alter the structure and functions of the natural ecosystem that serves as a habitat for the faunal species. Climate change is not only affecting ecological distribution and composition but is also anticipated to affect species-species and species-environment interactions (Ockendon et al., 2014). The changes in the global warming trend are experienced since the beginning of the 20th century affecting the functioning and distribution of ecological communities and it is supposed to continue in the future (IPCC, 2014).

Climate influences the species distribution and often acts as a limiting factor in the extent and location of species margins (Hill and Preston, 2015). Due to unexpected changes in the climatic conditions, the biodiversity hotspots are at high risk of species

* Corresponding author.
E-mail address: hukumsingh97@yahoo.com (H. Singh).

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extinction. Historical data has shown how the distribution of species varies over time (Hill et al., 2002). The consequences for range-restricted species would be more severe as they have limited habitats available for their sustenance. Within the last two decades, range shifts have increasingly been debated as proof of measurable climate change impact on bird species and communities. Researchers reported the geographical distribution of bird species is shifting from their native habitat (Avalos and Hernandez, 2015; Sekercioglu et al., 2007).

In northern temperate regions, the species shift has been reported towards the northeast or northwest (Lehikoinen and Virkkala, 2016), whereas evidence for corresponding southern shifts is very scarce (Gillings et al., 2015; Tayleur et al., 2016). It was due to an increase in temperature and shifting of species towards cooler regions (Parmesan, 2006). The Himalayan ecosystems are one of the most fragile and most vulnerable ecosystems to climate change (IPCC,2014). The bird species in the Himalayan biodiversity hotspot faces several threats due to degradation and fragmentation of forested landscapes (Tylianakis et al., 2008; Hu et al., 2015).

The most adjacent effect of climate change is on the distribution of species (Schweiger et al., 2008; Ockendon et al., 2014). A rise in global temperature may result in the shifting of bird species to the higher elevation (Chhetri et al., 2018). Any alterations in climatic variables might have a negative influence on some species that have limited suitable habitats such as the range-restricted species. The survival of the species under the influence of climate change would depend upon the adaptive capacity of the species. If the climate change is beyond the adaptive capacity, species may shift to suitable habitat to match their climatic niche else they may face extinction. Hence, this would be interesting to investigate the influence of climate change on the habitat suitability of important flora and fauna. Evidence of range shifts in trees (Kelly and Goulden, 2008), birds (Freeman and Freeman, 2014), moths and butterflies (Chen et al., 2009) due to climate change have already been noticed. These changes threaten the persistence of several species, alterations in community structure and function, that ultimately may affect the biological diversity (Santhakumar et al., 2018; Rai et al., 2020).

It is reported that birds with restricted ranges with lower mobility such as ground birds would be at considerable high risk from climatic changes and disturbances in mountain regions (Sekercioğlu et al., 2012). The climate envelope model helps to predict present as well as future suitable habitat of species under the influence of various drivers including climate change (Mokany et al., 2014, 2015). The Maximum Entropy (MaxEnt) model predicts the potential habitat considering entropy of different variables associated with present location data. This model is categorised under the species distribution models (SDMs) (Bertrand et al., 2012; Hu et al., 2015). The future climate projected by IPCC (2014) uses representative concentration pathways (RCPs) presented by RCP2.6, RCP4.5, RCP6.0, and RCP8.5. RCPs relates to radiative forcing values in the year 2100 relative to pre-industrial values by 2.6, 4.5, 6.0, and 8.5 W m^{-2} representing RCP2.6, RCP4.5, RCP6.0 and RCP8.5, respectively (IPCC, 2014). The impact of climate change on the Himalayan biodiversity particularly the shifting and distribution of suitable habitats of bird species endemic to the Indian Himalayan ecosystem is largely unknown. In this study, Western tragopan (*Tragopan melanocephalus*) (hereafter simply referred as 'Tragopan'), a vulnerable range restricted bird species of the northwest Himalayan region, threatened by the changing climate and land-use was selected to assess the extent of current habitat and to map suitable habitat under climate change scenarios. We predict the suitable habitat of western tragopan under three scenarios of climate change presented by RCP2.6, RCP4.5 and RCP8.5 for the year 2050 and 2070.

2. Methods

2.1. Study area

The study was carried out in the Indian Western Himalaya (IWH) which comprises of two states (viz. Himachal Pradesh & Uttarakhand) and two Union Territories (viz. Jammu and Kashmir & Ladakh), covering about 500 thousand km^2 area (Fig. 2A). The region is characterized by four distinct physiographic zones i.e. Shivalik zone, middle Himalaya, upper Himalaya, and Trans- Himalaya zone. Each zone has distinct flora and fauna. The Himalaya comprises about 80% of the total birds of the Indian subcontinent (Price et al., 2003). Moreover, it is home to most of the threatened bird species of Asia (Acharya and Vijayan, 2010). Presently, about 11 bird species are endemic to the West Himalaya and their habitat is further threatened due to increasing human pressure and changing climate. The climate in the region varies from scorching heat to arctic cold which depends upon elevation, aspect, size of the valley and various other factors. In Western Himalaya, huge latitudinal and altitudinal differences occur which regulate surrounding climate. The landscape has undulating planes with higher degree of altitudinal variations. Moreover, different degrees of slope and aspect also regulate the climate to form several microclimatic regions. The lower altitudinal region of the Himalaya has three major seasons such as winter (November to February), summer (March to June) and monsoon (July to October) besides having six minor season viz. spring, summer, rainy, autumn, pre-winter and winter (Shekhar et al., 2010).

