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- Impact of Climate Change on Himalayan Ecology

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G.B. Pant National Institute of Himalayan Environment
(An Autonomous Institute of Ministry of Environment, Forest and Climate Change, Government of India)
Kosi-Katarmal, Almora-263 643, Uttarakhand, India

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About the Bulletin

Environmental Information System (ENVIS) Bulletin on Himalayan Ecology is an annual non-priced publication of the ENVIS Centre, which was established at the headquarters of the G.B. Pant National Institute of Himalayan Environment (GBPNIHE) in the financial year 1992-93 with the fiscal support from the Ministry of Environment, Forest & Climate Change (MoEF&CC), Government of India, New Delhi.

The present volume of the ENVIS Bulletin is 27th in the series of its annual publication and contains 21 articles related to environment and ecology, forests, biodiversity conservation, medicinal plants, water and soil quality impact of climate change on Himalayan ecology, forests, biodiversity and medicinal plants. Few articles are also devoted on forest resources consumption and forest soil.

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Dr. G.C.S. Negi
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MORPHO TAXONOMICAL AND ECOLOGICAL STUDIES OF MACROFUNGI OF TRANS-HIMALAYAN LADAKH

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ABSTRACT

This paper gives an overview of the unique diversity of mushrooms in the cold desert of Ladakh. The paper further describes the fungal phenology pattern and substrate preference of macrofungiin the cold arid region of Ladakh. Ecological adaptation strategies of this group to overcome extreme high-altitude's climatic conditions of freezing temperature, dryness and intense solar radiations are also discussed. While most of the reports on larger fungi are from tropical areas where the weather conditions are favourable, very few of them are reported from extreme inhospitable cold arid zones of the globe. This survey heretofore enlists 32 species of macro-fungi with discussion on fungal morphotaxonomy and ecological aspects including diversity, distribution, phenological patterns, substrate preferences and cold adaptive strategies, from the cold arid desert of Ladakh.

Keywords: Mushrooms, Cold desert, Morphotaxonomy, Distribution, Phenology, Substrates, Adaptive-strategies, Ladakh.

INTRODUCTION

Mushrooms are perhaps the most mysterious living entity nature has bestowed to mankind and the curious nature lovers for centuries. Mushrooms form a large distinct epigeous or hypogeous fleshy fruiting body when the climatic conditions (temperature, light, moisture and food supply) are favourable, and are composed of a network of underground living mycelium. They are cosmopolitan, heterotrophic organisms that are quite specific in their nutritional and ecological requirements (Kumar *et al*., 2011). Based on their substrate preferences, they have commonly been described as humicolous, lignicolous, coprophilous, fungicolous, bryophilous, parasitic or may form ectomycorrhizal association with angiospermic and gymnospermic trees. In temperate and cold environment, they mechanize a multitude of adaptive strategies to withstand and survive the extremes of the environment in the niche they occupy. It is both interesting and intriguing, to understand the existence of such macrofungal diversity in this unique habitat of Trans- Himalayan Ladakhsince the environment of extreme cold to intense sunlight, very dry to barren mountains, heavy snowfall and prolonged sub-zero winter temperatures with low precipitation makes it a hostile proposition for any life to exist. In addition, sparse vegetation and strong climate variations from temperate to alpine cold desert conditions generally do not support much diverse life forms. The occurrence of mushrooms heretofore indicates that they have evolved a multitude of enduring strategies to withstand the cold desert's harshest conditions.The present paper gives an overview of the unique diversity of mushrooms in the cold desert of Ladakh with taxonomical and ecological discussion on 32 macrofungal species (Table 1).

MATERIALS AND METHODS METHODOLOGY

The field survey was conducted during the years 2011- 2014 in randomly selected localities of Leh, Nubra and Sham regions of Leh district. Morphological features of fungal sporocarps, based on fresh specimens, were recorded in the field. Data related to habit, substrate, phenology, altitude and plant associations were carefully noted on a field notebook and photographs of sporocarps were taken in their natural habitat. The collected specimens were sun-dried and packed in cellophane bags with crystals of 1,4-dichlorobenzene to protect from insect infestation. Microscopic studies were made by rehydrating a small section of dried sample in 3% KOH and then mounting in 1% aqueous solution of Congo red. In addition, sulphuric acid (H_2SO4) and hydrochloric acid (HCl) were used as chemical reagents for spore colour reaction. Camera lucida drawings of microscopic characters were sketched and more than 30 measurements were made for each character for description of average dimension. Published works by (Arora 1986; Kirk *et al*., 2008) were used for identification purpose.

STUDY AREA

Ladakh is located in the northern part of Indian subcontinent, and lies at 30˚45′ to 35˚50′ N Latitude and 75˚45′ to 80˚31′ E Longitude, in the Trans-Himalayan zone of Northern India (Jina 1996). Ladakh is a high altitude mountainous cold desert surrounded by Karakoram and Greater Himalayan Range. The region is one of the highest in the world, with an altitude of the inhabited places varying from 8,000ft. (2438m) above mean sea level near Kargil to around 20,000ft. (6096m) in some areas of Chang-thang sub-division of Leh district (Jina 1996).

Table 1. Members of Macrofungi recorded from the study area

Names of Fleshy fungal taxa	Family	Vernacular	Edibility	Area of collection
Agaricus campestris L.	Agaricaceae		E	N
Bovista minor Morgan	Agaricaceae		NE	L & N
Bovista plumbea Pers.	Agaricaceae		E	L & N
Bovista plumbea var. dens-caulis var. nov.	Agaricaceae		E	L & N
Bovista pusilla (Batsch) Pers.	Agaricaceae		NE	N
Calvatia bovista (L.) Pers.	Agaricaceae	Fargolokpa (3)	E	N
Coprinus comatus (O.F.Mull.)	Agaricaceae	Tung Shamo (2,3)	E	L & N
Coprinus quadrifidus Peck,	Agaricaceae	Skiakk Shamo (1)	NE	K
Cyathus olla (Batsch) Pers.	Agaricaceae	Nasi Banah (1,2)	NE	K
Coprinellus disseminatus (Pers.) J.E. Lange	Psathyrellaceae		NE	K &L
Coprinellus micaceus (Bull.) Vilgalys, Hopple and Jacq. Johnson	Psathyrellaceae	Lud Shamo (1,2)	NE	K &L
Coprinellus truncorum (Scop.) Redhead	Psathyrellaceae	Lud Shamo (1,2)	NE	K
Coprinopsis atramentaria (Bull.) Redhead, Vilgalys & Moncalvo,	Psathyrellaceae		E	L
Coprinopsis atramentaria var. nov.	Psathyrellaceae	Bong Shamo (1)	E	K
Coprinopsis lagopus (Fr.) Redhead, Vilgalys & Moncalvo,	Psathyrellaceae		NE	L
Coprinopsis picacea var. parvispora var. nov.	Psathyrellaceae		NE	K
Panaeolus semiovatus (Sowerby) S. Lundell & Nannf	Psathyrellaceae	Shamo Smugpo (1, 2)	NE	K, L & N
Panaeolus sp.	Psathyrellaceae		NE	K
Psathyrella fibrillosa sensu Maire	Psathyrellaceae		NE	K
Psathyrella piluliformis (Pers.)	Psathyrellaceae	Spang Shamo (2,3)	NE	N
Maire Helvella acetabulum (L.) Quél.	Helvellaceae	Landeh Koreh, Shatani Koreh (1,3)	NE	K
Helvella corium (O. Weberb.) Massee	Helvellaceae		NE	L
Helvella macropus (Pers.) P. Karst.	Helvellaceae		NE	K
Helvella queletii Bres.	Helvellaceae		NE	K & N
Morchella conica Pers.	Morchellaceae		NE	K
Morchella deliciosa Fr.	Morchellaceae		E	K
Morchella elata Fr.	Morchellaceae		NE	K
Morchella esculenta (L.) Pers.	Morchellaceae		E	K
Morchella tomentosa M. Kuo.	Morchellaceae	Tachung (1,2)	E	K
Peziza ammophila Durieu & Lev.	Pezizaceae		NE	K & L
Peziza ampliata Pers.	Pezizaceae	Balti Koreh (1)	NE	K & L
Peziza badia Pers.	Pezizaceae		NE	K

Collection sites: K = Khaltse region (1), **L** = Leh region (2) and **N** = Nubra region (3)
Edibility: E = Edible; **NE** = Not Edible
Accession No: BHJU = Botanical Herbarium Jammu University

Ladakh presents a combination of extremely cold conditions and marked water scarcity. The region is extremely cold during winter with temperatures down to -30˚C to -40˚C (Chaurasia *et al*., 2007). It has extremes of weather, intense heat by day and piercing cold by night besides very low oxygen and atmospheric pressure. Owing to its position, the region is rarely affected by monsoonal precipitation, which usually fails to cross the high crest of the main Himalayan range (Dvorsky *et al*., 2010). Consequently, the whole area receives very low but varying precipitation of 757mm at Drass, than dramatically decreasing towards northeast, and around 306mm in Kargil and very low of 115mm in Leh, that renders it extremely arid (Hartmann 2009).

In spite of its inhospitability, this region is an abode to uniquely adapted and diverse high-altitudinal life forms (Humbert-Droz *et al*., 2004). Likewise, it harbours a diverse but unusual and exceptional mushroom flora, representing different macrofungal groups- agarics, puffballs, morels, cup fungi, coralloid and bird nest fungi that are well adapted to the hostile habitat of cold desert's fragile ecosystem. Interesting mushroom fungi that have been recorded in the cold arid zones of Ladakh Trans-Himalaya include different species belonging to the classes Pezizomycetes and Agaricomycetes.

Fig. 1. 1. *Coprinopsis picacea var parvispora* **2.** *Panaeolus semiovatus* **3.** *Panaeolus sp.* **4.** *Psathyrella fibrillose* **5.** *P. piluliformis* **6.** *Helvella acetabulum* **7.** *H. corium* **8.** *H. macropus* **9.** *H. queletii* **10.** *Morchella conica* **11.** *M. deliciosa* **12.** *M. elata* **13.** *M. esculenta* **14.** *M. tomentosa* **15.** *Pezia ammophila* **16.** *P. ampliata* **17.** *P. babia*

RESULTS AND DISCUSSION

Morphotaxonomy (Fig. 1 and 2)

1. *Agaricus campestris* L. (Synonymy: *Pratella campestris* (L.) Gray)

Pileus: 4.0-6.0cm wide, convex, whitish, surface smooth, margins incurved; **Gills:** free, crowded, equal, pink initially turning blackish brown at maturity; **Stipe:** cylindrical, 1.5-3.0cm long and upto 2.8cm wide, central, smooth, concorolous with pileus, slightly bulbous at the base; **Annulus:** present; **Taste:** agreeable; **Spore print:** brownish; **Basidiospores:** broadly ellipsoidal to ovoid, 4.8-6.4 × 3.2-4.8µm, guttulate.

2. *Bovista minor* Morgan,

Sporophore: spherical to sub-globose, 2.5-4.0cm in diameter, 2.0-3.5cm in height, slightly embedded in substratum with minute stipe, whitish in young turning dark brown at maturity, surface smooth to irregularly ridged at maturity; **Gleba:** white when young turning dark brown at maturity; **Odour:** no particular odour; **Basidiospores:** globose to subglobose,

Fig. 2. 1. *Agaricus campestris* **2.** *Bovista minor* **3.** *B. plumbea* **4.** *B. Plumbea var. dens- caulis* **5.** *B. pusilla* **6.** *Calvatia bovista* **7.** *Coprinus comatus* **8.** *C. quadrifidus* **9.** *Cyathus olla* **10.** *Coprinellus disseminates* **11.** *C. micaceus* **12.** *C. truncorum* **13.** *Coprinopsis atramentaria* **14.** *C. atramentaria var.nov* **15.** *C. lagopus*

4.0-5.6 × 3.2-4.8µm (avL=4.8, avW=4.0, Q=1.2-1.2), thin walled, smooth, hyaline, mono- to biguttulate; pedicel (10.4-15.2µm in length) attached to spore.

3. *Bovista plumbea* Pers. (Synonymy: *Lycoperdon bovista* Sowerby.)

Sporophore: spherical ball shaped, 2.5-3.5cm in diameter and 2.3-3.3cm in height, loosely attached to substratum by rhizoids, pure white when young turning into dark brown at maturity; surface becomes slightly cracked, exoperidium easily peels off at maturity exposing smooth endoperidium; **Gleba:** pure white and fleshy when young turning into brown powdery mass at maturity; **Basidiospores:** globose to sub-globose, 4.8-6.4 × 4.0-4.8µm (avL=5.6, avW=4.4, Q=1.2-1.3), pale green (in Congo red), thick walled, monoguttulate; pedicel (9.6-14.4µm in length) attached to spore, pointed towards tip.

4. *Bovista plumbea* var. *dens-caulis* var. nov.

Sporophore: globose to subglobose, 2.5-3.2cm in diameter and 2.2-3.0cm in height, attached to substratum with rhizoids, pure white; surface smooth when young becoming reticulate at maturity, exoperidium easily peels off to expose the smooth endoperidium; **Gleba:** white at young turning to yellowish and then to brown spore mass after ages; **Basidiospores:** globose to sub-globose, 4.8-7.2 × 4.0-5.6µm (avL=6.0, avW=4.8, Q= 1.2-1.3), thick walled, hyaline, mono- to biguttulate; prominent pedicel (9.6-14.4µm in length) attached to spore, pointed towards tip.

5. *Bovista pusilla* (Batsch) Pers.(Synonymy: *Globariapusilla* (Pers.) Quel.)

Sporophore: spherical to subglobose, 2.0-3.5cm in diameter, attached to substratum with few rhizomorphs, usually pure white coloured turning brownish and dries up after ages and release brown dusty spores; surface dry, smooth and devoid of any scales or spines; **Gleba:** whitish and then yellowish turning brown at maturity; **Basidiospores:** globose to subglobose, 2.4-4.8 × 1.6-4.0µm (avL=3.6, avW=2.8, Q=1.5-1.2), thin walled, hyaline, mono- to biguttulate, pedicellate, pedicel up to 8.0-12.8µm in length, attached to spore.

6. *Calvatia bovista* (L.) Pers. (Basionym: *Lycoperdon bovista L.*)

Sporophore: globose to subglobose with prominent stipe, 2.5-6.0cm in diameter and 5.5-7.0cm in length, purely white coloured; surface dry, shiny white, rough having small polygonal reticulations, reticulations less conspicuous towards stipe; **Gleba:** purely white when young and fresh turning dark brown at maturity; **Basidiospores:** globose to subglobose, 3.2-4.8 × 2.4-4.0µm in diameter, thin walled, hyaline, mono- to biguttulate.

7. *Coprinus comatus* (O.F. Mull.) Pers. (Synonymy: *Agaricus comatus* O.F. Mull.)

Pileus: conical at young becoming expanded convex at maturity, 6.0-11.0 × 4.0-6.0cm, white coloured at young turning blackish-brown from margins at extreme maturity because of auto-digestion; surface semi-dry with conspicuous shaggy scales on entire surface, scales more pale brown towards apical portion; margins entire when young but eroded, slight curved upward with ages; **Lamellae:** free, crowded, whitish when young and blackish at maturity, deliquescing; **Stipe:** cylindrical with conspicuous bulbous at base, 8.0-12.0 cm in length, white, smooth, central, hollow, fleshy; **Annulus:** evanescent; **Basidiospores:** ellipsoidal to broadly ellipsoidal, 7.2-16.0 × 5.6-8. 0µm (avL=11.6, avW=6.8, Q=1.3- 2.0), olive green to brown (in Congo red), coffee brown (in water mount) but grey with blackish wall (in H2SO4), thick walled, apiculate, truncated.

8. *Coprinus quadrifidus* Peck

Pileus: conical in young expanding to convex or bell shaped at maturity, 2.2-3.5cm in diameter, 5.0-8.5cm in height, pale greyish, surface rough having minute scales, dull grey with minute longitudinal striations, margins dissected, undulating, slightly eroded; **Lamellae:** free, parallel to pileus, crowded, blackish, unequal; **Stipe:** slender with slightly bulbous base, 5.5-8.5cm in length, 0.5-1.5cm wide, central, fibrous texture, whitish, hollow; **Basidiospores:** ellipsoidal to broadly ellipsoidal, 5.6-11.2 × 4.0-6.4µm (avL=8.4, avW=5.2, Q=1.4-1.7), dark greenish brown (in Congo red), thick and smooth walled, truncated with germ pore, apiculate, mono- to bi-guttulate.

9. *Cyathus olla* (Batsch) Pers. (Synonymy: *Cyathus nitidus Roth*)

Peridium: cup or vase shaped, 0.7-1.0cm in diameter and 1.0-1.5cm, light brown to greyish, outer surface tomentose, covered with minute smooth hairs while the inner surface smooth and shiny, silver to blackish; fruiting body fully or partially open at maturity ones while completely closed when young; lids thick, pale whitish; margins circular, entire when young but turns wavy at maturity; **Peridioles:** about 2-3mm in diameter and attached to base of peridium by a funicular cord, oval or egg shaped, pure

silver or blackish coloured, 11 in number; **Basidiospores:** oval to slightly rounded, 8.0-11.2 x 6.4-8.0µm (avL=9.6, avW=7.6, Q=1.2- 1.4), hyaline, thin walled.

10. *Coprinellus disseminatus* (Pers.) J.E. Lange (Synonymy: *Agaricus disseminatus Pers.*)

Pileus: conical when young expanding to convex at maturity, 0.8-1.5cm in diameter, greyish brown to chamois (xxx b. 19". YO-Y) at tip, surface dull, covered with minute glistering granules, longitudinally striated except at the top, texture delicate; **Lamellae:** free, light brown turning black with ages, unequal; **Stipe:** slender, 2.5-3.0cm in length and up to 0.1cm wide, pale white, very light and delicate, central, equal to minutely narrowed apex; **Annulus:** absent; **Odour and taste:** no particular odour and taste; **Basidiospores:** ellipsoidal to broadly ellipsoidal, 5.6-8.8 × 3.2-5.6µm (avL=7.2, avW=4.4, Q=1.7-1.6), dark brown (in Congo red), thick walled, smooth, truncated with central to sub-central germpore, apiculate, multi-guttulate, cytoplasm turns light grey with complete black wall (in H2SO4).

11. *Coprinellus micaceus* (Bull.) Vilgalys, Hopple and Jacq. Johnson (*Synonymy:Coprinus micaceus* (Bull.) Fr.)

Pileus: conico convex to bell shaped up to 1.2-3.5cm in diameter colonial buff (xxx d. 21 ". o-yy) to isabella colour (xxx i.19". yo-y); surface deeply striated sprinkled with glistering mica like particles witch later disappear; margins striated, undulating greyish brown finally turning to black; **Lamellae:** free parallel to pileus, neutral grey (l iii b. neutral grey) crowded equal, **Stipe:** cylindrical 3.5-7.5cm in length and 0.1-0.4cm wide whitish equal fibrous smooth hollow slightly bulbous at base, **Annulus:** absent, **Odour and Taste:** odour none and taste mild, **Basidiospores:** ellipsoidal to sub ellipsoidal 5.6-9.6x4.0-6.4µM (avl=7.2, avw=5.2, q= 1.4- 1.5),dark brown (in congo red and water mount) but changes to light grey (in H2SO4) thick walled truncated with germ pore apiculatemultiguttulate (1-4).

12. *Coprinellus truncorum* (Scop.) Redhead (Synonymy: *Agaricus truncorum* Scop.)

Pileus: conical in young and expanded bell shaped when mature, 1.5-3.5cm in diameter, dark brown (antique brass) at the tip to tawny olive (xxx i. 17". O-Y) towards margin; surface wet, minutely longitudinally striated except tip portion, sprinkled with shiny white crystal powder; margins dissected, undulating; **Lamellae:** adnexed, whitish grey, crowded, unequal, straight; **Stipe:** slender, 3.0-5.5 cm in length and 0.4-0.6 cm wide, whitish, central, equal with slightly bulbous at the base, hollow from inside, fibrous texture; **Annulus:** absent; Odour: no particular odour; **Basidiospores:** ellipsoidal to broadly ellipsoidal, 6.4-8.8 × 4.0-6.4 µm (avL=7.6, avW=5.2, Q=1.6-1.4), yellowish brown, thick walled, mono-guttulate.

13. *Coprinopsisa trametaria* (Bull.) Redhead, Vilgalys and Moncalvo (*Synonymy:Coprinusa trametarius* (Bull.) Fr.)

Pileus: conical to convex-subumbonate, 4.0-7.0cm in diameter, greyish (sandstone), margins slightly curved inside, surface dull, rough, wrinkled longitudinally and splitted, margins incurved, eroded, irregular, rimose; **Lamellae:** free, crowded, blackish, deliquescing; **Stipe:** elongated, 4.5-9.0 cm, pale or dull whitish, central, equal with slightly bulbous at base; **Annulus:** absent; **Basidiospores:** oval to ellipsoidal, 6.4-10.4 × 4.0-4.8µm (a_vL=8.4, a_vW=4.4, Q=1.6-2.2), dark brown (in Congo red and water mount), thick walled, truncated, apiculate, mono- to multi-guttulate, cytoplasm turns light grey with black wall (in H_2SO_4).

14. *Coprinopsisa trametaria* var. nov.

Pileus: ovoid to conical when young expanding to convex at maturity 2.5-5.0cm in diameter and 4.0-6.5cm in height, pure white turning pale greyish surface dull white soft smooth semi wet margin circular entire when young but minutely splitting with ages and finally deliquescing; **Lamellae:** free parallel to stipe crowed greyish when young but turns black when mature deliquesce; **Stipe:** slender 6.0-12.0cm in height and 0.5-1.3cm wide white straight equal to slightly broader towards base fleshy texture fibrous hollow' **Annulus:** evanescent; **Odour & Taste:** no particular odour but good in taste; **Basidiospores:** broadly elliptical 6.4-10.4x4.8-6.4µM(avL=8.4, avW=5.6, Q= 1.3- 1.6), dark brown (in congo red), pale yellowish light brown (in water mount) but changes to light grey with blackish wall (in H2SO4) thick walled turncated with central germpore mono to multi-guttulate (1-3).

15. *Coprinopsis lagopus* (Fr.) Redhead, Vilgalys and Moncalvo(Synonymy: *Coprinus lagopus f. macrospermus* Romagn.)