Currently, temperature variation for the western Himalaya is much higher (the difference between the minimum and maximum temperature) (≈23 °C) than the eastern Himalaya (11 °C). In addition, predictions for the Himalayan landscape indicate a much warmer west (0.06 per year) than east (0.03 per year) in the future (Shrestha et al., 1999; Tsering, 2003; Sharma and Tsering, 2009; Ren et al., 2017). Such changes could potentially lead to changes in plant composition thereby altering the quantity and quality of food resources for birds. Precipitation is also expected to increase for the overall Himalaya and northern India. Warming in the Himalaya could have serious consequences for the terrestrial range-restricted species endemic to the Western Himalaya (Ramesh et al., 1999).

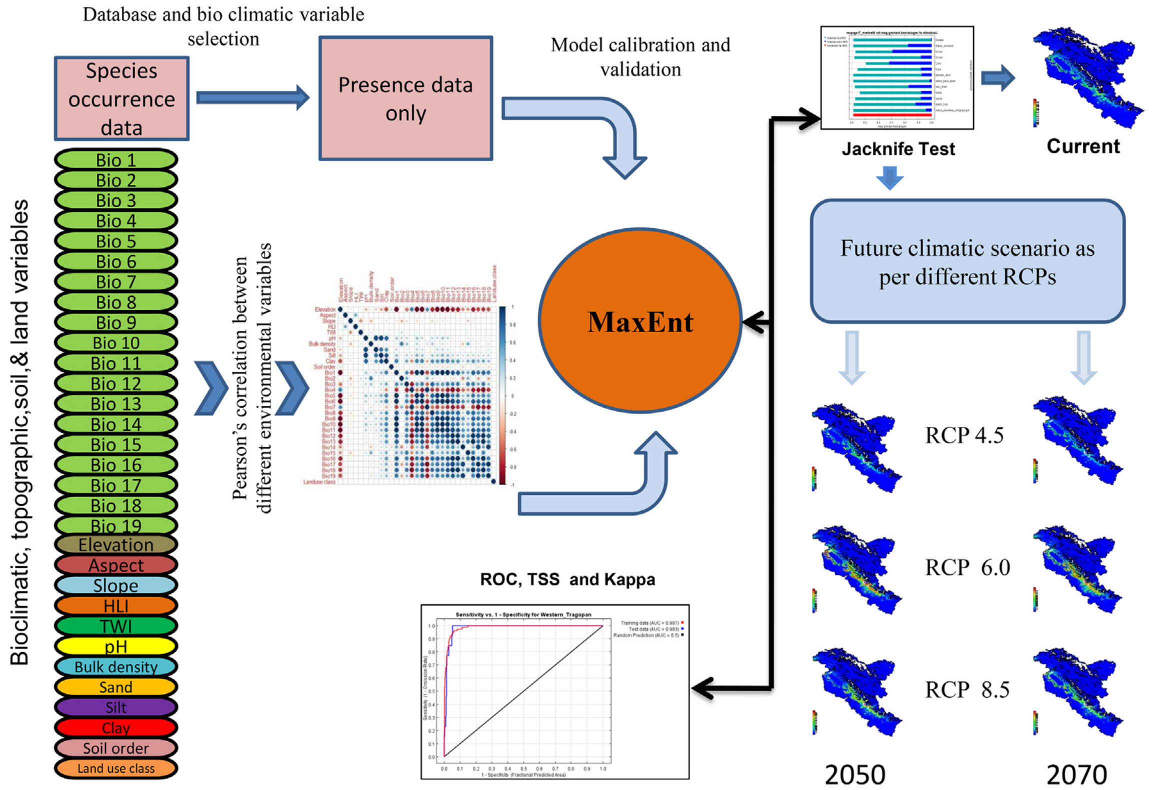

Fig. 1. Flow chart of database and methodology for the preparation of the model.

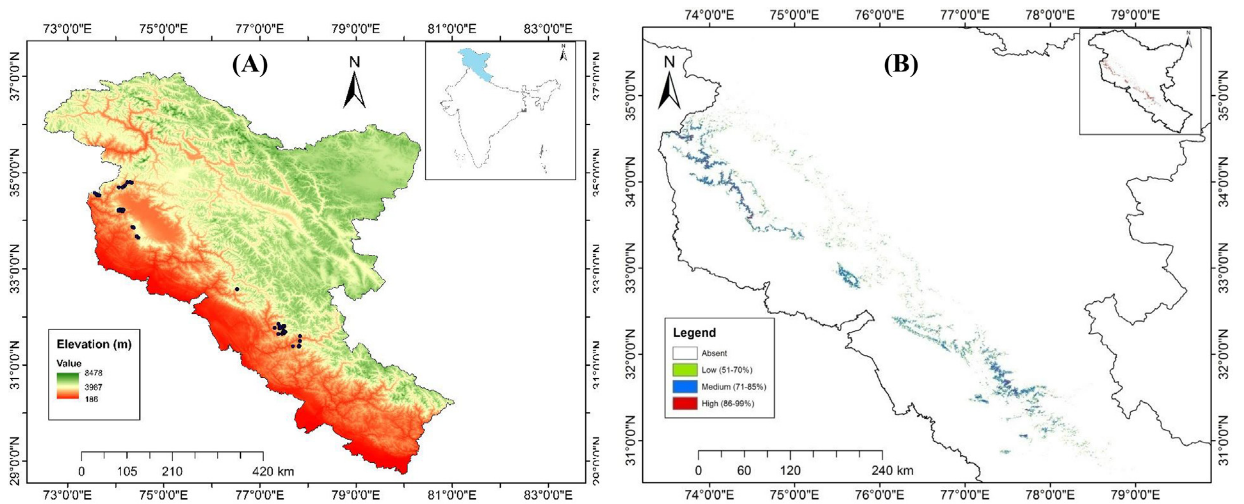

Fig. 2. A) Location map of the study area. The black point shows the species occurrence location. B) Potential habitat suitability distribution of Western Tragopan in current climatic conditions.