Pileus: ovoid when young becoming convex to hemispherical umbonate at maturity, 3.0-3.5cm in diameter, light greyish; surface rough, deeply striated longitudinally, covered with whitish to greyish delicate fibrillose universal veil remnants, margins entire; **Lamellae:** free, dark greyish, sub-distant, unequal; **Stipe:** elongated, 5.0-5.5cm in length, 0.3-0.5cm wide, pale white, central, equal to slightly bulbous towards base, surface dry, smooth, fibrous texture; **Annulus:** absent; **Odour:** no particular odour; **Basidiospores:** sub-globose to broadly

ellipsoidal, 8.0-12.0 × 6.4-8.0 µm (avL=10.0, avW=7.2, Q=1.2-1.5), dark brown (in congo red and water mount) but changes to blackish grey with thick wall (in H2SO4), thick walled, truncated with central to sub-central germpore, apiculate, multi-gutullate.

16. *Coprinopsis picacea* var. parvispora var. nov.
Pileus: convex to expanded convex, 5.5-6.0cm wide, whitish when young turning blackish with whitish towards tip at maturity; surface longitudinally striated, covered with irregular persistent whitish scales (veil remnants) on surface; margins striated, eroded, deliquescing; whole pileus later liquefies to form black ink; **Lamellae:** free, black, crowded, unequal, deliquescing at maturity; **Stipe:** cylindrical with bulbous base, 15-17cm length, 1.0-1.5cm wide, central, light yellowish, texture fibrous; **Basidiospores:** ellipsoidal to broadly ellipsoidal, 7.2-12.0 × 5.6-8.0µm (avL=9.6, avW=6.8, Q=1.3-1.5), dark brown with thick and blackish wall, smooth, apiculate, truncated.

17. *Panaeolussemi ovatus* (Sowerby) S. Lundell and Nannf. (Synonymy: *Coprinussem iovatus* (Sowerby) Gray)
Pileus: convex to campanulate, 1.5-2.0cm in diameter, cartridge buff (xxx f. 19".YO-Y.) to copper leaf coloured when young but butter cup-N coloured when mature, margins entire, circular, surface smooth, semi-wet, dull; **Lamellae:** sinuate, pale when young turning dark grey when mature, sub-distant, unequal; **Stipe:** slender, 5.0-6.0cm in length, 0.1- 0.2cm in wide, pale whitish, equal, central, delicate; Annulus: absent; **Odour:** no characteristic smell; **Basidiospores:** ellipsoidal to broadly ellipsoidal, 11.2-15.2 × 6.4-8.0µm (avL=13.2, avW=7.2, Q= 1.7-1.9), dark brown, thin walled, truncated.

18. *Panaeolus* sp.
Pileus: ovoid to convex, 1.0-2.0cm in diameter, conical, reed yellow (XXX b. 23".YELLOW), margins entire, circular, surface smooth, dry and dull; **Lamellae:** free, light brown (copper leaf), unequal; Stipe: elongated slender, 4.0-7.5cm in length, light brown, thin, equal, central; Annulus: absent; **Odour:** no particular smell; **Basidiospores:** broadly ellipsoidal, 7.2-14.4 × 4.8-8.0µm (avL=10.8, avW=6.4, Q=1.5-1.8), light green to brown coloured, thin walled, truncated, multi-guttulate.

19. *Psathyrella fibrillose* (Pers.) Maire, Mém. (Synonymy: *Agaricus fibrillosus* Pers.)
Pileus: conical in young and convex in mature, 2.5-5.0cm in diameter, whitish, margins entire, circular, slightly splitted, surface dry, rough having small irregular patches; **Lamellae:** adnexed, crowded, benzo brown (XLVI i. 13"".OY-O.), unequal; Stipe: 3.5-6.0cm in length, 0.2-0.5cm wide, white, central, equal, fibrous texture; **Annulus:** absent; Odour: unpleasant; **Basidiospores:** broadly ellipsoidal to ellipsoidal, 5.6-9.6 × 3.2-6.4µm (avL=7.6, avW=4.8, Q=1.7-1.5), blackish brown (in Congo red), thick walled, truncated, mono- to multi-guttulate (1-3).

20. *Psathyrella piluliformis* (Bull.) P.D. Orton
Pileus: convex to expanded convex, 2.0-5.5cm in diameter, light brown to brown (honey comb), surface wet, smooth, dull, longitudinally striated, cuticle easily peels off, context white, margins entire, slightly splitted and sometimes incurved; Lamellae:adnexed, normal, benzo brown (XLVI i. 13"".OY-O.), unequal; **Stipe:** 3.0-6.0cm in length and 0.2-0.7cm wide, whitish, equal, central; Annulus: absent; **Odour:** mild; **Basidiospores:** sub-globose to broadly ellipsoidal, 6.4-9.6 × 4.0-6.4µm (avL=8.0, avW=5.2, Q= 1.6-1.5), dark brown (in Congo red), thick walled, truncated, mono- to bi-guttulate.

21. *Helvella acetabulum* (L.) Quel.
Carpophore- cup shaped, 3.0-3.8cm in diameter, grey-brown (vintage walnut), buffy olive (XXX. 21"O-YYk) towards outer, margins slightly splitted, smooth, ribs prominent, whitish to creamish, extending nearly to the margin of the cup; **Stipe:** short, 3.0-3.2cm, short, white, broader at the apex and narrow towards end, interior chambered; **Ascospores:** sub-globose to oval, 12.8-16.8 × 11.2-13.6µm (avL=14.8, avW=12.4, Q= 1.1-1.2), thin walled, shiny white, smooth, mono to multiguttulate.

22. *Helvella corium* (O. Weberb.) Massee (Synonymy: *Cowlesia corium* (O. Weberb.) Nieuwl.)
Carpophore: saucer shaped, 1.0-2.5cm in diameter, blackish brown (XLV, 5"".OO-R.m), from inside as well as outside, depressed, surface smooth, dull, dry, crenate; **Stipe:** solid, 1.5-2.0cm long, concolorous; **Ascospores:** sub-globose to ellipsoid, 14.4-20.0 × 8.8-11.2µm (avL=17.2, avW=10.0, Q= 1.6-1.8), thin walled, smooth, hyaline with a large central spherical oil droplet.

23. *Helvella macropus* (Pers.) P. Karst. (Synonymy: *Helvella bulbosa* (Hedw.) Kreisel)
Carpophore: saucer shaped, 1.2-2.8cm in diameter, hymenium blackish, ribs usually absent, margins plane to slightly curved

over the surface of the cup; **Stipe:** 1.5-2.5cm long, slightly swollen near the base, upper part concolorous, paler below, smooth; **Ascospores:** sub-globose to ellipsoidal, 14.7-17.6 × 8.0-10.4µm (avL=16.1, avW=9.2, Q=1.8-1.7), thin walled, shiny white;

24. *Helvella queletii* Bres. (Synonymy: *Acetabula queletii* (Bres.) Benedix)

Carpophore: cup shaped, 4.5-5.0cm in diameter, hymenium smoke gray (XLVI, 21"".O-YY.f), margins entire, smooth, exterior creamish; **Stipe:** short, 2.0-2.5cm, white with branching ribs that do not extend onto the cup; **Ascospores:** sub-globose to oval, 10.0-16.0 × 8.0-12.0µm (avL=13.0, avW=10.0, Q=1.2-1.3), thin walled, shiny white.

25. *Morchella conica* Pers. (Synonymy: *Helvella esculenta*(L.) Sowerby)

Carpophore: conical to bell shaped, 7.0-9.0cm in length, up to 3.0cm wide at base and 1.0-1.5 cm at top, dark brown (vintage walnut), surface dull, wet, deep ferrous and ridges irregular; **Stipe:** 3.5-4.0cm in length and up to 2.2cm wide at base and 1.0 cm at top, light yellowish-brown to skin colour (ivory), surface smooth and broaden near base, the base of the stem splited into many parts; **Odour:** pleasant; **Ascospores:** ellipsoid 15.2-17.6µm (avl=16.4, avw=8.0, q=2.1-2.0), thick walled hyaline.

26. *Morchella deliciosa* Fr. (Synonymy:*Morchella deliciosa* var. *elegans* Boud.)

Carpophore: rounded to sub-globose, 7.5-9.5 × 3.5-5.0cm, dark brown, pits irregular, pits up to 1.0cm wide, irregular to rounded, ridges slight paler than furrows at early maturity but become more dark after drying; **Stipe:** 4.0-5.0cm in length and 3.5-4.0cm in width, white, equal to slightly broader towards base, smooth, irregular folded base.

27. *Morchella elata* Fr.(Synonymy: *Boletus esculentus* var. *pinguis* (Thore) Pers.)

Carpophore: conical, 11.5-14.0cm in length, 2.5-3.5cm wide, pits irregular to vertically elongated, up to 3.5cm in length and 0.5cm wide, grooves cinnamon brown (xxix b. 15". Y-O.), ridges are slightly paler when young turning dark brown at maturity; completely attached to stipe and hollow from inside; **Stipe:** cylindrical and elongated, 7.0-8.5cm in length, 1.2-1.5cm wide, slightly broad towards base (2.5-3.0cm wide), white, smooth, fleshy and hollow; **Ascospores:** broadly elliptical 16.0-20.8 x 10.4-12.8µm (avl=18.4, avw=11.6, q= 1.5-1.6), thick walled hyaline.

28. *Morchella esculenta* (L.) Pers. (Synonymy: *Morellus esculentus* (L.) Eaton.)

Carpophore: ovate with apex obtuse, 3.0-6.0 × 1.8-2.5cm, pitted, pits irregular to somewhat rounded, yellowish-brown, on drying changes to black; **Stipe:** 2.0-3.0 × 0.8-1.0cm, cylindrical, soft, hollow, concorolous with pileus or slightly creamish yellow; **Ascospores:** ellipsoidal, 18.4-25.6 × 9.6-10.4µm (avL=22.0, avW=10.0, Q= 1.91-2.4), uniseriate, sub-hyaline, smooth.

29. *Morchella tomentose* M. Kuo

Carpophore: conical, 4.0-5.5cm in length, 3.5-4.0cm wide, with irregular pits and ridges, buckthorn brown (XV k. 17'.O-Y.), pits irregular to rounded, up to 1cm in length and 0.5cm wide, ridges slightly whitish, pits pale brown at early maturity but become darker brown at late maturity, fleshy, hollow; **Ascospores:** ellipsoidal to broadly ellipsoidal, 16.0-20.0 × 9.6-12.8µm (avL=17.5, avW=11.2, Q= 1.6-1.6), thick walled, smooth, hyaline, multigutullate (1-3).

30. *Peziza ammophila* Durieu & Lév. (Synonymy: *Geopyxis ammophila* Sacc.

Apothecia: cup shaped, 0.6-1.2cm in diameter, army brown (XL i. 13"". OY-O.) inner surface to dark brown (honeycomb) from outer side, attached to ground with rhizoids, outer surface slightly rough but smooth shiny from inside; **Ascospores:** ellipsoidal, 13.6-16.0 × 6.4-8.0µm (avL=21.6, avW=7.2, Q= 2.1-2.0), smooth, thick walled, hyaline, mono- to multiguttulate.

31. *Peziza ampliata* Pers. (Synonymy: *Aleuria ampliata* (Pers.) Gillet)

Apothecia: cup or bowl shaped 0.8-1.8cm in diameter sayal brown (xl k. 17".o-y) to brown (nut brown) inner surface: shiny wet smooth margins entire smooth sessile directly growing ,min the soilthrough small hair like rhizodes, **Ascospores:** ellipsoidal to broadly ellipsoidal 16.0-20.0 x 10.4-12.0µM(avl=18.0, avw=11.2, q=1.5-1.7), thick walled hyaline.

32. *Peziza badia* Pers. (Synonymy: *Galactinia badia*(Pers.) Arnould)

Apothecia: cup shaped when young changing to inverted hemispherical at maturity, 1.5-2.5µm in diameter, sessile, Natal brown (XL k. 13"". OY-O.)from inside surface to light brown (honey comb) from outside, surface smooth, wet, dull; **Ascospores:** ellipsoidal, 14.4-18.4 × 7.2-8.8µm (avL=16.4, avW=8.0, Q=2.0-2.10), thick walled, hyaline, biguttulate.

Macrofungal diversity

Growth of macrofungi in Ladakh is expected to be limited by extreme cold, dryness, high radiation, strong winds, low precipitation and humidity, a desert like extreme barren landscape, steep and vertical glaciated slopes, minimal forest cover etc. However, the outcome of the study revealed that Ladakh constituted a unique habitat for mushrooms to flourish. As many as 32 macrofungal species belonging to 12 genera spread over in five family viz. Agaricaceae, Psathyrellacea, Helvellaceae, Morchellaceae and Pezizaceae were recorded (Table1). The prominent taxa included five species of Morchella, four species of Helvella and Bovista, three species of each of Coprinella, Coprinopsisand Peziza, two species of Coprinus, Panaeolus and Psathyrella, one species each of Agaricus and Cyathus. A total of 5 families of fleshy fungi belonging to 2 orders and comprising of 12 genera having 32 species (+ varieties) were recorded (Table 2). Of these, two families were from Pezizomycetes while remaining two were from Agaricomycetes. Within Agaricomycetes,Psathyrellaceae with 11 species and 4 genera, followed by Agaricaceae with 5 genera and 9 species were leading with respect to the diversity of species and varieties. Among Pezizomycetes, fungal family Morchellaceae was predominant with 5 species representing a single genus Morchella. Helvellaceae and Pezizaceae followed with 4 species and 3 species, respectively. Predominance of these families may be related to unique geographical location and cold climatic conditions of study area.

Distribution of macrofungi in the study area

Macrofungi collected from different locations of study area vary significantly with the place of collection (Table 3). Of the three collection sites (Khaltse, Leh and Nubra valley), macrofungal richness was found to be highest in Khaltse region with 20 taxa followed by Leh with a record of 11 larger fungal species (+ varieties) while 10 taxa were recorded from Nubra valley. Out of these thirty two described species and varieties, fifteen taxa were exclusively recorded from Khaltse region while three taxa from Leh and four macrofungi were collected from the Nubra valley exclusively. Furthermore, three taxa were common to Khaltse–Leh and Leh–Nubra valley while only one species was common in Khaltse – Nubra valley. In addition to these, one taxa (Panaeolus semiovatus) was common to all the three collection sites.

Phenology of macrofungi in the study area

Incidence of wild macrofungi tends to fluctuate widely from year-to-year and within seasons of a year. For comparative analysis of seasonal variations in the fungal phenology, twelve months of a year were divided into four intervals i.e. January-March, April-June, July-September and October-December. During April-June, the appearance of fruiting bodies of fleshy fungi abruptly begin with record of number of taxa while as the fruiting and availability of the macrofungi increased remarkably during July-September. However, the emergence of sporophores gradually declined with the onset of winter and, consequently, only few fleshy fungi were recorded during October-December. However, no sporophores of fleshy fungi were recovered during the month of January-March (Table 4).

Comparative analysis of the seasonal occurrence of fleshy macromycetes in Ladakh revealed that the maximum diversity of fleshy fungi was recorded during July-September followed by April-June and only few species of fleshy fungi were found during October-December. However, during January-March, no species were recorded from these three regions of the Leh district. Many of macrofungi show fructification during April-

Table 2. Dominant families of wild fleshy fungi in terms of genera and species

Family	Name of taxa	No. of Genera	No. of Species
Class: Agaricomycetes			
Agaricaceae	*Agaricus campestris, Bovista minor, B. plumbea, B. plumbea var. dens-caulis var. nov., B. pusilla, Calvatia bovista, Coprinus comatus, C. quadrifidus, Cyathus olla*	05	09
Psathyrellaceae	*Coprinellus disseminates, C. micaceus, C. truncorum, Coprinopsis atramentaria, C. atramentaria var. nov, C. lagopus, C.picaceavar. parvispora var. nov., Panaeolus semiovatus, Panaeolus sp., Psathyrellafibrillose, P. piluliformis*	04	11
Class: Pezizomycetes			
Helvellaceae	*Helvella acetabulum, H. corium, H. macropus, H. queletii*	01	04
Morchellaceae	*Morchella conica, M.deliciosa, M.elata, M. esculenta, M.tomentosa*	01	05
Pezizaceae	*P.ammophila, P. ampliata, P. badia*	01	03
	Total	**12**	**32**

Table 3. Distribution of macrofungi in various collection sites of study area

Names of macrofungal taxa	Collection sites of Khaltsi			Collection sites of Leh			Collection sites of Nubra		
	K1	K2	K3	L1	L2	L3	N1	N2	N3
Agaricus campestris	-	-	-	-	-	-	+	+	-
Bovista minor	-	-	-	+	-	-	-	+	-
Bovista plumbia	-	-	-	-	-	+	-	-	+
Bovista plumbia var. *dens-caulis* var. nov.	-	-	-	-	-	+	-	+	-
Bovista pusilla	-	-	-	-	-	-	-	-	+
Calvatia bovista	-	-	-	-	-	-	-	+	-
Coprinus comatus	-	-	-	-	-	+	+	+	+
Coprinus quadrifidus	-	-	+	-	-	-	-	-	-
Cyathus olla	+	-	-	-	-	-	-	-	-
Coprinellus disseminates	+	-	-	+	-	-	-	-	-
Coprinellus micaceus									
Coprinellus truncorum	+	-	-	-	-	-	-	-	-
Coprinopsis atramentaria	-	-	-	+	-	-	-	-	-
Coprinopsis atramentariavar. nov.	+	-	-	-	-	-	-	-	-
Coprinopsis lagopus	-	-	-	-	+	-	-	-	-
Coprinopsis picacea var. *parvispora* var. nov.	-	+	-	-	-	-	-	-	-
Panaeolus semiovatus	+	-	-	+	-	-	+	-	-
Panaeolus sp.	+	-	-	-	-	-	-	-	-
Psathyrella fibrillose	+	-	-	-	-	-	-	-	-
Psathyrella piluliformis	-	-	-	-	-	-	+	-	-
Helvella acetabulum	+	-	-	-	-	-	-	-	-
Helvella corium	-	-	-	-	+	-	-	-	-
Helvella macropus	+	-	-	-	-	-	-	-	-
Helvella queletii	+	-	-	-	-	-	-	+	-
Morchella conica	+	-	-	-	-	-	-	-	-
Morchella deliciosa	+	-	-	-	-	-	-	-	-
Morchella elata	+	-	-	-	-	-	-	-	-
Morchella esculenta	-	+	-	-	-	-	-	-	-
Morchella tomentosa	-	+	-	-	-	-	-	-	-
Peziza ammophila	+	+	-	-	-	+	-	-	-
Peziza ampliata	+	+	+	-	+	-	-	-	-
Peziza badia	-	+	-	-	-	-	-	-	-

June when environmental conditions became congenial after the prolong winter season and constitute the characteristic spring flora. These include *Helvella acetabulum, H. corium, H. macropus, H. queletii, Morchella conica, M. deliciosa, M. elata, M. esculenta, M. tomentosa, Peziza ammophila and Peziza ampliata*. However, the majority of species were recorded during the months of July-September as the warm environmental conditions and availability of water resources were at peak. These macrofungal species constitute the summer flora, and included species of *Agaricus, Bovista, Calvatia, Cyathus, Coprinus, Coprinellus, Coprinopsis, Panaeolus* and *Psathyrella.*

These results indicate that all the seasons, except the extreme snowbound winter period during December-February in Leh

district, had their characteristic mushroom flora. Majority of fleshy fungi predominantly produce fruiting bodies during spring (April-June) and rainy season (July-September). Variation in phenology of humicolousmacrofungal forms is principally due to soil temperature and moisture conditions. Onset of moderately warm climate after the long freezing winter and, consequently, melting of snow and glaciers might have provided optimum conditions of moisture and temperature for the emergence of fungal fruiting bodies in temperate and cold arid climate of Leh district during these months. Besides temperature and moisture, the timing and development of macrofungal fruit bodies are also influenced by a wide range of environmental factors including pH, light and inter- and intra-specific genetic heterogeneity. Furthermore, this unique assemblage of macrofungal flora during summers may be attributed to the nutrients availability in, though in very limited

Table 4. Seasonal occurrence of macrofungal in study area

S.No	Names of macrofungal taxa	Fruiting Period			
		Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec
1	*Agaricus campestris*	_	_	Yes	_
2	*Bovista minor*	_	_	Yes	Yes
3	*Bovista plumbia*	_	_	Yes	Yes
4	*Bovista plumbia* var. *dens-caulis* var. nov.	_	_	Yes	Yes
5	*Bovista pusilla*	_	_	Yes	_
6	*Calvatia bovista*	_	_	Yes	Yes
7	*Coprinus comatus*	_	Yes	Yes	_
8	*Coprinus quadrifidus*	_	_	Yes	_
9	*Cyathus olla*	_	_	Yes	_
10	*Coprinellus disseminates*	_	_	Yes	_
11	*Coprinellus micaceus*	_	Yes	_	_
12	*Coprinellus truncorum*	_	Yes	_	_
13	*Coprinopsis atramentaria*	_	_	Yes	_
14	*Coprinopsis atramentaria* var. nov.	_	Yes	Yes	_
15	*Coprinopsis lagopus*	_	_	Yes	_
16	*Coprinopsis picacea* var. *parvispora* var. nov.	_	_	Yes	_
17	*Panaeolus semiovatus*	_	_	Yes	_
18	*Panaeolus* sp.	_	_	Yes	_
19	*Psathyrella fibrillosa*	_	_	Yes	_
20	*Psathyrella piluliformis*	_	_	Yes	_
21	*Helvella acetabulum*	_	Yes	Yes	_
22	*Helvella corium*	_	Yes	_	_
23	*Helvella macropus*	_	Yes	Yes	_
24	*Helvella queletii*	_	Yes	_	_
25	*Morchella conica*	_	Yes	_	_
26	*Morchella deliciosa*	_	Yes	_	_
27	*Morchella elata*	_	Yes	_	_
28	*Morchella esculenta*	_	Yes	_	_
29	*Morchella tomentosa*	_	Yes	_	_
30	*Peziza ammophila*	_	Yes	Yes	_
31	*Peziza ampliata*	_	Yes	Yes	_
32	*Peziza badia*	_	Yes	_	_

quantities, the otherwise nutrient deficient sandy-loam type of soil in the region.