2.2. Model species

Western Tragopan (*Tragopan melanocephalus*) is an IUCN Red List vulnerable species (VU) (IUCN, 2016), an endemic montane pheasant and has a narrow distributional range in the north-western Himalayan region. Tragopan is also the state bird of Himachal Pradesh in India. The Tragopan is of shy nature and usually found as one individual at a time on the trees. It feeds on the ground during the early morning and late afternoon. The density of this species is very low and also habitat-specific. Usually, it occurs in the moist deciduous (viz. birch, oak, walnut, and maple) as well as in the coniferous vegetation (viz. spruce, pine and silver fir) in the temperate region. In winters it is found in high altitude of the forest (2150-2500 masl) while in summer it is found towards snowline

Table 1
List of environmental and bioclimatic variables used to predict the current and future habitat suitability for Western Tragopan (*Tragopan melanocephalus*).

Code	Environmental/ bioclimatic variables	Unit
Bio1	Annual Mean Temperature	°C
Bio2	Mean Diurnal Range (Mean of monthly (max temp–min temp))	°C
Bio3	Isothermality (Bio2/Bio7) (×100)	–
Bio4	Temperature Seasonality (standard deviation × 100)	C of V
Bio5	Max Temperature of Warmest Month	°C
Bio6	Min Temperature of Coldest Month	°C
Bio7	Temperature Annual Range (Bio5–Bio6)	°C
Bio8	Mean Temperature of Wettest Quarter	°C
Bio9	Mean Temperature of Driest Quarter	°C
Bio10	Mean Temperature of Warmest Quarter	°C
Bio11	Mean Temperature of Coldest Quarter	°C
Bio12	Annual Precipitation	mm
Bio13	Precipitation of Wettest Month	mm
Bio14	Precipitation of Driest Month	mm
Bio15	Precipitation Seasonality (Coefficient of Variation)	
Bio16	Precipitation of Wettest Quarter	mm
Bio17	Precipitation of Driest Quarter	mm
Bio18	Precipitation of Warmest Quarter	mm
Bio19	Precipitation of Coldest Quarter	
LULC	Land use and land cover	
ELE	Elevation	m
SLO	Slope	°
ASP	Aspect	°

(3350–4500 masl) (Miller, 2010). The distribution range of tragopan is from north-western Pakistan through Indian states of Jammu & Kashmir, Himachal Pradesh and it is also found in the western parts of Uttarakhand (Awan, 2010). This species became vulnerable because of human induced interferances while the role of climate change might also be a factor. It can be considered as a bio-indicator for the forest quality, and anthropogenic disturbances (Fuller and Garson, 2000; Miller, 2010). The species faces a huge problem due to forest loss, forest fragmentation, habitat degradation, and hunting.

2.3. Collection of species presence data

Extensive field reconnaissance surveys were done in the states of Jammu & Kashmir and Himachal Pradesh during the months of April to June 2019 for the collection of presence locations. A hand held GPS (Garmin Etrex 20X) with an accuracy of ± 5 m was used to mark the presence location during the field survey. The observations during field surveys were made between 05:30 am to 17:00 pm. A total number 100 presence locations were marked during the field surveys while we also retrieved 67 locations from the Ebird website (https://ebird.org/) and officers/staffs of forest department. Therefore, a total number of 167 locations were available for using in the model.

2.4. Environmental variables

In the present study, we used 19 bioclimatic variables (www.worldclim.org), five topographic variables derived from digital elevation model (SRTM) (elevation, aspect, and slope, heat load index and topographic wetness index), soil parameters (soil texture represented by percentage of sand, silt and clay, bulk density, soil taxonomy order) (Ramesh et al., 1999) and land use land cover data (Tables 1 & 4). Among these variables, only 12 variables were selected on the basis of the correlation analysis (Fig. 3). Variables that had correlation coefficient greater than 70%, only one variable was used in the model through logical inference for selecting the appropriate variables. As all of the variables were not available at same spatial resolution (Tables 1 & 4), the variables were re-sampled at a resolution of 250 m using ArcGIS 10.5. All variables were converted into ASCII format using ArcGIS software to use in the model.

2.5. Representative concentration pathways (RCPs) scenarios for future climatic change

Representative Concentration Pathways (RCPs) elaborate on four different pathways related to the emission of greenhouse gases that may increase the atmospheric concentrations of greenhouse gases. The pathways are described by the radiative forcing that will be generated by the end of the 21st century. Radiative forcing is the extra heat that is retained by the lower atmosphere as a consequence of greenhouse gases. The RCPs characterize the various range of greenhouse gas emission those include a stringent mitigation scenario with low emission (RCP2.6), two intermediate scenarios of moderate emission (RCP4.5 and RCP6.0), and a high emsission scenario of RCP8.5 (Table 2). Climate data version 5 (MIROC5) of global climate models (GCMs) was used for three representative concentration pathways (RCPs) for the year 2050 and 2070. Researchers reported that MIROC5 best represents the