Ecological habitat of macrofungi

Fleshy fungi, being specific in their nutritional and ecological needs, exhibit a wide array of habitat preferences. Being mostly saprophytic, they are preferably adapted to variety of substrates including well decomposed organic matter and humus, rotting branches, fallen dead wood, leaf litters and dung of herbivores while others specifically fruit on living trees or in association of bryophytes and higher plants. In this study the areas with water source and high humus content, wet grasslands, areas inhabited by bryophytes, cultivated fields of Barley and Wheat, mixed forest of Salix and Populus species, and areas contaminated with dung of animal and human constitutes the most preferred substrates for the fleshy fungi in study area. Out of 32 taxa recorded (Table 5) majority of the macrofungal forms were humicolousthat included species of *Morchella, Coprinopsis, Bovista and Calvatia, Peziza, Cyathus* and *Helvella, Agaricus, Panaeolus, Psathyrella*. Similarly, seven taxa of fleshy fungi were found growing on or

Table 5. Habit and habitat of macrofungal taxa in study area

Names of Macrofungal taxa	Habit	Plant association
Agaricus campestris L.	Scattered to gregarious	Mixed forests of *Hippophae rhamnoides* and *Salix sclerophylla*
Bovista minor Morgan	Solitary to scattered	Deciduous forests of *Populus nigra* and *Salix alba*
Bovista plumbea Pers.	Scattered	Open grassland
Bovista plumbea var. *dens-caulis* var. nov.	Solitary to scattered	On open grassland
Bovista pusilla (Batsch) Pers.	Scattered	Open grassland
Calvatia bovista(L.) Pers.	Scattered	temperate forests of *Salix alba* and *Populus nigra*
Coprinus comatus (O.F.Mull.)	Solitary	Marshy areas with mosses
Coprinus quadrifidus Peck,	Caespitose	Deciduous forests of *Salix alba, S. sclerophylla, S. tetrasperma* and *Populus nigra*
Cyathus olla (Batsch) Pers.	Scattered	Cultivated field of Hordium vulgare and mixed forests of, *S. alba, Populus nigra* and *P. caspica*
Coprinellus disseminates (Pers.) J.E. Lange	Gregarious or caespitose	Marshy areas dominated by mosses
Coprinellus micaceus (Bull.) Vilgalys, Hopple and Jacq. Johnson	Gregarious & Caespitose	Mixed orchard of *Prunus armeniaca* and *Juglans regia*
Coprinellus truncorum (Scop.) Redhead		*Coprophilous, gregarious and Caespitose, Prunus armeniaca, Jaglans regia and Populus nigra*
Coprinopsis atramentaria (Bull.) Redhead, Vilgalys & Moncalvo,	Caespitose & fasciculate	Deciduous forests of *Salix sclerophylla, S. alba, Populus nigra,* and *P. alba*
Coprinopsis atramentaria var. nov.	Gregarious to caespitose	Deciduous forest of *Salix alba, S. sclerophylla, S. tetrasperma* and *Populus nigra*
Coprinopsis lagopus (Fr.) Redhead, Vilgalys & Moncalvo,	Scattered and solitary	Deciduous forests of *Populusnigra* and *Salixalba*
Coprinopsis picacea var. *parvispora* var. nov.	Solitary	Temperate forests of *Salixalba, S. sclerophylla, S. tetrasperma* and *Populus nigra*
Panaeolus semiovatus (Sowerby) S. Lundell & Nannf	Scattered	Deciduous forests of *Salix excelsa*
Panaeolus sp.	Scattered or gregarious	Cultivated fields of *Hordium vulgare* and *Triticum aestivum*
Psathyrella fibrillosa sensu Maire	Gregarious to scattered	In the strands of *Populus nigra, Prunus armeniaca* and *Salix alba*
Psathyrella piluliformis (Pers.) Maire	Gregarious to caespitose	Deciduous forests of *Salix tetrasperma* and *Popolus nigra*
Helvella acetabulum (L.) Quél.	Scattered	Mixed forests of *Salix excelsa, S. alba, Populus nigra* and *P. caspica*
Helvella corium (O. Weberb.) Massee	Scattered	Deciduous forests of *Salix alba* and *Populus nigra*
Helvella macropus (Pers.) P. Karst.	Scattered	Marshy area dominated by mosses
Helvella queletii Bres.	Scattered	Among mosses under *Populus nigra* and *Prunus armeniaca*

Morchella conica Pers.	Solitary & scattered	Deciduous forest of *Populus* and *Salix* dominated by *S. alba*
Morchella deliciosa Fr.	Scattered	*Populus nigra, Prunus armeniaca* and *Salix alba*
*Morchella elata*Fr.	Gregarious	Deciduous forests of *Populus nigra* and *Salix alba*
Morchella esculenta (L.) Pers.	Solitary	Deciduous forests of *Salix excelsa* and *Populus nigra*
Morchella tomentosa M. Kuo.	Scattered & gregarious	Temperate forests of *Salix alba, S. tetrasperma* and *S. sclerophylla*
Peziza ammophila Durieu & Lev.	Scattered	Among mosses under *Populus*
Peziza ampliata Pers.	Scattered to gregarious	Among mosses in deciduous forests of *Salix* species
Peziza badia Pers.	Scattered	Among mosses,

**Substrate/Habitat: H= Humicolous, B= Bryophilous, C= Coprophilous, F= Fungicolous, L= Lignicolous, E= Ectomycorrhizal.

in association with bryophytes; predominantly the mosses, and were accordingly denoted as bryophilous. These were *Helvella macropus, H. queletii, Peziza ammophila, P. ampliata, P. badia, Coprinus comatus* and *Coprinellus disseminates.* Among the Coprophilous macrofungi those in habiting a variety of dung and faecal matters of herbivorous animals, and on soil contaminated with human excretawere represented by five taxa *Coprinus quadrifidus, Coprinellus micaceus, C. truncorum, Psathyrella fibrillose* and *Panaeolus* sp. Some taxa viz., *Helvella acetabulum* and *H. corium* were found growing in association with roots of *Salix alba, S. sclerophylla, S. tetrasperma, Populus nigra* and *P. caspica* and these were considered as ectomycorrhizal. However, only one species (*Cyathus olla*) was found to be lignicolous growing on wood pieces in soil.

Cold adaptation strategies of macrofungi

Living forms on earth have evolved special adaptive mechanisms to overcome the life-threatening effects of intense cold environs. Much work done on adaptation of microorganisms (Smith *et al.*, 1996; Jumpponen *et al.*, 1998; Widden *et al.*, 1979) has revealed the evolution of a complex set of adaptive strategies ranging from melanisation, production of cold-tolerant sterile hyphae, to synthesis of anti-freeze proteins, lipids, and other bio-chemicals to face harsh and cold weather. The majority of the macro-fungal taxa collected in this study were fleshy in texture and possessed dark-coloured fruiting morphologies ranging from dark brown to black, yellowish to brownish, orange to reddish and whitish grey, and darkly pigmented basidiospores. This intense colouration of sporocarps and basidiospores points towards excessive melanisation, which might be a protective strategy of these macro-fungi from intense solar radiation especially ultra violet radiations. It has been reported that melanin protects dark, septate fungal hyphae from extreme temperature and drought, and plays a significant role in the persistence of mycelium from year to year (Smith *et al.*, 1996; Jumpponen *et al.*, 1998). In the majority of the macro-fungal taxa studied, the sexually reproducing spores i.e. basidiospores and ascospores, were thick-walled and guttulated (i.e. filled with oil droplets). This could be another adaptive mechanism adopted by these macromycetes to withstand freezing temperatures as these oil droplets do not freeze even at sub-zero temperature thereby serving as a reserve of food in cold seasons. In the majority of mushrooms, thick-walled double- layered basidio spores probably confer endurance from freezing winter temperature. Likewise, in several macro-fungi, the spores are structurally designed with truncated germ pores and apiculation, which might have an important function to play in the life cycle of cold- adapted fungi. These structures perhaps help macro-fungi in spore germination during the short growing season. These inflated hyphae may act as cold-tolerant sterile mycelia, as denoted by (Widden *et al.*, 1979) who reported the predominance of sterile hyphae in fungi of freezing tundra soil.

CONCLUSION

The significant outcome of present study is that all these interesting fungi, their taxonomy, distribution, habitat, phenology, edibility status and vernaculars were recorded first time from cold desert of Ladakh where the climate is extreme and inhospitable for these organisms to grow. The study brings to light the existence of diverse macrofungi in the cold desert of Ladakh, well adapted to varying climatic conditions and substrates. Preliminary studies on phenology, habitats and cold-adapted strategies used by wild mushrooms in Ladakh provide a fascinating insight into the adaptability of life in cold and freezing environs. Further research on biochemical, cellular and molecular mechanisms of cold adaptation and freezing survival in these high-altitude mushrooms could open a new era of opportunities to identify novel biochemical prospects for biotechnology advancements. Further, the study will inspire more mycologist and researchers to undertake extensive research on high-altitude macromycetes.

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RAJAJI TIGER RESERVE- A UNIQUE REPOSITORY OF BIODIVERSITY IN UTTARAKHAND, INDIA

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ABSTRACT

Indian Himalaya is well known for its rich and diverse biodiversity. For effective *in situ* conservation, India has elaborated protected area network. Rajaji Tiger Reserve (RTR) is the second largest protected area in Uttarakhand state after Corbett Tiger Reserve in Shivalik region of outer Himalaya. The continuous loss of species and degradation of ecosystems in the reserve since its establishment have raised various concerns within Shivalik landscape. We have collected information from published data, field investigation, as well as by conducting interviews with local people. Here we have presented the current scenario of ecological and biological diversity as well as the eco- tourism potentials in RTR. Further we have alsoanalyzedthe conservation status of flora and faunal species in RTR as per the status of IUCN.

Keywords: Biodiversity, Species diversity, Rajaji Tiger Reserve, Shivalik

INTRODUCTION

The Himalaya is well known for its biodiversity richness and diverse cultural mosaic**.** It supports about 18,440 species of plants (Singh *et al.*, 1996) 1,748 species of medicinal plants (Samant *et al.,* 1998), 241 mammalian species and 979 birds species. The representative biodiversity rich areas of the Indian Himalayan region have been protected through a Protected Area Network (PAN) programme in the Uttarakhand state (Western Himalaya). Protected forests constitute approximately 28.52% of the total forested area of the country (Forest Survey of India 2011). The world famous RTR is the second largest protected area of Uttrakhand state after Corbett Tiger Reserve, representing vast flora and faunal wealth (Roy 2016), and approximately 90% of the total of 750 elephants occur in both Rajaji- Corbett Tiger Reserve and adjacent reserve forest of the state (Johnsingh *et al*., 1994). In Uttarakhand approximately, 1839 elephants are present as per the survey carried out by the forest department in 2015. The Chilla range of the reserve is one of the great centre of attractions for tourists (Akash *et al.,* 2018b). The entire belt is a natural home of *Elephas maximus* besides many other wild animals like *Panthera tigris, Panthera pardus, Melursus ursinus, Hyaena hyaena, Muntiacus muntjak, Nemorhaedus goral, Axis axis, Cervous unicolor, Sus scrofa, Ophiophagus Hannah.* Additionally, the tiger reserve is the western-most limit for distribution of tiger, elephant and king cobra.

Rajai Tiger Reserve: an overview

Rajaji National park (Now Rajaji Tiger Reserve) has inherited its name from Rajaji Sanctuary, which was one of the constituent unit by amalgation in which the National Park was created in 1983, (Rasily 2008). Rajaji Sanctuary was named after Rajaji C. Rajagopalachari lovingly known as Rajaji, the first Governor General of independent India, as it was on his behest that this sanctuary was created in Uttarakhand state. The intent notification of Rajaji Sanctuary as Rajaji National Park was issued on 12th august 1983 and recently changed to Rajaji Tiger Reservefor conservation of viable population of tigers. The whole area encompasses the Shivalik range, near the foothills of Himalayas spread in 820.42sq km within the three districts i.e., Dehardun, Haridwar and PauriGarhwal. The RTR is an essentials part of the terai landscape between Sharda and Yamuna river in Shivalik landscape (Akash *et al*., 2018a). The Chilla forest range of the RTR lies in the east of the river Ganges and attached to the Garhwal forest Division at an elevation between 302 and 1000m above sea level. The Chilla range of the reserveis one of the great centre of attractions for tourists (Akash *et al*., 2018c). The RTR extends over the Shivalic range from Dehradun-Saharanpur road in the north west to the Rawasanriver in the southeast, which falls within the Gangetic biogeographic zone (Rodgers *et al*., 2002). The topography, altitude and climate of RTR vary greatly, due to which it supports a rich floristic diversity in Shivalik landscape.

The reserve has ten forest range which are playing significant role in conserving of biodiversity. The Chilla range of the reserve is one of the great centre of attractions for tourists (Akash *et al.,* 2018b). The RTR is distinct in terms of scenic beauty and rich biodiversity which is foliated by number of different types of forest (Joshi *et al.,* 2010). It includes northern dry deciduous and *Acacia-Dalbergia* forest, mixed forest of *Shorea- Mallotus* and some area represents the Savannah. The area has the different weather condition. Winter start from november to February when the days are pleasant (approx. 20-25^{0}C), nights are cold but low in humidity. The temperature rises rapidly from 40-45^{0}C in the summer season (March to June) but the rainfall increases with the occasional thunderstorm. The level of humidity is high in the rainy season (July to October). The annual rainfall ranges from 1200-1500mm. Soils are generally poor and infertile, with accumulation of humus in only at few places of the tiger reserve. The area has traditionally been inhabited by Gujjars (a pastoralist community). They herd buffalo between high Himalayan pastures in summer and lower foothills in winters. There are different types of Gujjar community settlements within the tiger reserve.The Shivalik and foothills of the Himalayas arecollectly called as'Bhabar'. The terai belt consists of dense tall grasses along withthe Asiatic elephants andlarge number of mammalian fauna attracts the tourists most.

Flora of the park

In the Himalaya, approximately 8,000 species of flowering plants occur, out of which 1748 plants are mostly used for ethno medicinal purpose for curing different diseases (Akash *et al.,* 2018; Wani *et al*., 2015, 2016). Rajaji Tiger Reserve presents a rich and diverse forest ecosystem. Different studies revel that the forests of the RTR comprises of important plant associations such as the *Shorea – Mallotus- Adina* community, *Shorea– Terminalia- Bridelia* community, *Dalbergia- Acacia* community as well as the *Syzgiumcummini, Terminalia bellerica, Terminalia alata, Trewia nudiflora, Cassia fistula, Flacourtia indica* (Akash *et al.,* 2018; Joshi *et al.,* 2009; Joshi *et. al.,* 2010). All of the ranges of the RTR have great diversity of plant species. The area of the Chilla forest division comes under the protected area network but undergoing rapid changes in its ecological status and flora and fauna pattern due to the large scale anthropogenic forcing at some places in the form of lopping, grazing and hydro-power project, scraping, trampling and extraction of non timber products (Akash *et al*., 2019). But at the same time the RTR maintains its integrity due to large forest area. Based on the Physiognomy, vegetation of the park may be classified broadly under the northern tropical moist deciduous forest and can be grouped according to (Champion *et. al.,* 1988): (a). Sal forest (b). Mixed forest (c). Riverine forest (d). Scrubland (e). Grassland (f). Sub tropical Pine forest.

The Sal forest occupies the major part of the park and can be divided into two types; namely, tropical moist deciduous forest and tropical dry deciduous forest. The tropical moist deciduous forest is represented by the dominated tree species, *Shorea robusta* which forms pure tracts. The common species associated of the Sal forest are *Terminalia alata, Anogeissus latifolia, Adina cordifolia*, *Terminalia bellerica, Lannea corommandelica, Garuga pinnata, Sterospermum suaveolens, Mallotus philipensis* etc. Whereas the tropical dry deciduous represents *Terminalia bellerica, Cassia fistula, Mallotus phillipensis, Bombex ceiba* etc.

The mixed forest of the park is generally comprises of *Anogeissus laitolia, Albiza procera, Mallotus phillipensis, Bombex ceiba, Terminalia bellerica, Acacia catechu, Mitragyna parviflora, Erythrina suberosa, Embilica officinalis, Bredelia squamosa,Gmelina arborea, Listea glutinosa, Trewia nudiflora, Cassia fistula, Sterculia villosa, Zizypus xylopyra, Z. Mauritiana, Butea monosperma etc.* The mixed forest community also faced species depletion by various activites of the locals (Johnsingh *et al.*, 1990).

The Riverine forests occur in the low –lying waterlogged areas, along nullahs, riverbands and streambed and consist of evergreen species which are able to withstand the wetness of the occupied sites. The common species of this forest are *Syzium cumini, Ficus racemosa, Bischofia javanica, Trewia nudiflora, Pterospermum acirifolium, Albizzia procera, Toona ciliata, Calamus tenuis* etc.

The Scrub forest of the park generally represents degradation of the dry deciduous forests which are formed due to the biotic stresses like overgrazing, lopping, felling and fires. *Aegle marmelos, Lannea coromandelica, Erythrina suberosa, Cassia fistula, Flacourtia indica, Zizypus mauritiana, Z. xyloporaare* the main tree species of this forest.

The Other plant community of the park is Savannah (Grassland) which doesn't represent a climax stage in the park but have developed due to the various disturbance and anthrpogenic disturbance on the natural flora. *Desmostachya bipinnata, Phragmites karka, Cymbogon flexuosus, Digitaria* spp, *Eragrostris japonica, E. tennela, Setaria* spp, *Vetiveria zizaniodes,*

Heteropogon contortus, Butea monosperma, Acacia catechu, Helicteres isora, Carrisa opaca, Dendrocalamus strictus are the important plant species of the Grassland community. The sub tropical Pine forest occurs between dry deciduous forest and sal forest. The extent of this forest is very small and *Pinus roxburghii* occurs on the higher slopes of the Shivaliks, mixed with stunted forests.

Table. 1. Some of the rare plant species of Rajaji Tiger Reserveand with their IUCN status

Name	**Family**	**IUCN status**	**Remarks**
Catamixis bachharoides	Asteraceae	VN	Shrub, flowering time is june- july. Rare due to gradual crumbling of the Shivalikcliffs.
Eremostachys superb	Labiatae	EN	Herbal species with large yellow flowering stalk is generally found on the boundary of the western. Fowers bloom in feb-march. Grazing of buffaloes is the main reason for rareness.
Uraria picta	Labiatae	LC	It is small herb found on dry shivalic hills.
Euphorbia candicifolia	Euphorbaceae	LC	Small tuberous herb distriburted on the southern grasses slopes of the park.
Olax nana	Oleaceae	EN	It is a woody plant found near mansadevi temple of the Haridwar forest division.
Cordia vestita	Boraginaceae	LC	It is a deciduous tree found near Chilla range of the tiger reserve.
Coclospermum religiosum	Bixaceae	LC	It is commonly known as Buttercup tree found on dry shivalic hills.
Euphorbia fusiformis	Euphorbiaceae	LC	It is a small herb found near haridwar division the tiger reserve.
Some of the common orchids in the tiger reserve			
Genus	**Family**	**IUCN status**	**Remarks**
Aerides odorata	Epidendroideae	LC	It is common in the tiger reserve and along in wetern part of the Himalaya. it is highly fragrant and blooms in the late spring
Nervila aragoana	Orchidaceae	EN	It is a terrestrial orchid grows in the drier part of the tiger reserve. It blooms between January april.
Rhynchostylis retusa	Do	LC	It is found in the dried part of the rerserve and blooms in spring season.
Epipogium roseum	Do	Do	It is medium sized orchid grows in warmer region of the tiger reserve.
Nervilla crociformis	Do	Do	It is a terrestrial orchid found in the semi deciduous forest of the reserve.
Eulophia dabia	Do	TN	It is a small sized orchid grows in cold areas of the tiger reserve. It has beautifull yellowish green petals.
Goodyera procera	Do	LC	It is also a terrestrial orchid with beautifull flowers, blooms in eary springs.
Oberonia falconeri	Do	LC	It grows hanging underneath branches of the host plant blooms in espring season.
Peristylus lawii	Do	LC	It is a terrestrial orchid with white flowers bloom in rainy season. It is commonly found in the forest of western Himalays including Rajaji tiger reserve.
Goodyera procera	Do	LC	It is also a terrestrial orchid with white flowers, bloom in early spring.
Eulophia graminea	Do	LC	It is a terrestrial orchid with green flowers blooms in eary summer season.
Areides odorata	Epidendroideae	LC	It is also called t fragrant Fox Brush Orchid with light pinkish flowers. It blooms in summer season

(*Source: Akash et al,. 2018 a,b,c*)

EN = Endangered, LC= Least concern, TN= Threthened, VN= Vulnerable

Eco-tourism potential of Rajaji Tiger Reserve

Rajaji Tiger Reserve is opened for tourists from 15th of November to 15th of June of every year. The three ranges namely Chilla, Motichur, Ramgarh of the RTR has been opened for the last six years for tourists. The other seven ranges of the tiger reserve didn't open since last six years due to the dense forest and presence of the fauna. Some of the areas of the reserve has number of the tracks, which have great potential of eco-tourism. Asiatic elephant is one of the great attractions for tourists and during the period and elephants sighting is more common when park remained open for tourists especially in the chillla and Motichur forest dividion. On the other hand, presence of tigers, leopard, further ensures the feasibility of area for eco-tourism potentialities. Recently Motichur forest and Chilla forest of the tiger reserve is the centre of attraction for the tourist because approximately 90% tourist visit every year to enjoy wildlife safari and scenic beauty. Most of the sites inside the tiger reserve have typical diversity of species as per geographical locations (vegetation and fauna, variations in landscape) that is why some sites can be selected and diverted for eco-tourism purpose with controlled activities by the government.The tiger reserve has huge potentials of tourism in terms of elephant safari, birds watching and to enjoy scenic beauty. Birds watching are the centre of attraction and as a key for the researchers as well as scientist because the two range namely Chilla and Motichur have great diversity of birds. Months October and March are the best months for bird watching. Most of the birds area migrants and comes here from Northern part of America, south-East China, Europe, Russia, and some of the other countries which haveextreme cold climatic conditions during winter. Some of the important birds are: *Tadorna ferruginea*, *Aythyafarina*, *Anas platyrhynchos*, *Anas acuta*, *Anas clypeata*, *Anser indicus*, *Mycteria leucocephala* and *Ephippiorhynchus asiaticus* (Joshi *et al.,* 2010). These beautifull birds are key attraction for tourist.

Ecological value of the Rajaji Tiger Reserve

RTR is an important ecosystem comes under Rajaji- Corbett elephant reserve which maintains the elephants population as single entity of about 90% of 1000 odd elephants in Northern India (Singh *et al.*, 1986). The Asiatic elephants are the major attraction of the tiger reserve. In India it occurs in North-Western part. It has been estimated that, 800-1000 elephants occur in Rajaji- Corbett tiger reserve and the adjoining forest areas (Johnsingh *et al.,* 1994). The turbulent Ganges emerges from the Himalayas and begins its journey through the Indo- Gangetic plains at the park. The junctions of the Gangetic plains and the Outer Himalaya give rich eco-tone habitat in RTR that is unique in its diversity. It has vegetation representation of several distinct habitats including Chir- Pine forest, Scrublands, Broad leaves mixed forest, Riverine forest. *Shorea robusta* is the major dominant species especially along the Northern aspects. Thus unique to the rich biodiversity and the variety of ecological habitat, the RTR is unique repository of biodiversity in Northern India.

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WATER QUALITY OF SPRINGS IN DEOLIKHNAN RECHARGE ZONE OF KOSI WATERSHED, ALMORA, UTTARAKHAND

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INTRODUCTION

Kosi watershed of Kumaon Himalaya, a central zone of Indian Himalayan Region (IHR) falls within Almora and Nainital districts of Uttarakhand. The Kosi river originates from its north at Pinath (NW of Kausani, district Almora), which flows down towards the discharge point at Kosi Barrage (Ra mnagar, district Nainital). Geographically, the catchments have its spatial extension between 29^0 22' 41.60" to 29^0 52' 20.81" N latitudes and 79^0 02' 38.21" to 79^0 51' 15.08" E longitudes, which covers about 1868.64km^2 area. The absolute relief of the catchment ranges between 349m to 2758m from the mean sea level. Geology plays an important role in shaping the groundwater scenario in the watershed. The quality of water, flowing through basin, is affected by the rock present in that area. This paper is an attempt to understand the impact of geological composition on spring water quality in Deolikhan recharge zone situated in the Kosi river basin in district Almora.

MATERIAL AND METHOD

STUDY AREA

Deolikhan recharge zone, situated approx. 24km ahead from Almora city on Ranikhet road, covers Kayala, Garhwali, Lamtari, Papoli, Kathpuriya and Kwerali villages. The total area of Deolikhan recharge zone is 19.88km^2 with the perimeter of 23.875km. Out of this area, 0.97km^2 area with the perimeter of 6.11km has been selected for spring monitoring purpose. The study area lies between 29°38'11.02"N to 29°38'47.13"N latitude and 79°34'20.84"E to 79°35'20.72"E longitude with the altitudinal range of 1341m to 1620m. The study area was selected based on the different order of streams which are contributing in total water budget of that area. The stream area map was prepared using Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER-DEM). The streams were delineated using DEM in the Global Mapper v.20.1 and watershed map was prepared using Arc GIS 10.6 as shown in Fig.1A. The satellite image was draped over the area under investigation to get a better overview of forested and civil land. The area under the present study was classified into there small catchments A, B and C. The land use pattern of whole area was either civil forest or agriculture.

Topography and geology of the area

The topography of the study area is very undulating. So, for understanding it contour map was prepared using Arc GIS (version 10.1). For geological studies, lithology and mineral components of the rocks were identified through field survey. This helped to understand the types of rocks and its primary composition. Rock identification was carried out based on mineral components using their physical properties such as form, color, lusture, cleavage, fractures etc. (Gribble 2005). Based on mineral components, the rocks were grouped into categories.

Water sampling and analysis

Water samples were collected from different order springs based on the availability of water. During the month of December 2019, out of 23 springs (A catchment includes 4 first order, 1 second order; B catchment includes 8 first order, 3 second order; C catchment includes 5 first order, 1 second order and finally different first and second order springs met and formed a third order spring Fig.1. (A). water

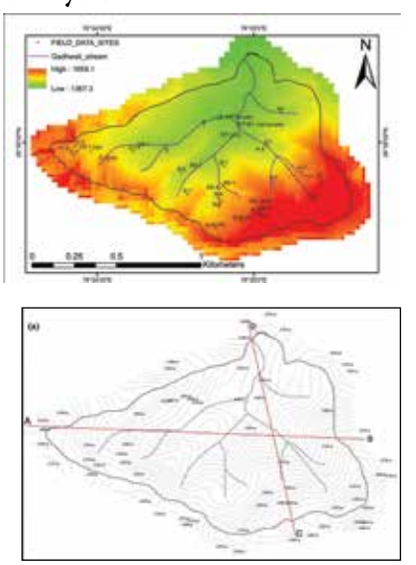

Fig. 1. (A). Different order streams (B) Contour map of Deolikhan Recharge zone

was available in 9 different ordered springs. So, water samples from these springs were tested for their quality. Garminetrex10 GPS was used to find the location of each sampling site and coordinates were imported to GIS platform for preparation of base map. Samples were filtered and stored in polyethylene bottles and further analyzed for various physical and chemical properties of water. pH, electrical conductivity (EC) and total dissolved solids (TDS) were measured in the sampling site using Eutech PC510, while other parameters were analyzed in laboratory using standard procedures. Calcium, magnesium, chloride, total hardness, alkalinity was analyzed using titration method. Fluoride was analyzed using Orion 920A with fluoride ion electrode (Thermo Scientific Rs order 9707BNWP). Sulphate ions were analyzed using photometer (ELE aqualab). Sodium and potassium ions were analyzed using flame photometer (model Systronics 128). The physico-chemical parameters of the analytical results of spring water were compared with standard guideline values recommended under International Standard for water quality. Due to the presence of iron-based mineral in the study area i.e., Almandine Garnet, possibility of iron content has been explored in different orders of springs. Iron content was analyzed following o-phenanthroline method APHA 3500-Fe B (Eaton *et al.,* 2005).

RESULTS AND DISCUSSION

Topography

Topographic map shows the surface relief, means undulation of ground surface and which type of slope present at the ground (gentle slope and steep slope), where is basin and where is the hill and hillock (Groshong 1999). The contour maps shown in Fig.2(A) represents the topographic conditions in the Deolikhnan recharge zone. Along the line AB, the contour spacing is more than that along the line CD. Along the line AB, the highest elevation is 1590m and lowest is 1380m with the total altitudinal difference of 210m. The topographic cross section shows that along the line AB, the zone represents valley area with steep slope Fig.1(B). Along the line CD, the highest elevation is 1605m and lowest is 1347m with the elevation difference of 258m. The zone along the line CD represents the steep slope with mild undulations. Hill and hillock are not present in this topographic section.

Geological observation

Through field survey, it was observed that the Deolikhan recharge zone have various types of metamorphic rocks such as Garnetiferous Mica Schist Fig. 2(A), Quartzite and Quartz veins which is highly fractured. The Garnetiferous mica schist is highly foliated which is mostly consist of Almandine Garnet and Muscovite Mica. Thealmandine garnets are a compositionally complex group of silicate minerals in which silicate tetrahedra are linked with octahedrally coordinated aluminum, and iron (rather than with other silica tetrahedra), although minor amounts of the other elements are usually present. Its molecular formula is $Fe_3Al_2Si_3O_{12}$. The crystal of Almandine Garnet is red in color Fig. 2(B), with vitreous luster and conchoidal or uneven fracture. Muscovite Mica is potash rich (K-rich) mica group of minerals with the molecular formula $K_2Al_4[Si_6Al_2O_{20}](OH,F)_4$ (Gribble 2005). It's a colorless mineral with platy form, pearly luster and perfect cleavage. Quartzite is usually white to gray in color. It comes under the silicate minerals with the chemical formula of SiO_2. The crystal structure is hexagonal with vitreous luster and conchoidal fracture.

Fig. 2. (A). Almandine garnet in Garnetiferous Mica Schist; (B): Almandine garnet

Water quality

In catchment A, water was available in first order spring AA and in catchment B & C, second order springs were found active along with the third order spring. The general physical and chemical properties for all the springs were found below the acceptable limit except the iron content. Iron was present above the desirable limit (i.e., 0.30mg/L) in all the springs (Table 1). Highest iron content was found in the first order stream of C catchment area while it was lowered in its second order stream (CS-1 and CS1'), which might be due to the dilution of second order spring water from subsurface water flow in that region. The iron content might be attributed due to the presence of Almandine Garnet which are found imbedded in Garnetiferous Mica Schist Fig. 2(A).

Embrechts *et al.,* 1982; Parisot *et al.,* 1983; Velbel 1984; Velbel 1993 suggested that almandine weathers by a transport-controlled (diffusion-limited) mechanism in oxidizing weathering environments such as saprolite. Both coated and

uncoated almandine grains can occur in the same soil (Graham *et al.,* 1989). Partially weathered garnets present in saprolites have thick coatings of limonite and persist in soils, whereas garnets that bypassed the coating formation, saprolitic stage of weathering (i.e., were removed to soils directly from fresh outcrops) weather much more readily (Embrechts *et al.,* 1982). In the soil, an environment in which biological processes dominate over inorganic processes, protective surface layers on the surface of almandine garnet cannot be formed, and preexisting layers may be removed. The weathering reactions are faster (e.g., Embrechts *et al.,* 1982) because they are no longer limited by diffusion through the surface layer, and surface-reaction control prevails. (Velbel 1988) had discussed about the weathering of almandine garnet where release of iron (ferrous hydroxides) in the form of solution were mentioned along with the deposition of gibbsite-goethite. The o-phenanthroline method targets the ferrous ions only, so it gives a direction on understanding the cause of presence of this ion in spring water sample.

Table 1. Water quality of different order springs with in Deolikhan recharge zone

Parameters	Drinking water Quality standard*		A catchment	B catchment			C catchment				
	Sample Id and spring order										
	Acceptable limit	Permissible limit	AA	BS-2	BS-3	C-1	H	CS-1	CS-1 (at temp)	BT-1 (UP)	BT-1 (at temp)
			First order	Second order	Second order	First order	First order	Second order	Second order	Third order	Third order
pH	6.5-8.5	No relaxation	7.6	7.3	7.16	7.56	6.67	7.57	7.64	7.25	7.02
EC (µS/cm)	750	2250	100.4	43.6	64.3	56.7	88.1	54.8	48.4	64.4	75.2
T(°C)			15.8	16	15.7	15.6	16	15.6	15.6	15.6	15.6
TSS (g/L)			0	0	0	0	0	0	0	0	0
Total Hardness (mg/l)	200	600	84	32	60	48	60	60	64	52	80
Na (mg/l)			1.06	0.91	1.01	0.81	1.39	0.76	0	0.94	0.85
K (mg/l)			5.42	2.18	3.62	2.32	5.58	6.4	2.96	1.48	1.63
Turbidity (NTU)	1	5	0.84	0	3.07	70.4	0.17	7.86	1.72	1.48	0.77
Chloride (mg/l)	250	1000	2.84	1.42	2.84	2.84	2.84	2.84	1.42	2.84	2.84
Alkalinity (mg/l)	200	600	25	25	25	25	25	25	25	25	25
Iron (mg/l)	**0.03**	**No relaxation**	**1.303**	**2.201**	**1.386**	**5.787**	**1.2**	**1.682**	**1.545**	**0.609**	**1.451**
Sulphate (mg/l)	200	400	1.661	0.182	0.798	0.18	0.289	0.18	0.068	0.787	1.02
Ca (mg/l)	75	200	20.18	6.72	10.09	8.4105	13.45	6.72	8.41	11.77	15.13
Mg (mg/l)	30	100	8.16	3.69	8.45	6.561	6.41	10.49	10.44	5.49	10.25

**Drinking water quality standard IS 10500; 2012*

CONCLUSION

The surface of the selected study area, under the Deolikhan recharge zone, undulated with steep slopes. The dominating rock type is metamorphic such as Garnetiferous Mica Schist, Quartzite and Quartz veins. The water quality was found affected by high iron content as its concentration is higher than the acceptable or desirable limit. This water, if stored, can block pipes or fixtures, and produce color, taste and rust flakes in water. It can also increase the growth of unwanted bacteria

that form a slimy coating in water pipes. The distribution of iron needs to befurther investigated in detail along with the in-depth geological investigations as it affects the overall water quality of the springs.

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CONSERVATION STRATEGIES AND SEED GERMINATION OF *VIBURNUM MULLAHA* BUCH.-HAM EX D. DON (INDIAN CRANBERRY) GROWING IN WESTERN HIMALAYA, INDIA

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ABSTRACT

Viburnum mullaha L. is a multipurpose plant species endemic to higher Himalaya. The aim of the present study is to work out its large scale multiplication of *V. mullaha* for conservation and its sustainable utilization. *V. mullaha* seeds were collected from three natural pockets namely Trijuginarayan, Sersi and Tala sites, Uttarakhand, and subjected under different hormonal treatments, temperature regimes, imbibition, seed viability and photoperiodic conditions to understand the suitable temperature and best treatment for suitable germination. Seeds of *V. mullaha* were examined in terms of germination at three different temperature regimes (10, 20, 30°C) in incubator at 24hr light condition for 107 days and different sets of alternating temperatures (10-20°C, 10-30°C, 20-30°C) on seed germination were conducted to determine optimum temperature for maximum seed germination. Physical dormancy was worked out by soaking seeds in water at room temperature (25°C) for 24 hr. Optimum conditions for seed germination were determined under varied concentrations of plant growth regulator-GA_3 (10, 50, 100ppm), light conditions and under different temperature. The maximum viability (81.21±3.23%) was observed in the seeds from Sersi site, maximum imbibition 90% also Sersi site and maximum germination (71.25±3.65%) in Trijuginarayan site found only at 10°C. At alternating temperature 10-20°C, the maximum germination (58.75±4.23%) was recorded for Trijuginarayan site and minimum (18.75±1.54%) was recorded for Tala site on temperature alternation of 10°C-30°C. When seeds were treated with GA_3 10, 50, 100ppm and stratified for 100 days, maximum germination (92.5±4.84%) was estimated for the seeds treated with GA_3 50ppm collected from Trijuginarayan site.

Keywords: Seed germination; Seed dormancy; Heritability, Plant growth regulator hormone; *Viburnum mullaha*

INTRODUCTION

The seed is a mature ovule containing an embryo, storage tissue and a protective outer covering which is the product of fertilization (Hartmann *et al.,* 1997). The activation of the metabolic machinery of the embryo leading to the development of a new miniature is known as seed germination (Hartmann *et al.,* 1997). It is the process of continuation of life and assuring the species survival in nature (Hartmann *et al.,* 1997). Seeds of many plant species have underdeveloped embryos at maturity (Martin 1946) and embryo growth is a prerequisite for germination (Baskin *et al.,* 1998). Embryos may be non-dormant or dormant at the time of seed dispersal. Non-dormant seeds generally germinate during optimum growth conditions, however, there is need to break dormant seeds by using appropriate methods. Studies of seed germination and dormancy of various species like *Viburnum punctatum, V. coriaceum* and *V. erubescens* have been performed (Baskin *et al.,* 1998; Baskin *et al*., 2014). Deep simple, epicotyl, morpho-physiological dormancy (MPD) has been reported in seeds of *Viburnum* species (Baskin *et al.,* 2014). Various levels of MPD have been distinguished based on warm and/ or cold stratification requirements to break physiological dormancy (PD), temperature requirements for embryo growth and responses to gibberellic acid (GA_3) (Nikolaeva 1977). Similarly, use of GA_3 to break dormancy of epicotyls in the seeds of *Viburnum* species was reported (Fedec *et al.,* 1973).

V. mullaha (Bhatmoliya) is wild edible medicinal plant and among the total of 18 species of *Viburnum* found in the India, two species namely *V. cotinifolium* and *V. mullaha* have been reported from the Kedarnath Valley (Naithani 1984). The genus

has horticultural as well as medicinal properties (Nobre *et al.,* 2000). The fruit is a one-seeded drupe consisting of a fleshy exocarp and mesocarp and a hard endocarp that is united with the seed coat (Ferguson 1966). The embryo is surrounded by ruminate endosperm (Dragone-Testi 1933) a feature also known to occur in almost all species of the genus (Rehder 1940).

As dormancy and low seed germination percent is observed in *V. mullaha* the objective of present study was to: (i) investigate the impact of different hormonal treatments different temperature regimes and photoperiodic conditions on the seed germination of *V. mullaha*, and (ii) to determine seed imbition and viability of *V. mullaha*. The study will be helpful in propagation of the target species as well as for its conservation planning in Uttarakhand.

MATERIAL AND METHODS

Mature seeds of *Viburnum mullaha* were collected from three sites (Trijuginarayan, Sersi and Tala) of Kedarnath valley, Uttarakhand, India during October, 2012. All seeds were wiped in lukewarm water and their pulp was removed. All the seeds were dried at room temperature for 1 week and stored in small cotton bags at 4°C. Various seed germination experiments were conducted up to sixteen weeks after collection. The seeds used for the experiment were viable and of high quality, the sample lots were subjected to viability test using the tetrazolium technique (Peters 2000). Hundred seeds (3 replicates) were subjected to 2, 3, 5, triphenyl tetrazolium chloride (TTC). The seeds were longitudinally sectioned and the sections were immersed in (0.5%) aqueous TTC solution (pH 6.5) for 24 hr at room temperature (25°C) under dark conditions. The TTC solution was drained and sections were rinsed 2-3 times with water. The topographical staining pattern of the embryos (plumule and radicle) and cotyledons were studied using dissection microscope (ISTA 2003). Water imbibition capacity of the seeds was determined following the standard method (Kandari *et al.,* 2008). To verify if the species have water impermeable seed coat, one hundred seeds (3 replicates) of *V. mullaha* were weighed and allowed to water in a beaker (100ml) at room temperature (25°C) under dark condition. At regular intervals (12 hr) seeds were removed, wiped dry with blotting paper and weighed. The seeds were transferred back to beaker containing water. The process was repeated till the seeds attained constant weight (Baskin *et al.,* 1998).

Dormancy in *V. mullaha* seeds were determined as follows, 1000 seeds (2 sets 500 seeds in each) were kept at 4°C and 20°C for 100 days, respectively. Physical dormancy was worked out by soaking seeds in water at room temperature (25°C) for 24 hr. Optimum conditions for seed germination was determined by subjecting the seeds to varied concentrations of plant growth regulator–GA_3 (10, 50, 100ppm). Seeds were kept in the treatment solutions for 24 hr for imbibition. After standard soaking, seeds were incubated for germination in Petri plates with two-layer Whatman No. 1 filter paper with distilled water (5ml). The moisture levels of filter paper were maintained by adding distilled water as required. The effect of different temperatures, on seeds as determined by incubating seeds at 10, 20, 30°C. These experiments were conducted in alternating light (12 hr) and dark (12 hr) and constant light (24 hr) conditions. The effect of different sets of alternating temperature (10°C and 20°C, 10 and 30°C, 20 and 30 °C) on seed germination was studied to determine optimum temperature for maximum seed germination. In this experiment seeds of the set (10 and 20 °C) were incubated at 10 °C and 20 °C for 12 hr and this process was followed for all sets viz., 10°C and 30°C, 20°C and 30°C), respectively. Cool white fluorescent lamps were used for providing light conditions in the incubation chambers. Control indicates no pre-treatment of seeds. Germination was monitored daily from the date of seed sowing to more than 107 days. Germination for seeds of constant light treatment was monitored under low green light. Seed with radical emergence (>2 mm) was considered as germinated. Germination percentage was recorded every day until no further germination was found.

RESULTS

Seed viability

The maximum viability (81.21±3.23%) was observed in the seeds collected from Sersi site followed by Trijuginarayan site (79.32±3.25%), whereas, the seeds of Tala site exhibited minimum (74.32±1.23%) viability (Fig. 1). After 6 months (180 days) the viability in the seeds calculated from Sersi site declined up to 13.24±1.22% followed by Trijuginarayan (8.84±0.89%) and Tala site (7.23±0.75%). Analysis of seeds stored for one year revealed that, seeds collected from Tala site exhibited maximum decline in viability (40.47±2.32%). However, seeds from Sersi and Trijuginarayan sites also showed decline of viability (38.76±2.89%) after storage for one year (Fig. 1). Seeds stored for 18 months (540 days) showed decline in viability Sersi (54.74±1.32%), Tala (51.43±1.98%) and Trijuginarayan (50.47±0.79%), respectively

Imbibition capacity

The imbibition capacity of the seeds was measured for 168 hr till it reaches the plateau. Poor imbibition capacity was

detected in the seeds of *V. mullaha* collected from all the sites. Imbibitions took 144 hrs for the seeds to initiate and develop a plateau of percent increase over initial weight of seeds (Fig. 2). However, seeds of Sersi site imbibed water at a faster rate (81.18%) followed by Tala (40.43%) while, the seeds collected from Trijuginarayan site exhibited a slower rate of imbibition (22.31%) over initial weight of the seeds at 24 hr (Fig. 2). Seeds collected from Sersi site exhibited maximum imbibition percent and reached up to 90% imbibitions capacity at 84 hr and finally attained 98.13% over initial weight of seeds however, seeds collected from Trijuginarayan site took maximum time for imbibition and attained only 37.47% over initial weight in whole experiment at 144 hr, which could not attain imbibition even up to 50% over initial weight. Seeds collected from Tala site attained 50% imbibition over its initial weight at 72 hr, which gradually showed slower rate of imbibition and finally attained 56.93% imbibition and reached a plateau over its initial weight at 144 hr during the experiment (Fig. 2).