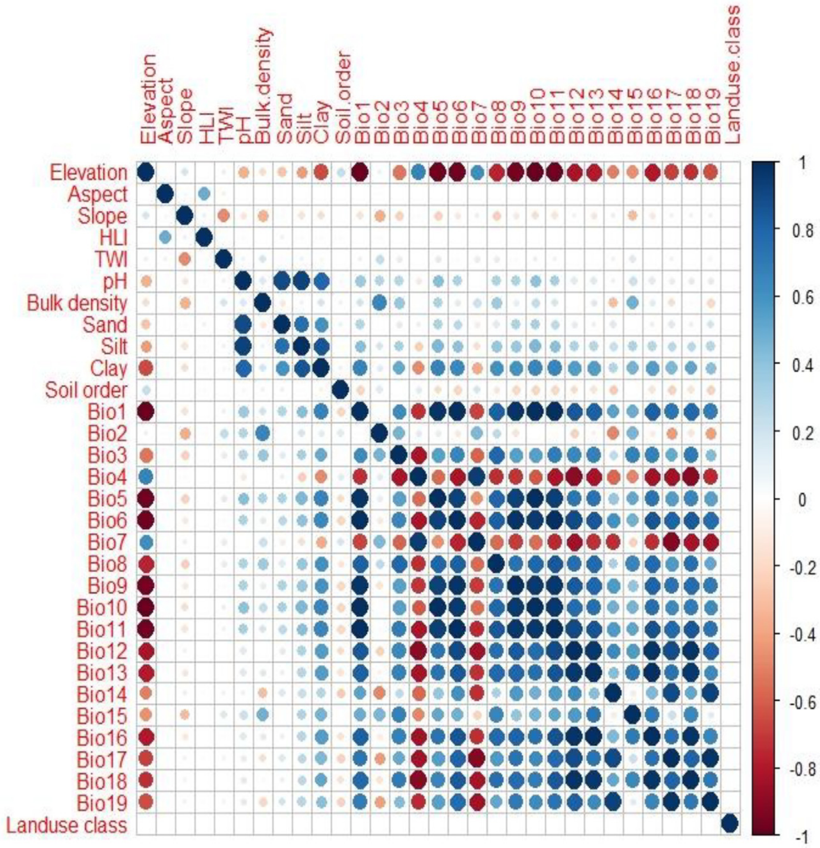

Fig. 3. Pearson's correlation between different environmental variables.

climatic variability of the South Asian region and the Himalayas (Mishra et al., 2014; Sharmila et al., 2015).

2.6. Species distribution modelling of western tragopan

The MaxEnt (version 3.3.3) model was used to predict suitable habitat of tragopan for present and future climate change scenarios of 2050 and 2070. The MaxEnt performs better even for small size samples unlike the other models which may demand large samples (Phillips et al., 2006; Rlith et al., 2011). From a total number of 167 presence locations, 70% of occurrence data was used to train the model and 30% was used for model validation. Further, the Jackknife method was used to measure importance of variables in mapping habitat suitability. The model was iterated 500 times with 20 replications using the bootstrap method and was used to map suitable habitat under present and future scenarios. The results of the model were validated using area under curve (AUC), TSS and Kappa coefficient that shows the ability of the developed model to discriminate presence and absence data and performance of the model. The methodology flow chart of the study is presented in Fig. 1.

3. Results

3.1. Model validation and influencing bioclimatic variables

The model performance was evaluated using area under curve (AUC) (Fig. 4 a). The AUC value was obtained as 0.983 for the test data which suggests good performance of the model. This indicates that the MaxEnt derived distributions were a close approximation of real-world distribution probabilities. The estimated values of TSS and Kappa was 0.98 and 0.71, respectively which further suggest the robustness of the model to predict suitable habitat.

3.2. Contributions of environmental variables

The jack-knife test results showed the importance of different bioclimatic, topographic, soil, and land use class variable while mapping habitat suitability (Fig. 4. B). The test results indicated the relative contribution of climatic variables for current distribution and is presented as a mean value of 20 replicate model runs. The results revealed that precipitation of driest month (Bio14), mean

Table 2
Different representative concentration pathways (RCPs).

S.N.	Radiative forcing	Atmospheric CO_2 equivalent (ppm)	Description	Reference
1.	RCP 8.5	(~1370 ppm)	Rising radiative forcing pathway leading to 8.5 Wm^{-2}	Riahi et al., 2007
2.	RCP 6	(~850 ppm)	Stabilization without overshoot pathway to 6 Wm^{-2}	Hijioka et al., 2008; Fujino et al., 2006
3.	RCP 4.5	(~650 ppm)	Stabilization without overshoot pathway to 4.5 $W\ m^{-2}$	Smith and Wigley, 2006; Wise et al., 2009
4.	RCP 2.5	(~490 ppm)	Peak in radiative forcing at ~ 3 $W\ m^{-2}$	van Vuuren et al., 2006; Van Vuuren et al., 2007a