Seed germination assessment

The fresh seeds of *V. mullaha* were examined in terms of germination at three different temperature regimes (namely 10,

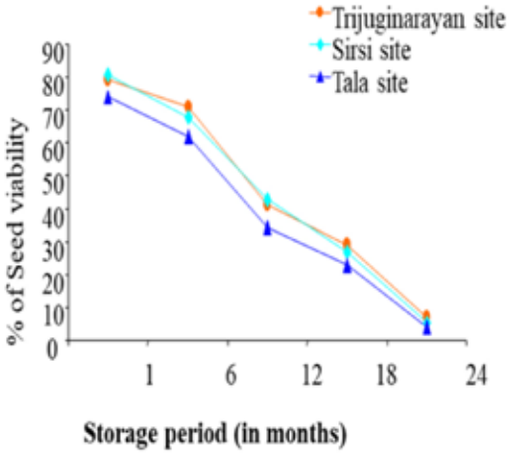

Fig. 1. Changes in seed viability of *Viburnum* mullaha during the passage of time at 4°C

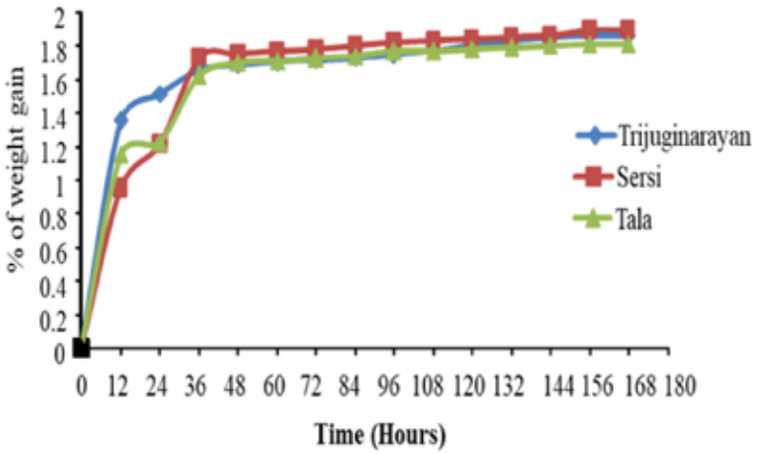

Fig. 2. Water imbibitions by seeds of *Viburnum mullaha* with time at 25°C under dark conditions

20, 30°C) in incubator at 24 hr light condition for 107 days to monitor the germination percent. The germination of seeds was observed only at 10°C temperature, while no germination of *V. mullaha* of the seeds detected at 20°C and 30°C. At 10°C seeds from Trijuginarayan site exhibited maximum germination (71.25±3.65%) followed by Sersi site (64.75±2.65%), whereas, seeds from Tala site showed minimum seed germination (56.75±2.11%). The experiments were further extended to break the physical dormancy of *V. mullaha* seeds through simulation of alternating temperatures with 12 hr light and 12 hr dark conditions. Among the alternating temperature regimes viz., 10°C and 20°C, 10°C and 30°C, 20°C and 30°C, at 12 hr light and 12 hr dark conditions, germination was found only at two alternative temperatures i.e. 10°C and 20°C, and 10°C and 30°C, while at rest of the alternating temperatures no seed germination was recorded.

At alternating temperature of 10°C and 20°C, seeds collected from Trijuginarayan site exhibited maximum germination (58.75±4.23%) whereas, minimum seed germination (18.75±1.54%) was recorded for the seeds collected from Tala site on temperature alternation of 10°C and 30°C (Fig. 3). Among the mechanical and hormonal treatments, soaking seeds in GA_3 10, GA_3 50 and GA_3 100 ppm and stratified for 50 days did not germinate. Though, under similar observations, when seeds were treated with GA_3 10, 50 and 100ppm and stratified for 100 days, GA_3 50ppm exhibited maximum germination (92.5±4.84%) was detected in the seeds collected from Trijuginarayan site whereas, minimum (66.5±3.56%) germination was recorded for the seeds collected from Tala site (Fig 4).

DISCUSSION

Natural regeneration of a plant species depends on the production of viable seeds, subsequent germination and successful establishment of seedlings. A number of physiological and biochemical processes are essential for retention of seed viability. Viability can be lost through the denaturation of water binding proteins and other stored metabolites if seeds

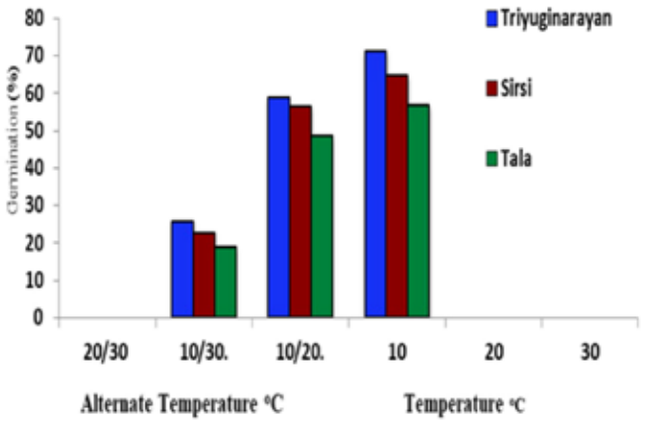

Fig. 3. Effect of different temperature regimes and alternating temperature regimes with light and dark conditions (12hr light and 12hr dark) on seed germination of *V. mullaha*

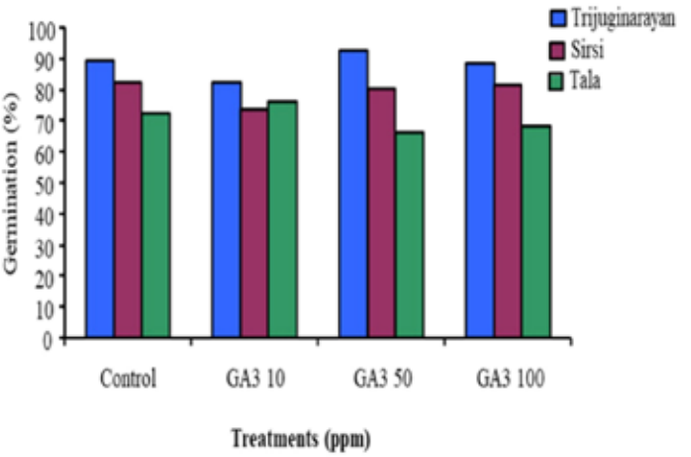

Fig. 4. Effect of different concentrations of GA3 at 10 °C on seed germination of *Viburnum mullaha*

are dehydrated too rapidly during early stage of germination (Roberts *et al.,* 1973). In present study, it was observed that seeds of *V. mullaha* remained viable for longer durations with declining viability (Fig. 1). The TTC test indicated that the seeds collected from different sites remained viable up to two years (730 days). Therefore, the result of present study highlighted that highest percentage of viability in the seeds can be achieved if seeds stored for one month, whereas, however, gradual decline in viability was recorded on long storage of seeds. After storage period of 365 days (one year) the decline in viability (40.47±2.32%) of the seeds collected from Tala site was observed whereas, seeds from Sersi and Trijuginaran sites revealed similar decline in viability (38.76±1.89%). In present study, the viability of *V. mullaha* seeds was observed to be decreased drastically after 6 month of storage. Finally, the viability decreased up to 4-7 % after 2 years (Fig. 1). Thus, it was noticed during the investigation that seed viability of *V. mullaha* decreases significantly with passage of time after collection.

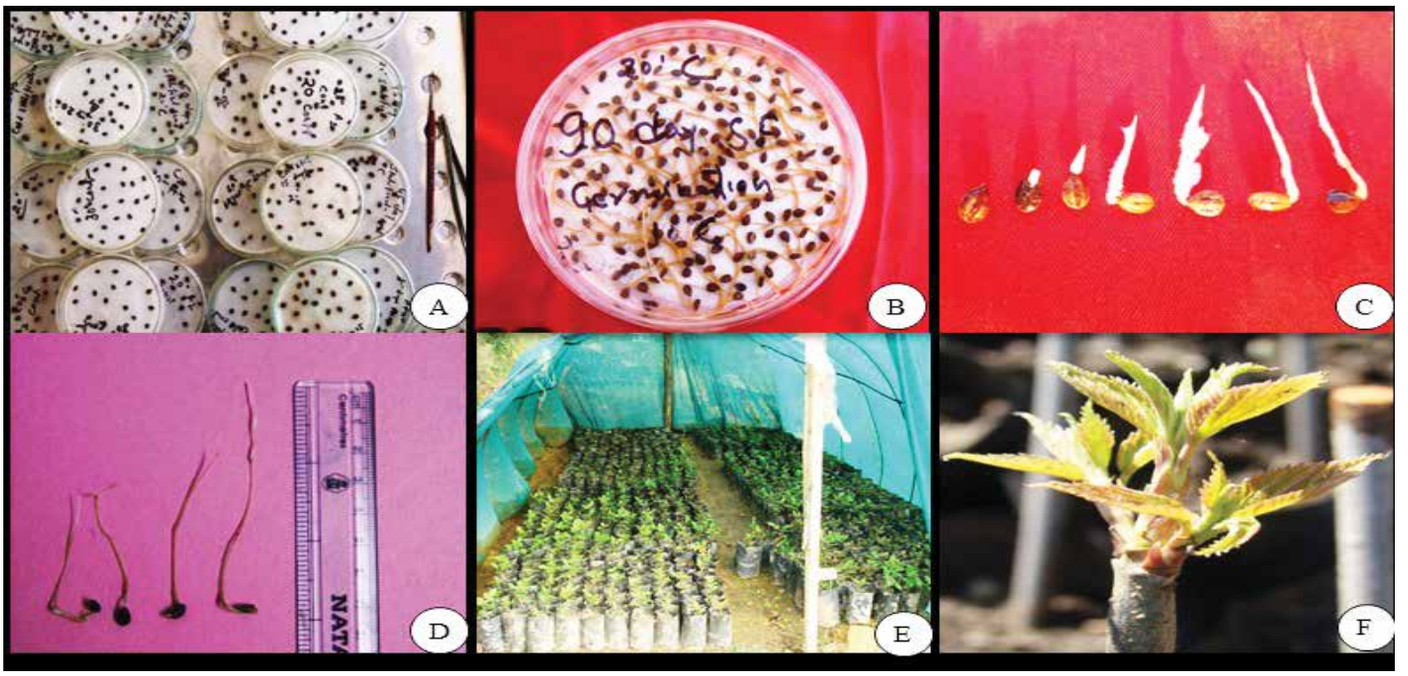

Fig. 5. Seed germination trials of *Viburnum mullaha:* **(A)** Healthy seeds for germination experiments **(B)** Initial stage **(C)** Different stages of germination. **(D)** Seed showing radical growth **(E)** Open nursery development **(F)** Healthy sprouting

Slow rate of water absorption in (144 hr to attain final plateau) the seeds of *V. mullaha* collected from three different natural sites (Fig. 2). These findings are in agreement with the earlier studies reported that pulp affects germination by preventing imbibition due to its imperviousness, high osmotic pressure from dissolved sugars, or by containing germination inhibitors (Mayer *et al.,* 1989). In present study pre sowing treatments of *V. mullaha* under different constant (10°C, 20°C, 30°C) and alternating temperature (10°C and 20°C, 10°C and 30°C, 20°C and 30°C) regimes revealed maximum germination in the seeds collected from Trijuginarayan site at 10°C, whereas, minimum germination was recorded for the seeds collected from Tala site (56.75±2.32%). Seed germination was found only at 10°C, while at 20 and 30°C seed germination did not occur (Fig.3). Seed germination in *V. mullaha* takes long time (107) days to develop and emerge out radical. Seeds of many plant species have under developed embryos at maturity (Martin 1946), and studies on these species have shown that *V. lantana* and *V. tenus* embryo growth is a prerequisite for germination (Baskin *et al.,* 1998). Embryos may be non-dormant or dormant at the time of seed dispersal. If embryo growth and radicle emergence are completed at suitable temperatures in about 30 days, without a dormancy-breaking treatment, seeds have morphological dormancy (MD). Deep simple, epicotyl, morpho physiological dormancy (MPD) has been documented in seeds of *Viburnum* species by (Giersbach 1937). Studies revealed that the seed storage at low temperature for long period does not affect the viability; however, storage under high humidity badly affects the seed germination (Baskin *et al.,* 1998).

Hormonal treatment in this study showed that the treatments of GA_3 substantially enhanced seed germination in the seeds stratified for the period of 100 days, whereas, the seeds stratified for 50 days and treated with GA_3 at different concentration were not germinated. The seeds stratified for the period of 100 days showed better germination results. Maximum germination was recorded for the seeds collected from Trijuginarayan site (92.51±3.62%) treated with GA_3 (50ppm), whereas, minimum germination was observed for the seeds from Tala site (66.5±2.53%) under similar treatment. Studies have shown that application of GA_3 promote seed germination by breaking dormancy in a wide range of seeds in wild edible and medicinal plant species (Bradbeer 1988), and the efficacy of GA_3 to enhance germination is already been demonstrated in several studies (Singh *et al.,* 1987; Pandey *et al.,* 2000).

CONCLUSION

Domestication of *V. mullaha* has a good potential in the study area as this species will not only improve the economic condition of the local people but will also help in the conservation of biodiversity.

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SUITABILITY OF CLASSIFICATION APPROACHES OVER THE VERY HIGH RESOLUTION PLEIADES SATELLITE IMAGERY OF 0.5M FOR A PART OF DEHRADUN, UTTARAKHAND

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ABSTRACT

Recent advancement in the field of satellite based data acquisition has enabled the sensors to capture the information of earth surface with the effective resolution of sub-metre scale. Pleiades-1A is the satellite platform of Airbus Defence and Space, France. Pleiades 1A is an optical satellite constellation providing very high-resolution products (50cm) with a 20km swath and a dynamic range of 12 bit for high detection capabilities. Extracting the features captured in the satellite imagery can be optimized if the best suitable approach of classification can be established. Traditional approach of pixel based classification has been proved effective in classification of coarser satellite data products of spatial resolution of more than 10m. However, the object based classification is also required to be tested for extraction of feature along with pixel based approach so as to perform the comparative analysis of the results. The paper discusses about the effectiveness of various classification approaches on very high resolution satellite imagery (VHRSI) Pleiades having the half metre spatial resolution through the accuracy assessment for a part of Dehradun (Uttarakhand).

Keywords: Pleiades 1A, Very high resolution, Pixel based classification, Object based classification, VHRSI

INTRODUCTION

Very high resolution satellite imagery (VHRSI) presents the detailed information of the earth surface. VHRSI may be referred to the satellite datasets having the resolution of the order better than 1m. However, to extract the features present in the satellite imagery, suitable classification approach is essentially required. Classification approach may differ with respect to process involved but the objective remains the same to extract the information in the form of Land Use Land Cover Classes. The popular pixel based approach of classification involves three types of classification supervised, unsupervised and hybrid approach that classifies the image at pixel level. However, VRHSI represents a feature through combination of pixel of varying digital number (DN) unlike low resolution satellite imagery where the single pixel represents numerous features. Other than the pixel based classification, object based classification segments the image into objects and instead of pixel level, the image is classified at object level. Weih *et al*., (2010) highlighted that for medium to very high resolution satellite imagery, the object based classification outperforms the pixel based classification methods as Object-based classification methodologies that take advantage of both the spectral and contextual information in remotely sensed imagery. The object-based method has outperformed the pixel-based method for both high and medium spatial resolution satellite images in the urban and sub-urban landscapes (Estoque *et al*., 2015).

In order to study the problems such as urban sprawl, infrastructure augmentation over a period of time, etc., detailed information of the earth surface for a period of time (temporal datasets) is required. Therefore, the theme of the study actually decides the spatial resolution of the imagery that would be required. With coarser resolution, a user can study the larger cluster of built up area only and the dispersed built ups or even the new clusters which are less than the spatial resolution of satellite imagery are not captured. However, for studying the problem of urban sprawl for a particular area especially in the hilly terrains as that of IHR where the built ups are not constructed in clusters and over the period of time the built ups are constructed in the discrete pattern, low resolution dataset does not yield better results for precise calculation. In case of dispersed expansion of settlements, there is the need of high resolution

imagery because the coarser resolution of even~10m would be missing the information of built ups having the dimension of less than 33ftX33ft on ground. These built up features are represented as impure pixels having the average reflectance of nearby surroundings as well. For such study, data products with resolution better than 1m may be utilized. Temporal sets of such datasets can further help in identification of rate of urban sprawl, change detection, etc. with high level of accuracy. A remote sensing application to estimate population based on the number of dwellings of different housing types in an urban environment (single-family, multi-family), usually requires a pixel size ranging from about 0.25 to 5m for identification of the type of individual structures (Jensen *et al.*, 1999). Similar type of study conducted in Quick Bird data reveals that object-based classifier produced a significantly higher overall accuracy~90% whereas the maximum likelihood classifier produced~67% (Myint *et al.*, 2011). This paper is therefore, designed to give the insight to the user about practical aspect of approaches of pixel based as well as object based classification taking the case study of a part of district Dehradun (Uttarakhand).

METHODOLOGY

Study area

Dehradun, mainly lies in Doon valley at an elevation ranging from 400 to 700m having an area of 3088km^2, out of which 2200.56km^2 is covered by forests. The population of the district is 1.7 million as per Census 2011. This district consists of six tehsils (viz. Dehradun, Chakrata, Vikasnagar, Kalsi, Tiuni and Rishikesh); six community development blocks (viz., Chakrata, Kalsi, Vikasnagar, Sahaspur, Rajpur and Doiwala); 17 towns and 764 villages. Out of total villages, 746 villages are inhabited and 18 are uninhabited. The city shares its boundaries with national parks and forest area. The Dehradun city was declared as the capital of Uttarakhand in November 2000. Since then the region has been witnessing huge growth of urban colonies in outskirts of Dehradun at the expense of mainly agricultural land parcels. This study includes a smaller area of approximately 80km^2 due to high cost of imagery of a part of the Dehradun city (Latitudes 30.2294 to 30.3045 and Longitudes 77.141 to 77.993) and depicted in Fig. 1.

Data sets used

For the purpose of extracting the features from very high resolution satellite imagery using different approaches of pixel based classification and object based classification, pansharpened multispectral 4-band (Blue, Red, Green and Infrared) product of Pleiades 1 A satellite sensor data having 0.5m spatial resolution has been used. The bundle data product contains multispectral data at 2m with red, green, blue and infrared bands and panchromatic data at 0.5m. The imagery is pansharpened to generate the multispectral data products at 0.5m. The image obtained is free from errors and therefore does not require any image correction or enhancements. Moreover, the image is also orthorectified which is necessarily required when the terrain is undulating or hilly.

As evident in (Fig. 1.), the detailed information at the building level, the road networks, etc can be discriminated easily in the imagery. As the resolution increases, more information is available in the datasets and the user can therefore extract more number of classes and perform detailed level of classification such as local road networks, which otherwise at lower resolution would have misinterpreted to other classes in case of coarser imagery.

Image classification

Satellite imagery may be classified to extract the content or features associated in the imagery based on the training datasets or class assignments provided by the users. Classification of the imagery is necessary so as to extract the relevant information from the imagery and moreover to calculate the statistics of the features being classified such as area, perimeter, etc. Such studies find tremendous application when the temporal changes of the land use and land cover of the area is to be studied. The overall objective of image classification procedures is "to automatically categorise all pixels in an image into land cover classes or themes" (Lillesand *et al.*, 2008)

Most common approach to classify the imagery is the pixel based classification such as supervised, unsupervised and hybrid approach. The satellite imagery provides the raster datasets which is arrangements of the pixels in rows and columns. Each pixel represents piece of information of the real ground feature and is assigned a digital number (DN) for each of the bands in the imagery. For rendering any image to its true colour format, the natural colour composite (NCC) of the image is prepared by assigning the red, green and blue palette layer of the software package to the corresponding red, green and blue band imagery in the data product. In Pleiades imagery, bands 1, 2 and 3 were assigned blue, green and red layer, respectively to represent as natural colour.

Object based classification is advanced approach of classification. Unlike the conventional approach of pixel

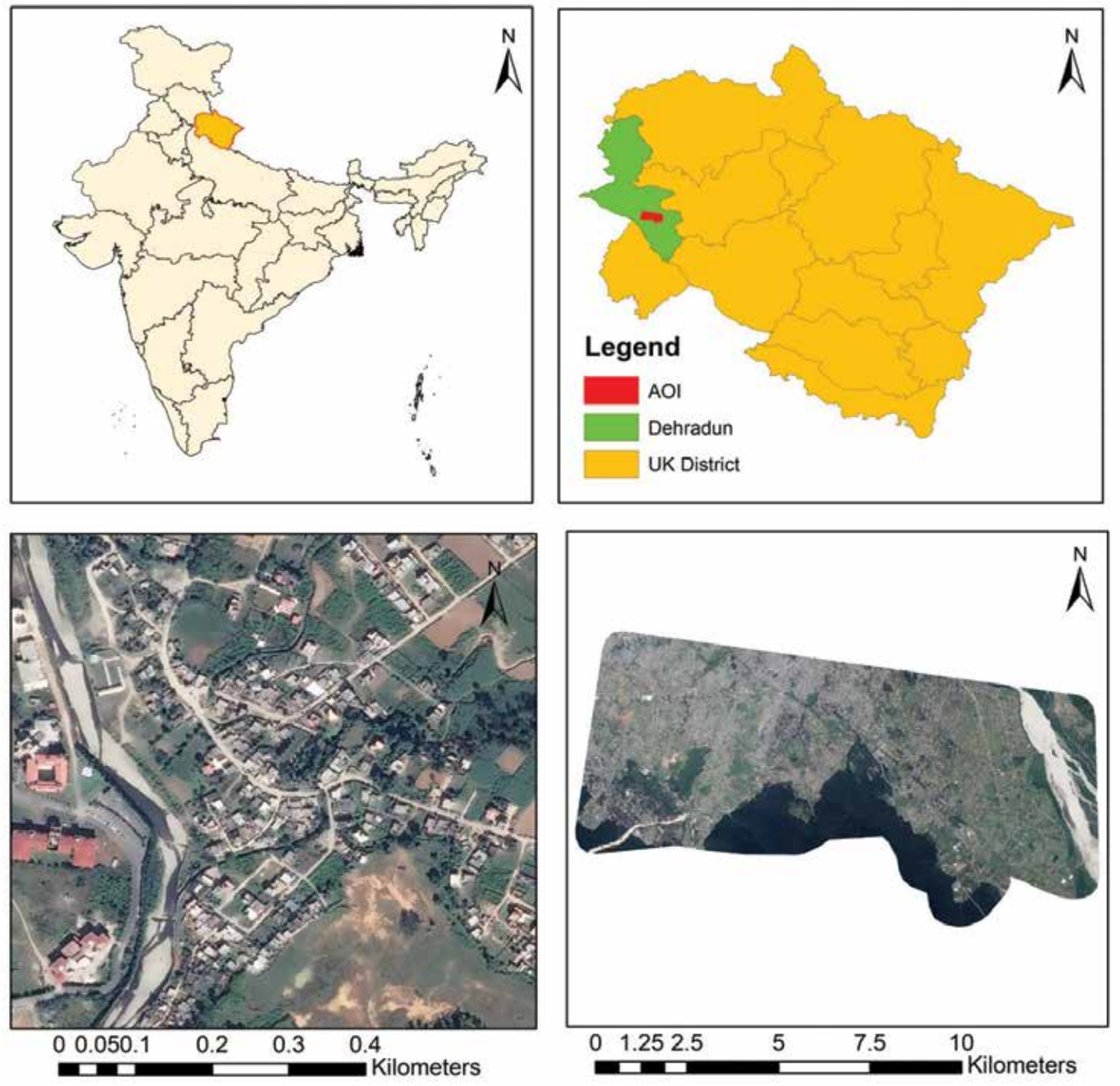

Fig. 1. Location map and high resolution image of the study area

based classification where the pixels are the basic unit for classification, object based classification involves the process known as image segmentation, the image is segmented by grouping the homogeneous pixels into objects and these objects acts as the basic unit of classification. For calculation of the area and perimeter of the region, the satellite imagery is required to be projected. In our case the UTM 44N has been selected as the region falls within the 44N zone of UTM projection along with WGS 84 coordinate system.

Accuracy assessment

Irrespective of classification approach adopted viz. Pixel based or object based classification, it is essential to perform the accuracy assessment of the classified imagery. It is achieved

by generating random points over the classified imagery. The coordinates of these known points are extracted and the user then performs the ground truth for its actual class (truth) in the real world and vice-versa is also possible. Based on this, an error matrix is generated which is typically a square matrix where the random points over the classified imagery is compared with actual feature on the ground. The matrix stores the information of random points for each reference class on ground against its correct classification and misclassification. For example out of total hundred random points generated for the study area, 10 random points were generated for reference class "Builtup" and ground truth reveals that out of these 10 points, only 8 were correctly classified, one point is misclassified as urban actually belongs to water body and another one misclassified should have been classified as open. The correct classification is represented by Users Accuracy and the misclassification will be represented by error of commission. There can be another scenario where some of the feature of other classes have been misclassified as Builtup making the number of Builtup features more than the real ground. Such type of accuracy is given by producer's accuracy and extra erroneous addition of other feature is represented by error of omission. So, a table representation is prepared known as error matrix stores such information.

Scheme of image classification

The pansharepened satellite data product for Pleiades at 0.5m 4 band multispectral imagery (red, green, blue and infrared bands) has been used for study area to classify the imagery using the pixel based approach (supervised, unsupervised and hybrid classification) and object based classification approach. The satellite image was found to contain seven different features such as Vegetation, Shadow, Water, Builtup, Open, Road, and Forest/Tree.

For supervised classification, a signature file is required to be created. Approximately 25 samples were picked from satellite imagery for each of seven classes to be classified. These samples were merged to create a mean signature for individual classes. The output of the classification is represented in Fig. 2(A).

For unsupervised classification, Isodata method of classification was used. The algorithm requires the expected range of spectral classes in which the imagery will be classified. For our study, range of classes to 140–150 was provided. The algorithm classified the satellite imagery into 150 spectral classes based on the pixel value of individual pixels. The classified image is superimposed on satellite imagery and all the 150 classes were interpreted individually for their reassignment to the most suitable ground classes out of total seven in which the complete imagery is required to be classified. Once the renaming was completed, all the hundred and fifty classes were 'Recoded' to only seven classes finally. The output of the classification is represented in Fig. 2(B).

For hybrid approach of classification, the samples of the different features on the map were provided as the training data to create a signature file similar to that of supervised classification. But the signatures for a particular class was not merged which is to be done in supervised approach. Therefore, hybrid approach is different from supervised classification in the total number of samples in the signature file which in case of supervised method is equal to the total number of classes (in this case 7) in which the image was to be classified, for hybrid it is the sum total of all individual samples across all the classes. For this study on an average 20 classes were sampled under individual category making the total samples in signature file around 140 for different 7 classes. After the classification is performed and the image is classified into 140 classes, these classes are recoded similar to the unsupervised classification into final seven classes. So the method utilizes the approach of supervised classification in preparation of signature file and of unsupervised classification in recoding the output of the classification into the final desired classes. The output of the classification is represented in Fig. 2(C).

For object based classification, multiresolution segmentation was used to segment the imagery at pixel level optimizing the scale parameter, shape and compactness. A layer weight of (1,1,1,2) was assigned for achieving the segmentation (weight of 2 was assigned to infrared band). A scale parameter of 25, Shape value 0.1 and compactness value of 0.2 were tuned to achieve the initial segmentation at pixel level. It may be noted that the multiresolution segmentation can be performed both at pixel and object level. However, initial segmentation is done at pixel level only whereas the subsequent segmentation can be performed over existing segmentation at object level as well.

Therefore, initially the segmentation was done to create the objects of smaller size so that the extraction of simpler and easier feature could be achieved with high precision. Vegetation, shadow, water-bodies and peculiar buildings having hue of red, green, blue or white (reflecting) rooftops were extracted initially. The remaining imagery was resegmented at object level again using the multiresolution segmentation but with higher scale

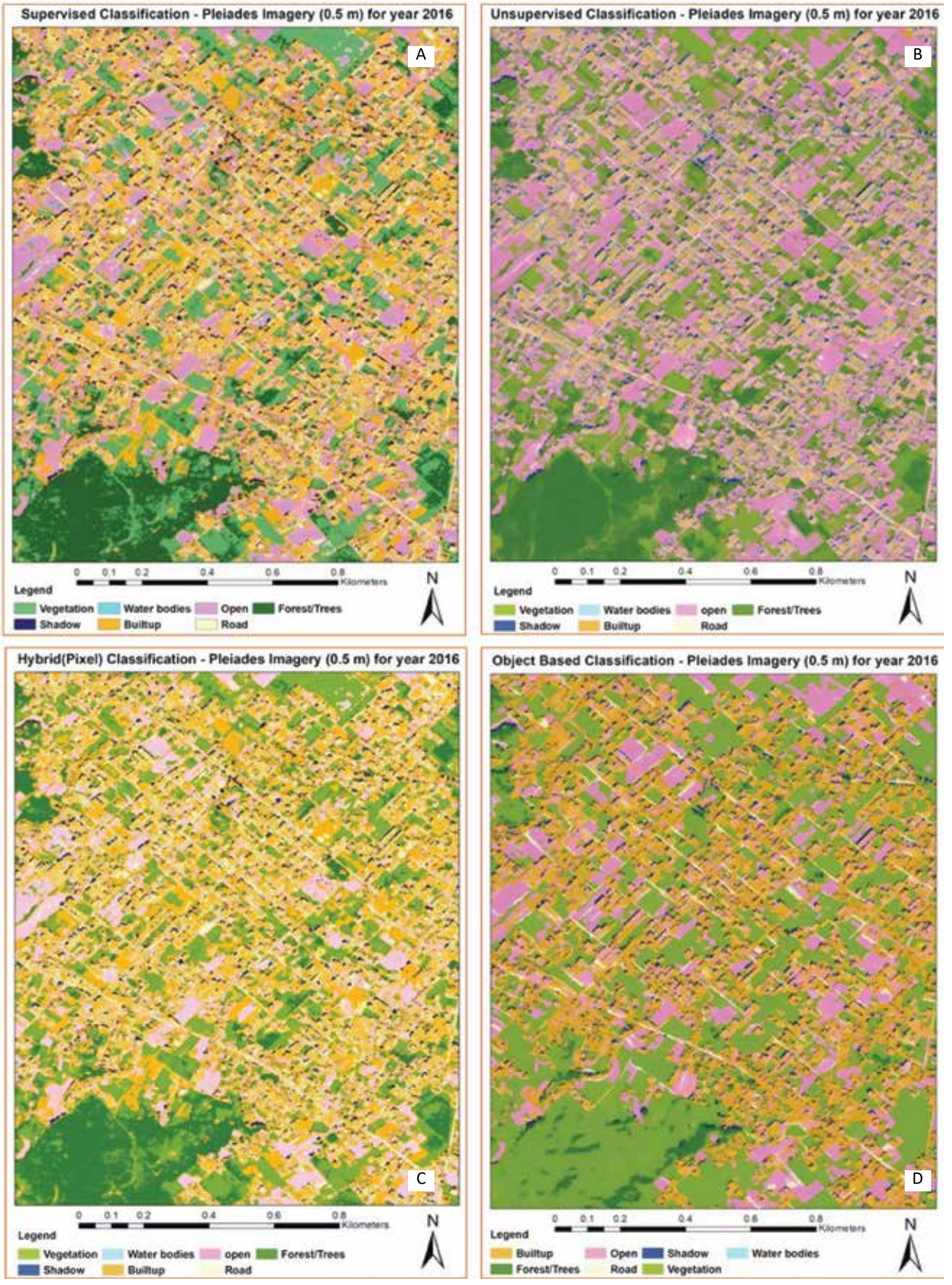

Fig. 2. Classification outputs using four different approaches

so that the bigger objects may be identified which normally includes the objects of individual builtups, builtups cluster, open areas, industrial areas and road features. Extraction of larger features is bit complex process as certain features may interfere or their feature values intersect with two or more classes eg. Features of road, builtups and open areas may interfere with each other. Also in earlier case the features of shadow interfered with the features of water bodies. The output of the classification is represented in Fig. 2(D).

It may be noted that all the misclassifications cannot be completely avoided. However, using other existing feature values and also using these values to customize the new features values, the extraction may be optimized to much better accuracy. A Table 1 is presented below along with the features values that can be utilized to extract the features from the satellite imagery.

Table 1. Important parameters for object based extraction

S.N	Feature to be extracted	Important Feature values	Interfering Features
1	Vegetation	NDVI*	Some blue and green rooftops may be misclassified
2	Shadow	Brightness	Water bodies such as drainage may be misclassified
3	Water	NDWI#	Shadows can be misclassified
4	Builtup	Ratio layers (Infra red Band); Builtup index	Some open areas including Road are misclassified
5	Open	Standard deviation, geometrical features: Area, customized features	Some homogeneous larger rooftops are misclassified
6	Road	Geometrical Features: Density, Shape index, Asymmetry, Length/width ratio	Some industrial buildings and other rectangular rooftops are misclassified
7	Forest/Tree	NDVI for a particular range	Nearly give optimum results

*NDVI = $((Band_{NIR} - Band_{RED})/(Band_{NIR} + Band_{RED}))$; #NDWI = $((Band_{NIR} - Band_{Blue})/(Band_{NIR} + Band_{Blue})$

RESULTS AND DISCUSSION

The classification of the imagery was performed using the four different approaches that are supervised, unsupervised and hybrid based pixel based classification and also using the object based image classification. In order to verify the agreement of the classification with the real ground values, 259 points were randomly generated onto the map for validation with ground points. An error matrix was prepared for individual classification scheme and their users and producers accuracies were established along with their respective error of omission and error of commission. Moreover, the Kappa statistics were also derived for each classification scheme. Table. 2 highlights the performance of individual approach of classification and presents the comparative assessment of deviation in their accuracy.

Table. 2. Summary of Accuracy and Kappa value of four different approaches

Approach	Users Accuracy	Producers Accuracy	Overall Accuracy	Kappa Coefficient
Supervised	66.68	66.16	68.34	0.62
Unsupervised	47.45	47.11	47.88	0.39
Hybrid	51.34	57.02	47.49	0.39
Object Based	**86.35**	**85.34**	**87.26**	**0.85**

It is evident from Table. 2 that object based classification outperforms the accuracy of pixel based approach. Among the different approaches of pixel based classification, supervised classification comparatively performs better and yielded ~69% accuracy on the contrary hybrid approach performed worst and yielded only ~48 % accuracy. The reason of poor performance of hybrid approach may be attributed to the fact that the different signature created for road, builtup and open classes

interfered with each other as they could not be merged. Also, the signature of green roof tops were misclassified green signature of vegetation. Similarly there were misclassification between shadow and water as well. Therefore, the method yielded poor performance over supervised classification that merges all the spectral signatures for individual classes. Most importantly, the object based classification performed nearly equally good for all seven classes. Some misclassification has been also observed in OBIC between builtup, open and road but the degree of misclassification is significantly reduced than those for pixel based approach. The area distribution of all seven different classes classified under the land use and land cover classification for the study area through object based classification approach and its corresponding percentage to the total area is described under Table 3.

Table. 3. Land use land cover distribution in the study area derived using object based classification

S.N.	Class name	Area (m^2)	Area (km^2)	Percentage Area
1.	Builtup	14400992.8986	14.40	18.36
2.	Forest/Trees	16882026.8421	16.88	21.52
3.	Open	10522611.1407	10.52	13.42
4.	Road	2495510.4413	2.50	3.18
5.	Shadow	4053058.7269	4.05	5.17
6.	Vegetation	30055451.0333	30.06	38.32
7.	Water bodies	22470.8534	0.02	0.03

The work can be extended to the entire Dehradun district based on the availability of satellite imagery as VRHSI is bit costly. But if the detailed studies are required such as builtup density, urban sprawl, temporal assessment of LULC variation with high accuracy, the Pleiades 1A imagery may be effectively used and can be classified with high accuracy using the object based image classification technique. Moreover, there is always the chance to improve the ruleset by bringing in more features and mathematical values to further improve the accuracy even better than 90%. The 0.5m satellite datasets also give conspicuous details of the shadow of the builtups and also can be extracted effectively from the imagery. Based on the metadata of the data product such as time of acquisition, sun zenith angle, etc. the shadow can be utilized to perform the analysis of number of storeys of the individual builtup area based on the relationship of the object of the shadow with the object of the builtup. This will address the limitation of remote sensing based observation where only the area of the builtup can be calculated which is same for single storey and multiple storeys buildings.

CONCLUSION

High resolution satellite imagery of Pleiades at 0.5m resolution presents the detailed information of the earth surface. The 4 bands of the pan sharpened imagery may be effectively used to extract the detailed information in the imagery to extract the features of the satellite imagery with high accuracy. It has been observed that due to similarity of spectral signature among classes such as builtup, open and road; shadow and water pixel based approach is not much effective to distinguish between these similar spectral classes as the algorithm solely relies on individual DN value only. Moreover, a feature is represented by many number of pixel, therefore the chances of misclassification is also increased at pixel level. On contrary the object based classification segments the image into objects where each object contains full or part of homogeneous feature that is easier to distinguish applying the existing parameters or through customized arithmetic features of the application. Different algorithm further helps to manipulate the objects as per the need of the user to yield much higher accuracy. It is therefore concluded that OBIC is most effective method to classify the multispectral 4 band high resolution Pleiades dataset at 0.5m. The accuracy can also be further improved, if ruleset is refined further in future and if high resolution digital surface model (DSM) data is also integrated with the imagery. The study also reveals that among approaches of pixel based classification such as supervised, unsupervised and hybrid classification, the supervised classification approach worked the best yielding the accuracy of ~69%.

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HABITAT EXPANSION OF WHITE RUMPED MUNIA (*LONCHURA STRIATA*) IN WESTERN HIMALAYAN REGION OF UTTARAKHAND

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Climate change is one of the greatest environmental issues in the world in recent decades. It has been estimated that the current rate of greenhouse gas emissions will be responsible for the rise in global temperature from 1.5 to 4.5°C by 2100 (IPCC 2018). This rise in temperature has affected the climate pattern causing effect on biotic and abiotic components of the ecosystem. IPCC (2018) report emphasized that climate change is impacting species distribution, population size and the timing of reproduction and migration. Climate change and habitat loss are the two greatest threats to biodiversity in the present century (Jetz *et al*., 2007). The western Himalayan region of Indian Himalayais recognized for its biological diversity and ecological values. This area has been recognized as the Endemic Bird Area (EBA 128) by BirdLife International (Stattersfield *et al*., 1998). Rich abundance and diversity of avifauna attract the researchers, scientist and bird watchers in the Himalaya region.In this articleobservations made in Uttarakhand are shared which indicate the habitat expansion of avian species from the Sothern part of India to the Northern part (Himalayan region). However, it is very early to say that habitat extension is happening only because of climate change. However, such observations are evidence of the long-term effects of climate change on avian fauna.

Thus stusdy is based on a survey conducted between 2013 and 2018 at Doon valley forests, Uttarakhand, focusing on "White-rumped Munia (*Lonchura Striata*)". The White-rumped Munia belongs to Estrildidae family and has approximately 140 species which are widely distributed across the world. The size of this bird is about 10–11cm with dark breast, streak upperparts, white rump, and faint brownish streak with the grayish buff belly (Fig. 1). In India, this species is widely distributed (breed/ residence) in some states India viz. Kerala Tamil-Nadu, Odisha, Assam, Guwahati, Goa and some districts of Maharashtra, and Madhya Pradesh (Khot *et al*., 2016; Satose *et al*., 2018; Saikia *et al*., 2011; Purkayastha, 2018; Desai *et al*., 2012; Praveen, 2015; Ramesh *et al*., 2012; Pradhan, 2013).

Fig. 1. White-rumped Munia (*Lonchura Striata)* founded in Dehradun

In Uttarakhand, the first record of White-rumped Munia is in the Tarai region of the Nainital district, in 1900 by Walton HJ, a British forester. Afterwards, Indian ornithologist Salim Ali reported it in a wide sub-Himalayan belt on the eastern side of Garhwal (Ali 2012). Many scientific notes and checklists have introduced the presence of White-rumped Munia species in Dehradun district (Singh 2002; Vijay *et al*., 2010; Joshi *et al*., 2015). On the other hand for the first time we reported White-rumped Munia with their juveniles, in November 2013, April 2015, June 2016 and May 2017 in Chamoli district of Karanprayag (500m), Tharali (665m) and Nandprayag (856 –1,010m) region (Joshi 2018). The presence of This bird in the Chamoli district (Uttarakhand) indicates that the species range is extending in the hilly area of Uttarakhand. However, the weather data (secondary database) from the open sources

indicate that temperature of this region has increased by about 0.24 °C between 1991 and 2015. This increase in temperature may be one of the causes behind habitat extension of White-rumped Munia from the southern part of India to the Northern part of India especially in the Himalayan region of Uttarakhand. However, a systematic and periodic study is required in this region in order to understand the effects of increasing temperature in avian habitat expansion.

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PROMOTING CONSERVATION OF THREATENED PLANT SPECIES IN WEST HIMALAYAN REGION THROUGH CULTIVATION- A PARTICIPATORY APPROACH

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INTRODUCTION

Indian Himalaya is a biodiversity rich region and constitutes a large portion of the Himalayan Global Biodiversity Hotspot (Singh 2002; Palni *et al*., 2010). The rich plant biodiversity of this region having approximately 18,440 species of flora are used as medicine, wild edible, fuel, timber, etc. by the local inhabitants (Singh *et al.,* 1996; Pant *et al.,* 2010). Over, 1748 species of Himalayan plants have been recognized for their medicinal uses. Moreover, 700 medicinal plant species are being used by pharmaceutical industries in India of which about 50% species are from the Himalayan region (Kala 2015). These medicinal and aromatic plant species (MAPs) have been recognized as important resources in traditional medicines as well as pharmaceuticals, cosmetics and herbal industries (Kala 2015). Global market of herbal products is continuously expanding and it is expected to touch the mark of US$ 5 trillion by the year 2050, from the US$ 62 billion in 2004. Despite being major traders, the share of India in global trade of MAPs is only 0.5 per cent.

The high demand of medicinal plants, commercial trade, over-exploitation, over-grazing, climatic uncertainties and others factor have led to the over-harvesting of many plants from the wild, which subsequently results in the loss of their existing populations and face the threat of extinction (Reed *et al*., 2011). The continued exploitation of several medicinal plant species from wild and substantial loss of their habitats due to restricted distribution have resulted in population and biodiversity decline. Therefore, conservation initiatives for medicinal plant requires immediate attention and a number of agencies are recommending that wild species be brought into cultivation systems (Lambert *et al*., 1997). Globally, China, Hungary, Europe are centres of the cultivation of medicinal plant species (Schippmann *et al.,* 2002), and more than 400 plant species used for production of medicine by the Indian herbal industry, fewer than 20 species are currently under cultivation in different parts of the country (Uniyal *et al*., 2000). Therefore, cultivation of medicinal plants and their management becomes highly remunerative both in financial as well in economic terms for the small-scale growers (Phondani *et al*., 2016). A major bottleneck in medicinal plant cultivation is lack of suitable agronomic practices and limited awareness of farmers. This article give an account of awareness programmes organized in Chaundas valley located between Kali and Dhauli rivers in the border region of Dharchula Tehsil, (Pithoragarh District of Uttarakhand) having the altitudinal range between 2000 to 3800m asl. The main objective was to motivate farmers for cultivation and conservation of prioritized high value medicinal plant species through sharing of technical knowledge for cultivation and marketing,

METHODOLOGY

Pre-structured questionnaire survey was conducted to know the knowledge and status of medicinal plants cultivation in the area. The survey was conducted in 5 pre-scheduled places of different villages covering maximum area of the valley and overall 11 villages were covered. To get more brief information about medicinal plants we selected different age interval of local peoples i.e. (18-40, 41-60 and 61-80 years and above). Questionnaire includes question like: (i) knowledge of medicinal plants growing in their forests, (ii) ethnobotanical uses of medicinal plants, (iii) application of medicinal plants in treatment of diseases, (iv) reasons of decline of medicinal plants in natural habitat, (v) export to herbal mandis or to traders, (vi) cultivation practices in use for medicinal plant, and (vii) local perception regarding conservation and management practices (e.g., undertake research for cultivation, sustainable harvesting, raise awareness on conservation and control grazing etc.) (Fig.1).

Based on information obtained from questionnaire survey data was analysed for village specific species prioritisation for cultivation. Based on the survey, it was observed that villagers are well aware about the abundance and uses of the medicinal plants of the region (Fig. 1).