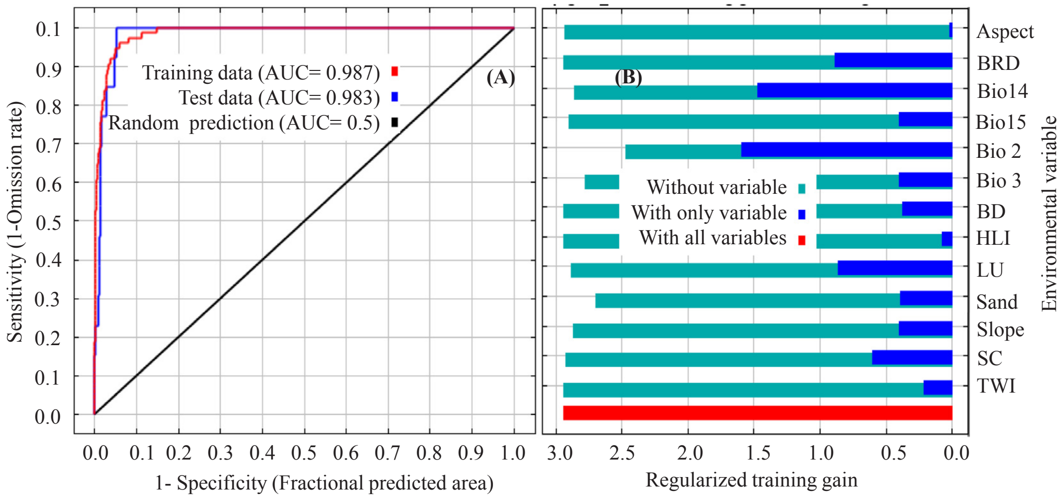

Fig. 4. A) ROC curve and AUC value for MaxEnt model. B) The Jackknife test indicates the contribution of the different variables in the current distribution of the species.

diurnal range of temperature (Bio2), land use classes and sand proportion in the soil contribute by more than 70% in the model to predict the habitat (Fig. 5 a). The response curves showing the effect of individual variables for model prediction are presented in Figs. 6–8. The results revealed that the response of different variables in the model was positively nonlinear. These curves elaborated response of different variables for the mapping of habitat suitability.

3.3. Suitable habitat for the western tragopan under current climate

The suitable habitat for the Tragopan based on current environmental factors is shown in Fig. 2B. The probability distribution output was divided into three categories i.e. highly suitable (> 85%), moderately suitable (71–85%), low suitable (51–70%). Under current climatic conditions, the model identified an area of 297.06 km^2 as highly suitable and 1883.38 km^2 as moderately suitable while 358423.75 km^2 of the area observed as low suitable for the current habitat of the species.

3.4. Suitable habitat for western tragopan under future climate

The outcome of future habitat suitability for the species under different RCPs predicted by the MaxEnt model showed that the changing climatic condition alters the distribution of future suitable habitat of Tragopan (Fig. 9). The species distribution model was developed for three RCPs i.e. 4.5, 6.0 and 8.5 for the year 2050 and 2070 and it showed that areas that are less suitable for the range-

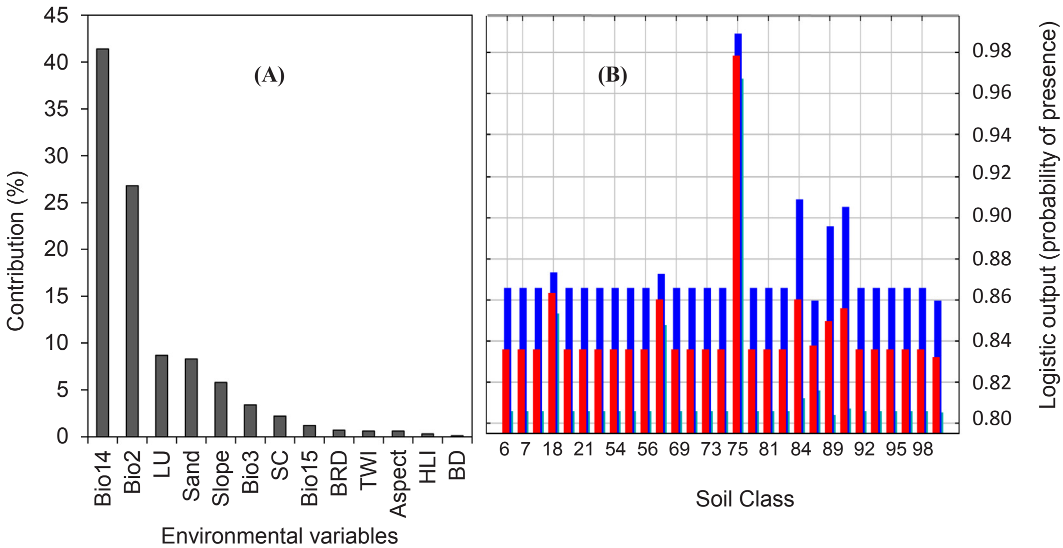

Fig. 5. A) Contributions of environmental variables to MaxEnt model performance.