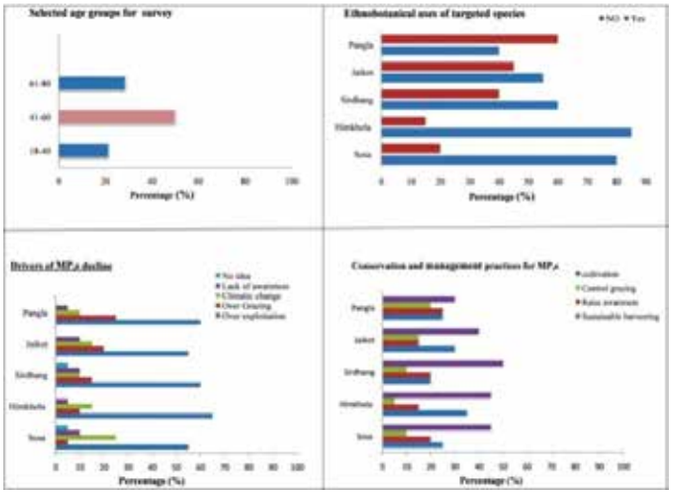

Fig.1. Analysis of Pre questionnaire survey

RESULTS AND DISCUSSION

A pre-structured questionnaire survey was conducted in the different villages namely Himkhola, Pangu, Sirkha, Sridang, Rung, Sosa, Chhalma- Chhilanso, Niyang and Pasti. A total of 196 participants (approx-50% females) attended a consultancy meeting organized by us. The discussion indicated that indigenous communities are well aware regarding importance of medicinal plants, their abundance and utilization in traditional and modern medicine system, etc. The main target of the meeting is to sensitize the community towards cultivation, sustainable utilization, and conservation of the medicinal plant species. Selection of the area was based on (i) natural habitats for medicinal plants, (ii) dependency of villagers on agriculture and natural resources and (iii) availability of land for developing medicinal plant cultivation demonstration site. During the interactions with local people and, institute scientists highlighted major issues for medicinal plant status (rare or endangered category) due to anthropogenic pressure, habitat destruction, unscientific collection of plants, etc. People were also assured about providing planting materials, technical support during land preparation, plantation and collection of the species in their agriculture land and collaboration with diverse private and government agencies for buy-back system. Total seven medicinal plant species namely, *Allium stracheyi* (jambu), *Angelica glauca* (Choru), *Cinnamomum tamala* (tejpata), *Hedychium spicatum* (van haldi), *Picrorhiza kurroa* (kutki), *Saussurea costus* (koot) and *Valeriana Jatamansi* (samyo) we are prioritized for large scale cultivation based on suitable habitats, market demand, conservation value, status of the species in IUCN category, demands in traditional and modern medicines for preparation of various formulation/ products, etc. (Table 1).

Table 1. Prioritization of high value medicinal plant species for cultivation and conservation

Plant	Local name	Altitude (m asl)	Demand in India (MT/ year)	Status	Uses
Allium stracheyi	Jambu	3000-3600	40-50	Critically Endangered	Digestion, condiments
Angelica glauca	Choru	2100-3500	50-60	Endangered	Dysentry, gastric complaints, mennorrhea, stomach complaints, vomiting
Cinnamomum tamala	Tezpatta	500-2100	500-1000	Vulnerable	Used in rheumatism, colic, diarrhea, nausea and vomiting
Hedychium spicatum	Van haldi	1000-3000	300-400	Threatened	Anticancer, liver complaint, diarrhoea, asthma, dry cough
Picrorrhiza kurooa	Kutki,karoo	2800-4000	200-500 (416*)	Critically endangered	antibacterial, cathartic, laxative, stomachic and bitter tonic, hepatoprotective, anticholestati
Saussurea costus	Kuth	2800-3800	(100-200) 1192**	Extinct from wild	Used in asthma, toothache, dysentery, skin diseases, rheumatism, leucoderma, epilepsy, hysteria
Valeriana jatamansi	Mushkbala Samyo	1000-3000	100-200 (123**)	Threatened	Lipid lowering activity, antifungal activity, CNS activity

** Source: (*Ved *et al.,* 2008*); **Source: Centre for Research and Planning Action*

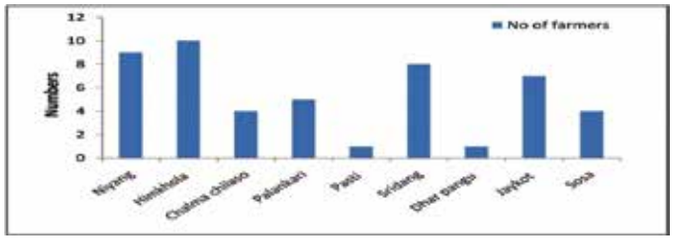

Fig.2. Farmers initiated cultivation of *Hedychium spicatum* in Chaudas area

This activity sensitized the local farmers of the region and initially, 49 farmers of targeted 9 villages started cultivation of *Hedychium spicatum* (Fig. 2).

Before plantation, a nursery was established and vegetative method was followed for its cultivation in well prepared plots in the farmer's fields. The rhizomes are cut into small pieces with apical buds and buried into mother beds in the nursery. Propagules sprout between 25 and 30 days after plantation and transplanted during April-May. The rhizomes are planted in furrows at a depth of 10–12cm, at an optimum spacing of 45 cm × 30cm. At this spacing, about 1100 propagules per nali will be required. Saplings should be taken for transplantation when they attain a height of 12–15cm and immediately planted in cultivation plots after uprooting them from the nursery bed. The crop is biennial and matures in the net season during October–November, depending upon the elevation. Dried leaves and stalks are removed after they turn yellow, while rhizomes are left in soil for about 20–25 days for ripening before it is dug out.

While discussing with participants about cultivation of medicinal plants following points were emerged: availability of planting material of medicinal plants, quality of medicinal plants, livelihood linkages of medicinal plants, trade of the medicinal plants, value addition of medicinal plants and regulations of medicinal plants.

The main occupation of these communities has been Trade, Sheep Rearing, Agriculture and collection of Medicinal herbs, with main emphasis on Keeda Jadi (*Cordyceps sinensis*) from Alpine meadows. Market linkages are important aspect for trading of medicinal plants for income generation, keeping this in view, a one day meeting was also organized at Dharchula for promotion and develops market linkage for selling of cultivated medicinal raw material and different stakeholders in which representatives of NGO's/ GoI and experts from different organizations participated. As an outcome of developed MoU with Human India, Srinagar and Surkanda Jadi-buti Bhejas Sangh, Bageshwar for selling farmers cultivated medicinal raw material. Also 9 farmers from different villages were registered under HRDI for the propagation of *H. spicatum*. A framework was presented incorporating various suggestions of this meeting for conservation, cultivation and income generation from medicinal plants (Fig. 3)

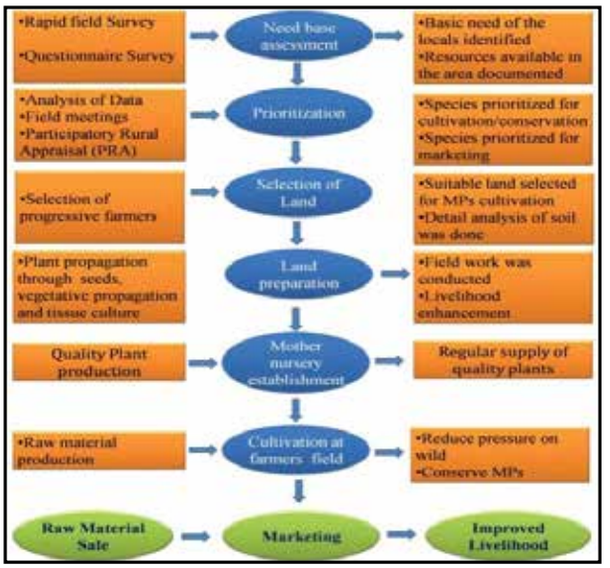

Fig. 3. Indicating activities through flowchart diagram

Fig. 4. Cultivation of *H. spicatum* in farmers land

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EFFECT OF LONG-TERM INORGANIC AND ORGANIC MANURE ON PHYSICAL AND BIOLOGICAL PROPERTIES OF SOIL IN UTTARAKHAND - A REVIEW

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ABSTRACT

This review summarizes the current knowledge on the effect of long-term inorganic fertilizers and organic manures on soil physical and biological properties. Most of investigators confirmed that combined application of inorganic fertilizers and organic manures are improved the physical and biological characteristics, and nutrient status of the soils. Long - term application trials results in increased soil organic matter concentrations. Organic fertilizer improves physical and biological activities of soil but they have comparatively low in nutrient content, so larger quantity is required for plant growth. However, inorganic fertilizer is usually immediately and fast containing all necessary nutrients that are directly accessible for plants. But continuous use of inorganic fertilizers alone causes soil organic matter degradation, soil acidity or alkalization, soil deterioration and environmental pollution. Combined application of inorganic fertilizers and organic manure has an alternative system for the sustainable and cost-effective management of soil fertility. The objective of the present review is to assess the effect of long-term chemical fertilizers and organic manure on soil physical and biological properties.

Keywords: Organic manure, Chemical fertilizer, Long-term management, Physical properties, Biological properties.

INTRODUCTION

The long-term field experiments are cogitate about to provide the best practical approximation to a test of sustainability of farming practices. The long-term fertilizer experiments that have been in operation in India for last many years have distinctly indicated that they could be used to measure and evaluate the effect of continuous cropping and fertilizer used on soil quality and hence the sustenance of the system. Soil physical characteristics have a vital role in soil productivity and are necessary components of soil quality assessment. Physical parameters such as bulk density, particle density, porosity, mean weight diameter, aggregate stability, hydraulic conductivity, soil strength and particle size distribution regulates the soil functions (Wagnet *et al.,* 1997).

Organic amendments including composts, green manures and sewage sludge usually increase the soil microbial biomass, soil respiration and soil enzymes' activity along with SOC and concentration of plant nutrients. Changes in soil microbial community compositions are also observed after the addition of organic and inorganic amendments (Sun *et al.,* 2004). Eubacterial community, soil fungal population, ammonium-oxidizing bacteria and denitrifying bacterial community are some of the microbial parameters so far reported to be affected by long-term application of organic and inorganic nutrient amendments. However, only few studies have been conducted in India on the influence of long-term addition of mineral fertilizers and manures on the soil biological properties (Vineela *et al.,* 2008).

Physical properties

The physical indicators of soil play an important role in determining its sustainability for crop production. The physical properties of soil such as bulk density, aggregate stability, water holding capacity and mean weight diameter serves as the most important parameters of soil. Incorporation of fertilizers and organic manures in soil improves bulk density, particle density, aggregate stability, water holding capacity and mean weight diameter.

Bulk density

Havanagi *et al.,* (1970) in a long-term experiment observed that the treatment which received continuous application of FYM gave significantly lower bulk density of 1.43Mg m^{-3} as compared

to 1.45 and 1.46Mg m^{-3} in control and fertilizer treatments, respectively. From a long-term integrated nutrient management study it is reported that bulk density of soil reduced markedly due to different combinations of organic and inorganic fertilizer sources of nutrients compared to application of only inorganic fertilizers from a long-term experiment. The significant decrease in the bulk density has been noticed in the treatments where organic manure @ 6t ha^{-1} was incorporated along with N@80 kg ha^{-1} and P_2O_5@30 kg ha^{-1} in rice crop as compared to the treatments where only N@120 kg ha^{-1} was applied without P fertilizer application and organic manure application (Dhaliwal *et al.* 2015).

Particle density

Nandapure *et al*. (2014) observed a significant decrease in the particle density of surface soil with the application of 100% NPK + 10t FYM ha^{-1} and highest particle density was observed under control treatment. Dhaliwal *et al.* (2015) reported significant decrease in the particle density of surface soil in the treatments where organic manure @ 6 t ha^{-1} was incorporated along with N@80 kg ha^{-1} and P_2O_5@30 kg ha^{-1} the rice crop as compared to the treatments where only N@120 kg ha^{-1} was applied without P fertilizer and organic manure.

Porosity

Pore spaces in soil consist of that portion of the soil volume not occupied by solids, either mineral or organic. Under field conditions, pore spaces are occupied at all times by air and water. Air exchange and water holding capacity of a soil is dependent on both the porosity and pore size. To the growing plant, pore sizes are of more importance than total pore space. Pores can be divided into several size groupings as: coarse pores (greater than 0.2mm in diameter), medium pores (0.2-0.02mm in diameter), fine pores (0.02-0.002mm in diameter) and very fine pores (less than 0.002mm in diameter). Water drains out by gravitational force from pores larger than about 0.03-0.06 mm. In comparison, root hairs are between 0.008 and 0.012mm in diameter. In a long-term experiment at pantnagar the highest porosity in surface and sub-surface soil layers was recorded with application of N_{180}+ P_{80}+ K_{40}+ Zn(F)+ FYM, whereas, the lowest was observed under control (Bhatt *et al*., 2017).

Hydraulic conductivity

Hydraulic conductivity of soil is largely determined by soil properties such as texture, structure, compaction and exchangeable cations. Highest water holding capacity and hydraulic conductivity in surface and sub-surface soil layers was recorded with application of N_{180}+ P_{80}+ K_{40}+ Zn(F)+ FYM, whereas, the lowest was observed under control (Bhatt *et al*., 2017).

Selvi *et al.* (2005) observed that in long-term fertilizer experiment water holding capacity was highest in the plots receiving 100% NPK+FYM. Maximum water holding capacity (77.68%) was found with fallow treatment in surface and (75.75%) in sub-surface soil, and lowest with the control in soils of both the depths. Application of FYM along with NPK fertilizers recorded significantly higher water holding capacity (75.46 and 73.87%) in soils of both the depths, respectively as compared to control and all other fertilizer treatments.

Sudha *et al*. (2014) observed that the water holding capacity of various treatments ranged from (53.30%) to (60.30%) and it was significantly higher (59.43%) at 0-15cm and at 15-30cm depth (60.30%) in the plot reciveing 100% NPK +FYM as compared to control plot.

Dhaliwal *et al.* (2015) reported significantly higher water holding capacity in the treatments where organic manure@ 6t ha^{-1} was added along with N @ 80 kg ha^{-1} and P_2O_5 @ 30 kg ha^{-1} to the rice crop as compared to the treatments where only N @ 120 kg ha^{-1} was applied without P fertilizer and organic manure.

Aggregate stability

Manure affected the distribution of soil aggregate sizes by reducing the amount of < 0.1 mm size in the 0.15 to 0.30 m depth (34% to 31%) and increased the amount of > 1 mm size in the 0.0-0.15 m (30.2 to 40%) and 0.15 to 0.30 m (25 to 33.6%) depths. The water stable aggregates > 0.24 mm were significantly higher (58.2%) in fallow than in cultivated plots (Kurnal *et al.,* 2004).

Long-term application of organic materials increased the proportion of the large WSA (>2 mm) and decreased the proportion of the small WSA (<1 mm), and consequently resulted in an increase of mean weight diameter of WSA (Haynes *et al.,* 1998). An application of FYM enhanced water stable aggregates > 0.25 mm (80.7%) and MWD (0.81 mm) than control (69.7% and 0.61 mm), respectively (Bhagat *et al.,* 2002).

Mean weight diameter

Reddy *et al.* (2002) found that the incorporation of crop residue like wheat straw @ 5 t ha^{-1} in combination with fertilizer application and tillage operations resulted in improvement

of soil physical characteristics (infiltration rate, water stable aggregate and moisture retention).In a long-term fertilizer experiment under rice-wheat cropping sequence it is found that the mean weight diameter varied from 0.63 to 1.04 mm. Highest mean weight diameter in surface and sub-surface soil layers was recorded with application of N_{180}+ P_{80}+ K_{40}+ Zn(F)+ FYM, whereas, the lowest was observed under control (Bhatt *et al*., 2017)

Infiltration rate

Acharya *et al*., (1988) reported that infiltration rate and cumulative infiltration rate (for 180 min), which showed a greater variation owing to the imposition of different treatments. 100 per cent NPK + FYM and 150 per cent NPK showed the highest infiltration rate of 18.9 and 18.4 cm hr-1 respectively. More (1994) observed that application of FYM, organic waste and manures decreased soil pH but increased the infiltration rate. Gangwar *et al.,* (2002) reported that in rice - wheat system, there was tremendous increase in infiltration rate from 0.58mm hr^{-1} of initial value to 1.97mm hr^{-1} with the addition of Sesbania seaban lopping @5t ha^{-1} year as green manure incorporation in sandy loam soil. This higher infiltration rate could be associated with decreased bulk density and increased porosity of Vertisol.

Marathe *et al.,* (2005) noted that application of recommended dose of fertilizer had higher infiltration rate (1.27cm hr^{-1}) and cumulative infiltration (108mm) over control (0.80cm hr^{-1} and 63mm) reported that green manuring with sesbania or green gram residues incorporation in combination with 100 per cent N (120kg ha^{-1}) treated plot recorded increased infiltration rate i.e. 2.21 and 2.19cm hr^{-1} respectively, over the fallow plots (2.13cm hr^{-1}). These treatments are pre-rice treatment and observations were recorded at the time of wheat sowing. Residue incorporation resulted in reduction in BD and increase in soil aggregation, which in turn increased infiltration, percolation rate and hydraulic conductivity of soil.

Effect on biological indices of soil quality

Soil biological processes refer to the processes involving organism that improve plant growth by means of symbiosis, mineralization of organic matter, dissolution of nutrients, soil aggregation etc. A soils capacity to support biological fertility is determined by inherent physical and chemical characteristics as well as management practices. Soil microbes dictate all biochemical cycles in nature vis-à-vis soil quality. Soil respiration and enzyme activity play a major role in maintaining a fertile soil. Soil microbes are principle decomposers of organic residues resulting in the formation of humus with release of several nutrients. Soil ecosystem has a diverse population of microorganism. Microbial population of soil is one of the important indicators of a soil quality.

Microbial populations

Application of 100% NPK + 15 t FYM ha^{-1} recorded highest population of bacteria (24.8 and 29.8 cfu × 106 g^{-1}), fungi (25.4 and 25.9 cfu × 104 g^{-1}) and actinomycetes (40.1 and 41.9 cfu × 105 g^{-1}) after rice and wheat crops, respectively while, lowest in control (Bhatt *et al.,* 2016). Rankov *et al*., (1981) conducted a field experiment for 3 years and reported positive effect of combined application of NPK fertilizers on microbial development and biological activity of the soil than N, P, K applied singly. Significant positive correlation of bacteria and actinomycetes population was found with crop yields while fungi shared positive effect under inorganic treatments and negative effect under FYM. Similar results of improvement of microbial population with addition of FYM have been reported by (Naidu *et al.,* 2001).

Soil enzymes

Soil enzyme are important in soil functioning because of the following features: 1) they play a critical role in the decomposition of organic materials and the transformation of organic matter, 2) they release available nutrients to plants, 3) they participate in N_2 fixation, nitrification and denitrification processes, and 4) they take part in the detoxification of xenobiotics, such as pesticides, industrial wastes, etc. Furthermore these can begin to change much sooner (1-2 year) than other properties (organic carbon), thus provide an early indication of soil quality due to change in soil management. Nidaye *et al., (*2000) reported the enzyme activity in soil holds the potential in managing ecosystems for long-term sustainability.

Dehydrogenase activity

Dehydrogenase activity can serve as a good indicator of soil quality. Dehydrogenases, as respiratory chain enzymes, play a major role in the energy production by microorganisms in the soil (Boltan *et al.,* 2004). Incorporation of organic matter to the soil increased soil dehydrogenase activity (Singh *et al.,* 2007). The organic materials amended to soil serve as an electron donor in dehydrogenase process. The soil under continuous treatment of NPK+ organic manures inherited higher dehydrogenase activity than the soil under NPK treatment. Long-term fertilization of a

loamy-sand soil with different dose of cattle slurry significantly improved the activity of dehydrogenase enzyme as compared to the NPK treated soil.

Phosphatase activity

Phosphatase play key roles in phosphorus cycling, including degradation of phospholipids. Incorporation of organic matter to the soil increased phosphatase activity in the soil (Singh *et al.,* 2007). The phosphatase activity increases when the sources of nutrients have an equilibrated balance between C and N. Different long-term fertilizer treatments greatly affected alkaline phosphatase activity. The alkaline phosphatase activity was low in the control and only N fertilizer treatments however increased significantly with manure and optimum NP application (Mandal *et al*., 2007). Garg *et al*., (2008) found an increase in alkaline phosphatase activity with both organic and inorganic fertilization. The increase in alkaline phosphatase activity over the years with the application of inorganic nutrients was attributed to greater input of root biomass due to better crop productivity; and with FYM may be due to enhanced microbial activity and perhaps diversity of phosphate solubilizing bacteria due to manure input over the years. However, this observation was not consistent with that of (Bohme *et al*., 2006), who reported that organic fertilization stimulated alkaline phosphatase activity while P fertilizers had a negative effect. A significant effect of fertilization with manure and mineral nitrogen on acid phosphatase activity in barley crops was observed.