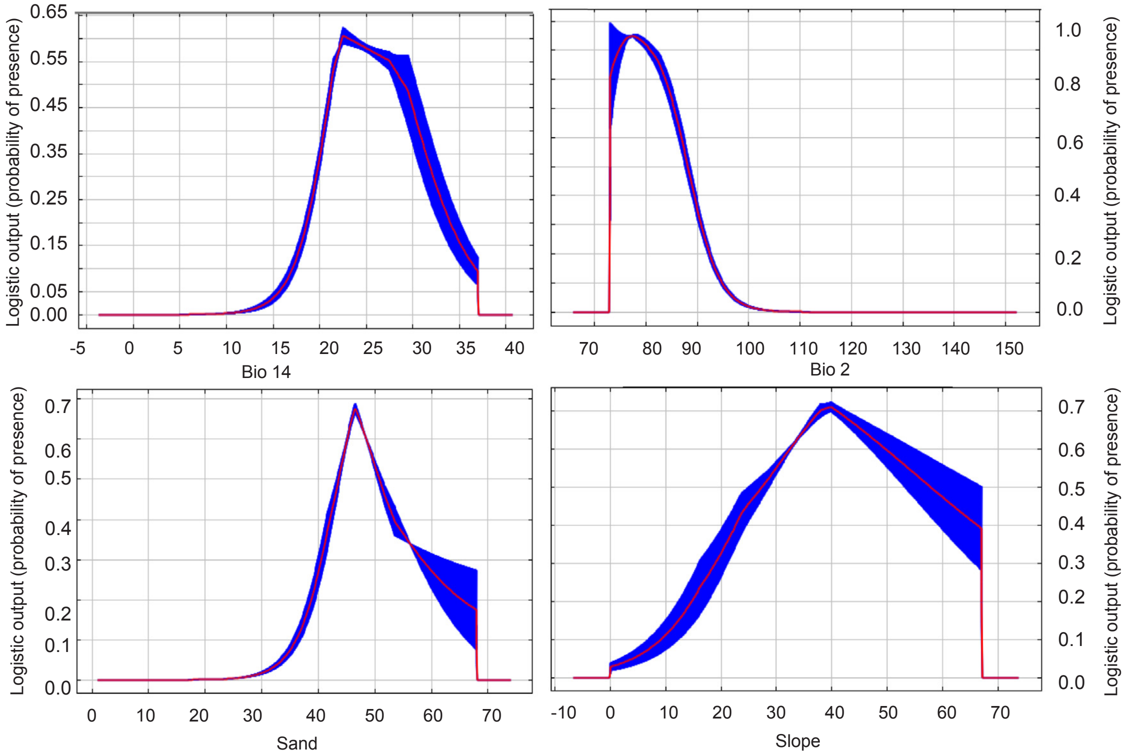

Fig. 6. Response of various bioclimatic and other variables viz Precipitation of Driest Month (Bio14, CV), Mean Diurnal Range of temperature (Bio2), Sand, and Slope on the probability of species presence. In the figure y axis indicates the probability of presence (logistic output). The variation in variables may positively influence the species distribution. Red curves show the average response and blue margins are ± SD calculated by 20 replicate runs.

restricted birds would increase with respect to the current potential distribution. For the period of 2050, under RCP 4.5 the increase in area for high suitability was found by 2779.75 km^2 and a decrease in suitabile area was recoded by 1301.06 km^2 while there would be no change in suitability classes for an area of of 3535.81 km^2. Similarly, under RCP 6.0 an area for the suitable habitat would decrease by 24509.25 km^2 compared to the suitable area observed under current climate while no change would be observed for a total area of 4825.81 km^2. In the prevailing scenario of RCP 8.5, the decrease in area of suitability would be by 1434.19 km^2 compared to current climate. Similarly the observations were compared for the year 2070 and it was observed that under RCP 4.5 suitable area would decrease by 1365.31 km^2 compared to current climate. A detailed representation of changing suitability under different scenarios for the year 2050 and 2070 is shown in Table 3. It was observed that the suitable habitat of western tragopan would shift towards eastern regions with decrease in the suitable habitat with respect to present scenario by 5 to 35% under different RCPs for the years 2050 and 2070 (Fig. 9).

4. Discussion

Future changes in the climatic condition are expected to alter the natural distribution of species due to change in the structure and functions of the forest community (Kumar et al., 2018; 2019a,b). For assessing the impacts of climate change on a specific ecosystem, the use of species distribution modelling has widely been done by researchers to assess the influence of climate change on habitat suitability (Kelly and Goulden, 2008; Freeman and Freeman, 2014; Chen et al., 2009). It is assumed that under the influence of climate change, species may develop adaptations to novel environmental conditions, shift their distribution to track suitable environmental conditions or can face extinction (Phillips et al., 2006; Qin et al., 2017). In addition, habitat losses posed by the land-use intensification and the degradation of forests can change the habitat suitability (Newbold et al., 2015; Linshan et al., 2017).

The distribution of suitable future habitat of western tragopan was found to be under threat in future scenarios. The results showed the loss of suitable habitat by 5–35% under different RCPs which emphasise the requirements of conservation measures. Further, identified sites that are suitable for the western tragopan should be conserved to protect the bird. Loss of suitable habitat poses a major threat to Tragopan. The species is listed as Vulnerable (VU) in IUCN Red Data List and Schedule I of the Indian Wildlife (Protection) Act, 1972. It is a major concern for the forest department and policymakers, therefore, we need to focus on the conservation of the species by identifying suitable habitat. The population of the selected species is highly fragmented and declining as the year's pass which depicts the risk of extinction of the species in the wild (Malviya et al., 2011; Chhetri et al., 2018). Most of the western tragopan occurrence has been found in the forests of spruce (*Picea smithiana*), deodar (*Cedrus deodara*) and brown oak

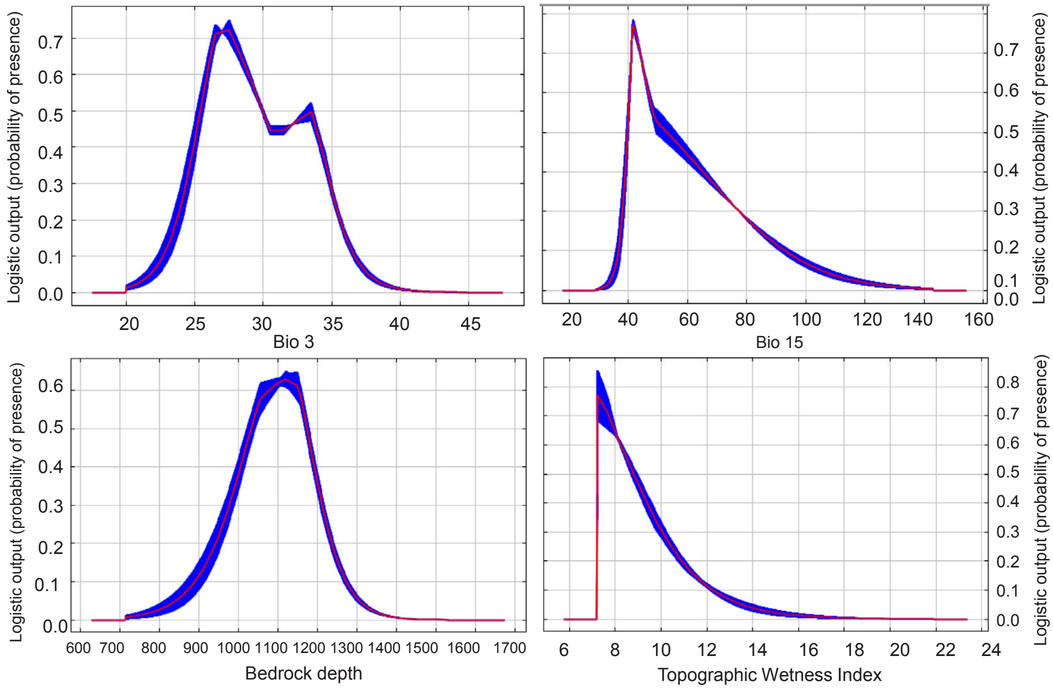

Fig. 7. Response of various bioclimatic and other variables viz Isothermality (Bio3), Precipitation Seasonality (Bio15, mm), Bed rock depth, Topographic Wetness Index on the probability of species presence. In the figure y axis indicates the probability of presence (logistic output). The variation in variables may positively influence the species distribution. Red curves show the average response and blue margins are ± SD calculated by 20 replicate runs.

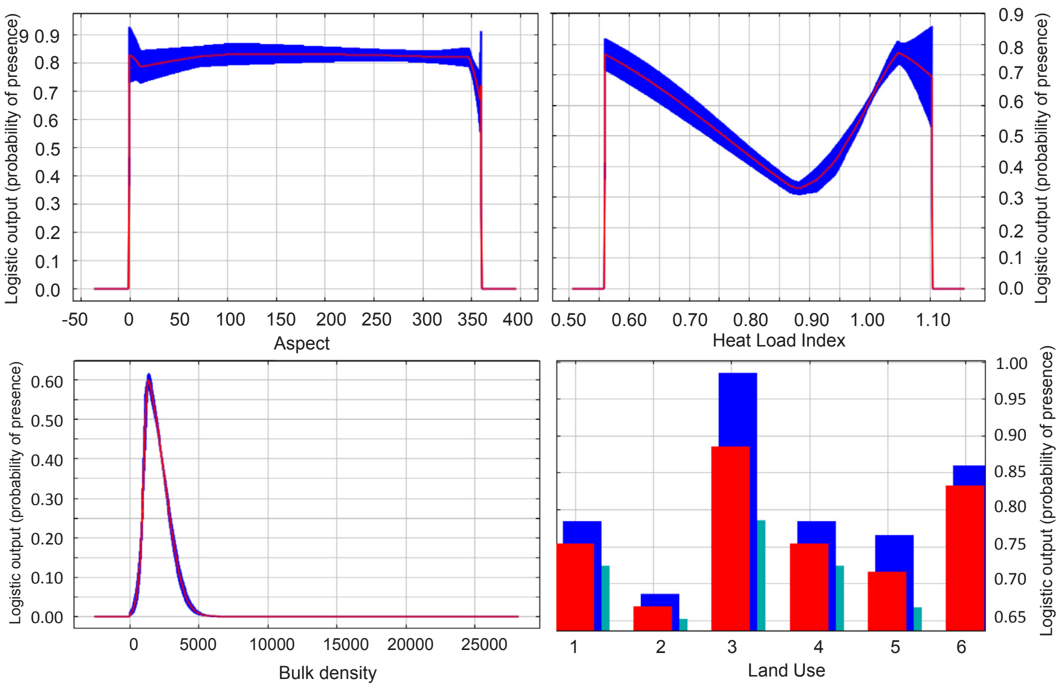

Fig. 8. Response of various bioclimatic and other variables viz Aspect, Heat Load Index, Bulk density, Land Use and Soil class on the probability of species presence. In the figure y axis indicates the probability of presence (logistic output). The variation in variables may positively influence the species distribution. Red curves show the average response and blue margins are ± SD calculated by 20 replicate runs.

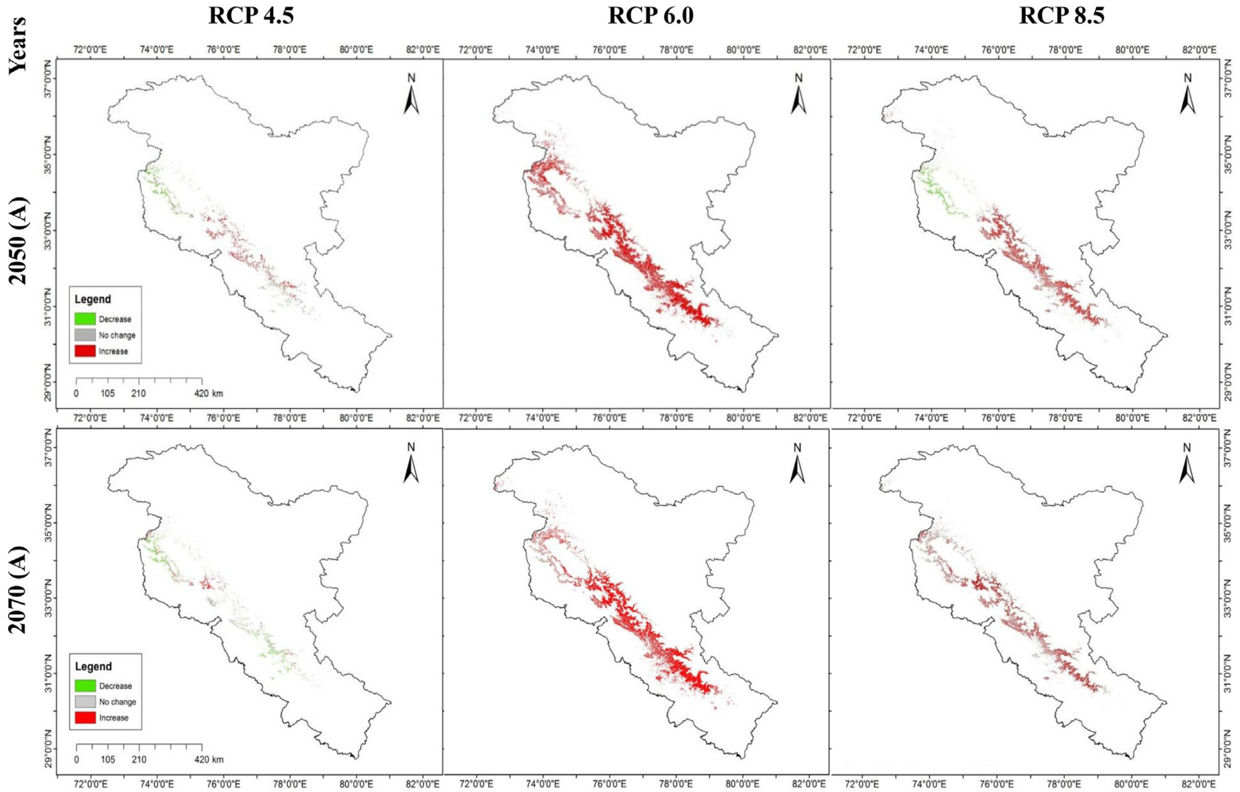

Fig. 9. Prediction of suitable future habitat of Western Tragopan (*Tragopan melanocephalus*) in various RCPs.

Table 3
Changes in habitat suitability of western tragopan under different RCPs.

Climate model	Suitable class	Species distribution area (km^2)		
		RCP 4.5	RCP 6.0	RCP 8.5
2050	No change	3535.81	4825.81	3402.69
	Decreased	1301.06	11.06	1434.19
	Increased	2779.75	24509.25	11686.50
2070	No change	2903.50	4729.81	4764.56
	Decreased	1933.38	107.06	72.31
	Increased	1365.31	23714.94	10469.06

Table 4
Sources for obtaining the SRTM dataset, soil data set and land use and cover data, bioclimatic parameters, and Species location data.

S.N.	Data	Resolution	Source
1.	Elevation (SRTM)	30 m	https://earthexplorer.usgs.gov/ (United States Geological Survey)
2.	Soil parameters	250 m	https://soilgrids.org/ (International Soil Reference and Information Centre)
3.	Land Use and Land Cover Map	23.4 m	FSI India
4.	BioClimatic parameters	1000 m	http://www.worldclim.org/ (University of California, Berkeley)
5.	Species location data	Point data	http://www.gbif.org (Global biodiversity information facility), eBird, BirdLife International, Field visit

(*Quercus semecarpefolia*) at the elevation of 2600–3000 masl during summer and in winter it occurs in dense coniferous and broad leave forests at the elevation in between 2000 and 2800 masl. The results revealed that the changing climatic condition will alter the suitable habitat of the bird. The present findings indicate that the habitat that are suitable for the western tragopan is mostly under the influence of precipitation of driest month (41.4% contribution), mean diurnal range of temperature (26.8%), land use classes (8.7%), sand percentage in soil (8.3%), slope of terrain (5.8%) while rest of the variables have less influence.

It was reported that the population of western tragopan is limited by several climatic factors throughout its range. The world population of this species has been confined mostly in the range of 1600 to 4800 masl. The distribution of birds depends on the altitude and climate of the region. It was recorded that the distribution of the species in the lower altitude is around 1350 m elevation range besides that in some areas during winter it was recorded at nearly 1750 m elevation. However, under suitable weather the distribution is found upto 3000 masl. In summer the presence are also recorded in the range of 2500–3600 masl (Remya et al., 2015; Singh and Tu, 2008; Sarania et al., 2016).

5. Conclusion

MaxEnt modelling approach can be adopted for mapping the suitable habitats of different species that are under the influence of topographic and climatic factors. The present study reveals the locality and extent of the distribution of western tragopan. The areas identified as suitable habitat can be protected to ensure the conservation of western tragopan for the current as well as future scenarios. It is observed that the habitat of western tragopan will shift towards the higher altitude in eastward direction under prevailing scenarios of climate change for the assessment year 2050 and 2070. It is also observed that a total decrease in area of suitable habitat would further restrict the range of western tragopan under prevailing scenarios of climate change for the assessment years. Though there can be certain limitations in mapping habitat suitability and distributions of species under climate change scenarios, therefore the finding of this study should be interpreted very carefully. We highlight that the Indian Himalayan Region preserves the habitat of western tragopan and thus it must have a focused conservation approach for the protection of viable number of Tragopan. The Himalayan region are habitat to many other important species and thus there is a need to identify the suitable habitat of selected priority species for conservation and protection, especially those which are on the verge of extinction.

CRediT authorship contribution statement

Hukum Singh: Conceptualization, Writing - review & editing, Supervision, Investigation. **Narendra Kumar:** Methodology, Data curation, Writing - original draft. **Manoj Kumar:** Writing - review & editing, Software. **Ranjeet Singh:** Methodology, Data curation, Writing - original draft.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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