Table. 1. Long term effect of chemical fertilizers and organic manure on functional groups of microbes

1. **Azobactor**	• The Biofertilizer microorganisms are more suitable for high crop yields, protection from different pathogens, pesticides and help in maintaining soil health by decomposition of dead and decaying matters in the soil (Verma *et al.,* 2010). • These biofertilizers microorganism also help to provide suitable environment for flora and fauna. The addition of FYM and chemical fertilizer increased the population of bacteria, fungi, actinonomycetes and *Azotobacte*r as compared to control. This may be due to the organic manure such as FYM or vermicompost increasing the mineral nutrients, growth hormones, and vitamins improving other physical character in soil might have significant influence on microbial population. • Maurya *et al.,* (2012) found that the *Azotobacter p*opulation density in rhzospheric soil sample of rice-wheat crop rotation ranged from 10 x 10^{4-} 13 x 10^{4} ^{C}FU g^{-1} soil due to high organic matter in the soil.
2. **Phosphorus solubilizing bacteria (PSB)**	• The nutrient supplied through inorganic fertilizer along with FYM had higher total population (*Azotobacter* and phosphorous solubilizing bacteria) than the control and fertilizer treatment (Upadhyay *et al.,* 2011). • Phosphate solubilizing bacteria are considered among the most effective plant assistants to supply phosphorus at a favorable level. These fertilizers are produced on the basis of selection of beneficial soil micro-organism which had the highest efficiency to enhance plant growth by providing nutrients in readily absorbed form (Kalaigandhi *et al.*, 2010). • Bhadoria *et al.,* (2011) showed that populations of PSB, soil enzyme activities, and phosphorus solubilizing power in the FYM + chemical fertilizer treated plots significantly increased compared to sole chemical fertilizer treatments under both lime and no lime application. • Vineela *et al*., (2008) also indicated the PSB populations are generally more under integrated use of organic and inorganic fertilizers as compared to control.
3. **Potentially mineralizable nitrogen**	• Mineral fertilizer and the combination of mineral and organic fertilizers influenced the potentially mineralizable nitrogen content in soil. The PMN is positively correlated with soil organic carbon, soil organic nitrogen and microbial biomass in the soil. The higher levels of mineralizable N and C probably reflect higher amounts of readily decomposable substrate and greater biological activity arising from increased levels of N and organic materials added to the soil. • Biplab *et al.,* (2015) highest value of mineralizable nitrogen was observed under application of the highest rate of chemical fertilizer 150% RDF in combination with FYM (193.18 and 200.08 kg ha^{-1}), correspondingly the lowest value were observed under application of the lowest rate of chemical fertilizer 75% RDF in combination with no organic manure (143.16 and 153.07 kg ha^{-1}).
4. **Urease activity**	• Urease enzyme in soil is involved in the hydrolysis of urea to carbon dioxide and ammonia, and plays an important role in the N cycling. Application of NPK + 15 t FYM ha^{-1} recorded highest urease enzyme activity of 7.46 and 7.52 mg urea g^{-1} 24 h^{-1} after rice and wheat (Bhatt *et al.,* 2016). • Chhonkar *et al.,* (1981) found that activities of the soil enzymes were significantly and positively correlated with organic C and microbial population in the soil. Application of 100% NPK was at par with 150% NPK and gave significantly higher urease enzyme activity in soil over the imbalanced fertilizer treatments.
5. **CO_2 evolution**	• CO_2 evolution represents decomposition of organic matter in soil and is considered an indicator of microbial activity. Application of 100% NPK + 15 t FYM ha^{-1} recorded the maximum and significantly higher CO_2 evolution than all the other treatments. Treatment of 50% NPK was at par with the unfertilized control; however, increasing the levels of NPK increased the CO_2 evolution after both rice and wheat crops (Bhatt *et al*., 2016). • Ingle *et al*., (2014) reported higher CO_2 evolution due to the application of organic manure in conjunction with 100% recommended chemical fertilizers. An increase in CO_2 evolution with increasing NPK levels can be ascribed to accumulation of more root biomass due to higher plant growth and yields as a result of long-term fertilization.

CONCLUSION

This review concluded that the incorporation of fertilizers and organic manures in soil improves bulk density, particle density, aggregate stability, water holding capacity and mean weight diameter. Soil biological processes refer to the processes involving organism that improve plant growth by means of symbiosis, mineralization of organic matter, dissolution of nutrients, soil aggregation etc. A soils capacity to support biological fertility is determined by inherent physical and chemical characteristics as well as management practices. Organic fertilizer improves physical, chemical and biological properties of a soil but the nutrients may not be as readily available to the plants. However, inorganic fertilizer is usually immediately and fast containing all necessary nutrients those are ready for plants. The excess use of chemical fertilizers in agriculture can lead to soil deterioration, soil degradation, soil acidification or alkalization and environmental pollution. The integrated soil fertility management system is an alternative approach for the sustainable and cost-effective management of soil fertility and is characterized by reduced input of inorganic fertilizers. Integrated use of inorganic fertilizers and FYM improved the soil physical and biological properties. Continuous cropping without fertilizers deteriorated the soil health. In the light of above, holistic, systematic and in depth work is warranted to evaluate the impact of long-term application of fertilizers and organic and inorganic nutrient management practices improved the soil physical and biological properties, and also improved crop productivity, soil health under various agro-climatic conditions; and processes involved in long-term impact of these practices on ecosystem and environment needs to be pinpointed.

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MICROBIAL ANALYSIS OF MILK AND MILK PRODUCTS COLLECTED FROM SRINAGAR, PAURI GARHWAL, UTTARAKHAND

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ABSTRACT

Milk has high proportion of the dietary components which makes it a perfect food for infants, children and adults. Consumers always demand for nutritionally enriched milk and dairy products. However, milk is always subjected to adulteration and thus is a serious concern throughout the World. The present study was carried out to check the quality of milk and milk products in Srinagar local market. A total of 38 bacterial isolates were recovered from milk and milk products. Amongst the recovered bacteria *Lactobacillus* was the most dominant (24%) followed by *Clostridium* (16%), *Streptococcus* (13%), *Staphylococcus* (13%), *Alcaligenes* (10%), *Pseudomonas* (8%), *Bacillus* (8%), *Micrococcus* (3%), *E. coli* (3%) and *Shigella* (2%). The sensitivity of dominant bacterial isolates towards antibiotics was tested. *Staphylococcus*, *Streptococcus*, *Alcaligenes* and *Bacillus* did not show any sensitivity against any of antibiotics used while *Pseudomonas* was found to be maximally sensitive against Azithromycin while *Clostridium* and *Lactobacillus* were found to be maximally sensitive against Norfloxacin.

Keywords: Milk, Milk Products, *Lactobacillus,* Srinagar, Antibiotics.

INTRODUCTION

Milk is an important source of all basic nutrients for mammals. It is considered as a complete diet because it contains the essential nutrients, *viz*., lactose, fat, protein, mineral and vitamins in balanced ratio rather than the other foods (Khan e*t al*., 2007).The average production of milk in India, as per 2015-16 statistics, was 155.5 million tones which make India the largest producer in the World (Nalwaya *et al*., 2018). Milk from various mammals are used for producing different dairy products including milk cream, butter, yogurt, ghee, sour milk, etc. (Hossain *et al.,* 2013). According to World Health Organization (WHO) standards the quality milk should contain 2.6% fat, 3.5% protein, 0.17% TA, 7.71% SNF and SG 1.030. The pH 6.6 ensured the milk freshness at boiling point 100 °C -117 °C (Hossain *et al.,* 2013).

Milk in the udder of a healthy cow is almost free of bacteria. The milk can get contaminated, during the milking process, by the skin of udder, unclean milking equipment, brittle gum parts of the milking system or dust and dirt in the air of the cow-shed. The milk is also contaminated when it is passed through the teat-channel. The microbial population can vary from 100 to 10000 Cfu/ml with significantly higher count in mastitis cows (Bytyqi *et al*., 2009). Besides the proliferation of pathogens in milk and milk products, an important consideration has to be given on the antibiotics resistance, which is a major clinical obstacle in medicating disease especially in the developing countries (Jilani *et al*., 2008). The bacterial resistance against antimicrobial agents may be driven by the interplay of several genetic factors (Canton 2008). The quality of raw milk encompasses such milk characteristics as chemical composition, physical properties, microbiological and cytological quality, sensory properties, technological suitability and nutritive value (Shahida *et al*., 2015).

MATERIALS AND METHODS

Collection of samples– A total of 5 milk samples were collected from different shops/local people in autoclaved bottles. 2 samples of sweet made with milk, cheese, cream and paneer were taken from different local shops. These samples were immediately transferred to the laboratory in an ice bucket.

Recovery of bacterial isolates– The bacterial isolates was recovered after plating on Nutrient agar medium. The population count was recorded. The pure culture of bacterial isolates was preserved in glycerol stocks at -20 °C.

Characterization of bacterial isolates– The bacterial isolates were identified based on morphological characteristics *viz.*, colony morphology (shape, size, form, elevation and margin) and cell morphology (Gram's reaction, cell shape and arrangement) and biochemical characteristics viz., Oxidase test, Indole-Methyl Red -Voges-Proskauer- Citrate Utilization test (IMViC), Triple Sugar Iron (TSI) test, Urease and Nitrate reduction tests was carried out according to (Cappuccino *et al.,* 1992).

Antibiotic sensitivity testing- It was done by disc diffusion method on Mueller-Hilton agar (Bauer *et al*., 1966). The cultures were aseptically swabbed on the surface of sterile MHA. After 3 to 5 minutes, 4 antibiotics discs were placed at equidistant. The plates were incubated in an upright position for 24 hrs at 37°C. The diameter of zone of inhibition was measured.

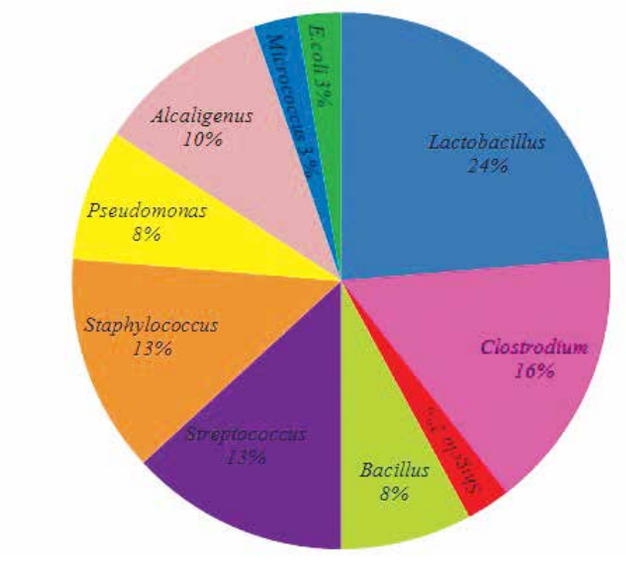

Fig. 1. Percentage distribution of recovered bacterial isolates in milk and milk products

RESULTS AND DISCUSSION

The microbial analysis of milk is quite significant as it can pose serious health hazards. It should be done on regular basis. In the present study, there was no significant difference in the microbial load in milk samples collected. The population count was found to vary from 4.096 $\log_{10}$cfu to 4.146 $\log_{10}$cfu/ml. The population count in milk sweet was found to vary from 3.95 to 3.98 $\log_{10}$cfu/g while that of cheese, from 4.079 to 4.12 $\log_{10}$cfu/g; from 4.120 to 4.125 $\log_{10}$cfu/g in cheese and 3.95 to 3.96 $\log_{10}$cfu/g. These samples were found to have maximum microbial load. These samples can be consumed safely though it should be less.

The milk samples should also be tested for the presence of pathogenic bacteria. In the present study, a total of 38 bacterial isolates were recovered. *Lactobacillus* was found to be the most dominant bacteria (24%) followed by *Clostridium* (16%) (Fig. 1). *Micrococcus*, *E. coli* and *Shigella* were found to least abundant. The dominant isolates were screened for their antibiotic sensitivity. *Staphylococcus*, *Streptococcus*, *Alcaligenes* and *Bacillus* were found to be resistant against the antibiotics used. *Pseudomonas* exhibited maximum sensitivity towards Azithromycin (39mm) while *Lactobacillus* was found to be maximally sensitive towards Norfloxacin (22mm) (Fig. 2). *Clostridium* was found to be resistant against Trimethoprim, Cotrimoxazole and Cefpodoxime but maximally sensitive towards Norfloxacin (32mm).

CONCLUSIONS

The milk and milk product samples collected from different shops/ local people of Srinagar were not found to contain a very less microbial count. However, pathogenic microbes were present in the samples. This kind of data should be collected on regular basis to find out the places where adulteration practices are going.

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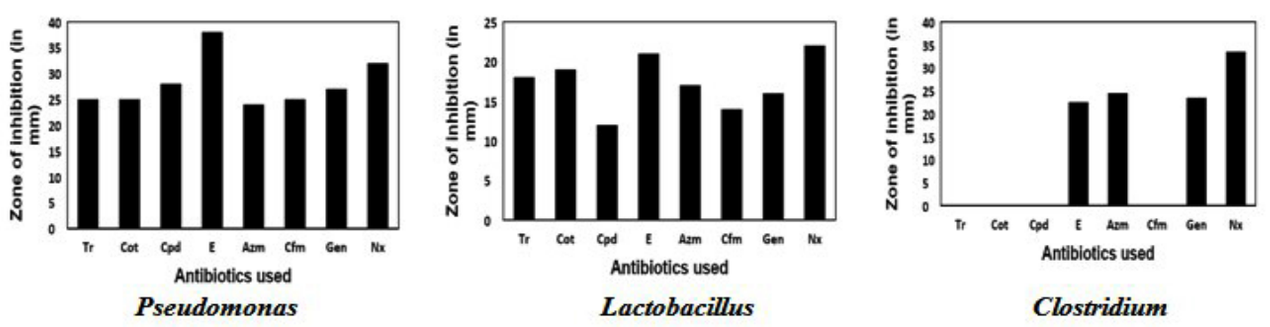

Fig. 2. Antimicrobial susceptibility of dominant bacterial isolates of milk and milk products

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DIVERSITY OF SEED-BORNE MYCOFLORA OF *MORINGA OLEIFERA* IN KUMAUN REGION OF CENTRAL HIMALAYA

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ABSTRACT

Moringa olifera is a medicinally important plant native of the sub-Himalayan regions of northwest India. Only leaves of this plant can cure more than 300 diseases. However the propagation of Moringa olifera through seed is difficult especially in high altitude. The plant belongs to Moringaceaefamily seed germination of the plant is very poor and most seedlings die during early establishment phase. In view of above, the aim of present investigation was to identify the seed born fungi of MO. Total 11 fungi species was identified during the work namely ,*Acremonium sp., Alternaria alternate, Alternariasolani, Alternaria tenuissima, Aspergillus flavus, Cercosporidium Sp., Cladosporium cladosporioides, Cordanapauc iseptata, Fusarium roseum*, *Ochroconis sp., Physarum sp., Spegazzinia sp., Stachybotrys chartarum, Tetraploa aristate, Trichoderma harzianum and Verticillium sp.* Seed germination could achieve by inhibiting above identified fungi.

INTRODUCTION

Moringa oleifera Lam. (*M. oleifera*) or horseradish tree or drumstick tree, is a cruciferous plant that belongs to the family Moringaceae. It is a well reported plant with diverse nutritional and medicinal properties (Kou *et al*., 2018). Traditionally the plant is widely used in various diseases like headaches, worms, diarrhoea, stomach ulcers, skin conditions, anemia, infections, fevers, urinary problems, liver and spleen problems, arthritis and rheumatism("ujert-2-4-2.pdf," n.d.). The plant is considered to be the richest source Vitamins A, B, C, D, E and K and also contains minerals like Calcium, Copper, Iron, Potassium, Magnesium, Manganese and Zinc. It is been extensively used in more than 80 countries, all over the world (Nand, 2017; Mahmood *et al*., 2010). But the seed germination rate of the plant is very poor and most seedlings die during early establishment (Mohamedy *et al.*, 2014). Seed-borne pathogens can affect the seed quality by damaging external or internal seed tissues and cause the important seed diseases like seed rot, seed necrosis, and seedling damage through the local or systemic. Some of common fungi include *Altenaria, Curvuliaria, Humicola, Bispora, Chaetomium, Penicillium*, etc. harbour outside or inside the seeds and causing great loss. The present study was carried on Moringa oleifera seeds to identify the seed borne fungi and subsequently determine their effect on germination of seeds. Therefore, this investigation will be useful in increasing productivity as well as inducing early emergence of seedlings of the plant.

METHODOLOGY

MATERIALS AND METHODS

Sampling and morphological study

Samples of drumstick fruit were collected at Kakrighat area District Almora (29°32'52.67" N; 79°31'41.65" E), Uttarakhand, India during the summer months (April-July) of 2019, placed into Ziploc plastic bags and takento the laboratory. The plant materials (fruit, seeds etc.) were placedin sterile moist chambers and incubated at ambient temperature (22–25 °C) in the laboratoryand periodically examined over a week for the presence of micro fungi. The cello tape technique was used for the identification of fungusspecies using the methodology described by (Gupta 2016 and Dubey *et al*., 2018). The adhesive side of a small section of cello tape (1.5×3cm) was gently pressed against the decomposing fruit/seed. The cello tape was pulled off and mounted directly on a glass slide containing a freshly prepared mixture of lacto-phenolcotton blue (LPCB) for microscopic examination. By using this relatively simple

and fast technique, conidia of micro fungi were obtained firmly attached to conidiophores and myceliumin a natural condition (Maiti *et al.,* 2017). The various fungal structures were examined, measured, and photographed using light microscopy. The identification of species was accomplished through comparison with Hughes (1951, 1955, 1965, 1977), Ellis (1966, 1971) relevant taxonomic literature.

RESULTS AND DISCUSSION

The causal pathogen of early blight is the fungus *Alternaria solani*. There is no known sexual stage and hence it is classified under Deuteromycete group of fungi. The genus *Alternaria* is a large and important group of pathogenic fungi, which cause a significant number of important diseases. The mycelium is haploid and septate, becoming darkly pigmented with age. The asexual conidia are borne singly or in a chain of two on distinct conidiophores. The beaked conidia normally possess 9–11 transverse septae (Kemmitt *et al.,* 2002). *Verticillium* comes under Deuteromycetes (fungal class), which do not have a known sexual stage. *Verticillium* is named for this "verticillate" (whorled) arrangement of the phialides on the conidiophores. As the diseased plant senesces, the fungus becomes saprophytic and colonizes the dying tissues. The vegetative mycelium is hyaline, septate, and multinucleate. The nuclei are haploid. Conidia are ovoid or ellipsoid and usually single-celled. They are borne on phialides, which are specialized hyphae produced in a whorl around each conidiophore. During colonization, the fungus forms micro sclerotia, which are masses of melanized hyphae. Conidia dimensions: 2.3-10x1-2.6 microns. Found in decaying vegetation, on straw, soil and arthropods (Berlanger *et al.,* 2000). Spegazzinia fungus (spores develop by means of asexual cell division) is included in the classification group "Hyphomycetes". *Spegazzinia* spores can be identified in air samples by their distinctive structure, and have the potential to produce a colony within seven to ten days. Colonies are considered relatively slow growing, and are brownish-black to black in color. This saprobederiving its nourishment from nonliving or decaying organic matterand found in warm-temperate to tropical areas in soil and on dead leaves, stems, trees, and other various kinds of plant debris (Hatcher *et al.,* 2006; 2008). *Tetraploa* sp. of fungi belong to the Dematiaceous family, also named brown-pigmented fungi because of the presence of melanin in their cell walls, which imparts the characteristic dark colour to their spores and hyphae. The name Phaeohyphomycosis refers to a

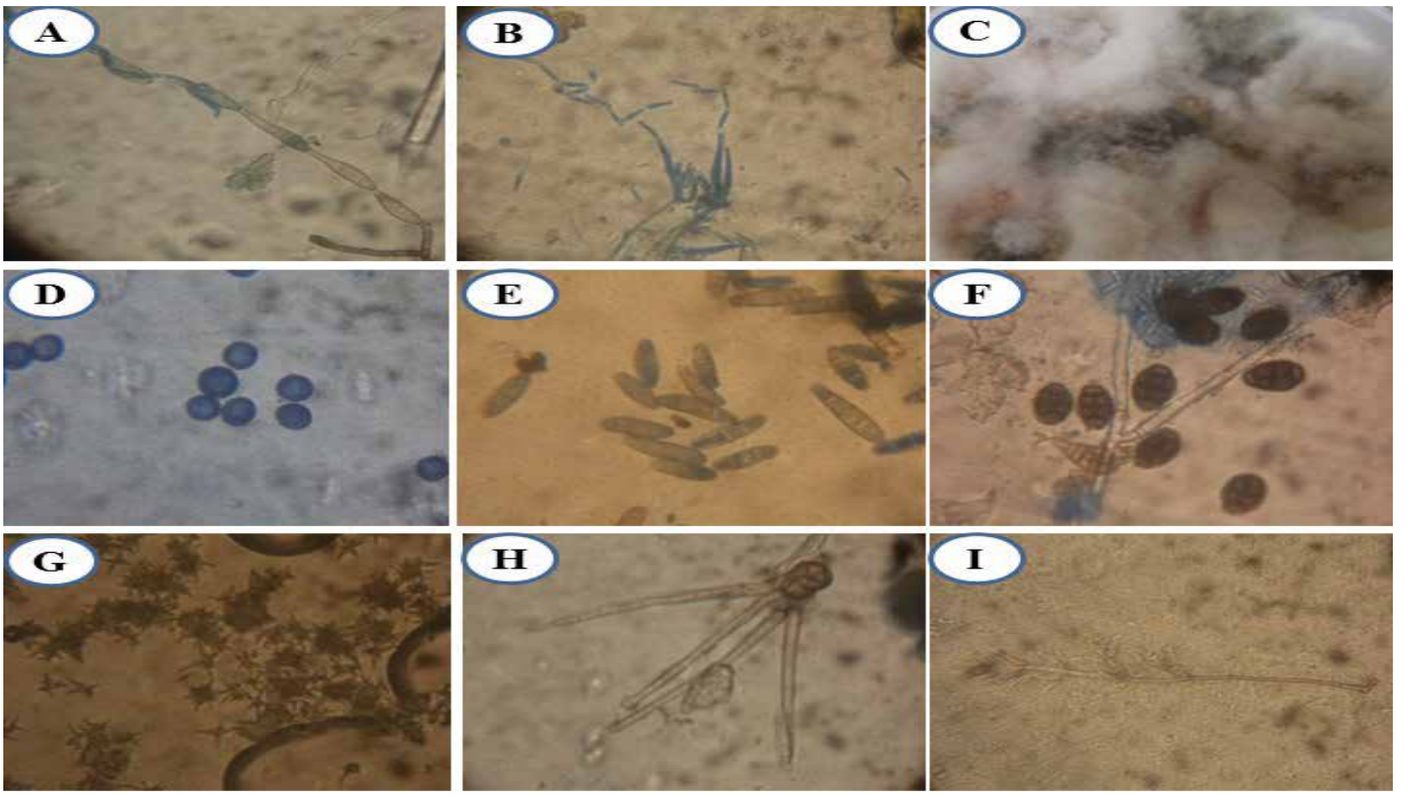

Fig. 1. (A) *Alternariasolani,* **(B)** *Chalara species,* **(C)** *Fusarium roseum,* **(D)** *Gilmaniella species,* **(E)** *Helminthosporium species,* **(F)** *Pithomyces chartarum,* **(G)** *Spegazzinia species,* **(H)** *Trichoderma harzianum*, **(I)** *Verticillium species*

series of diseases, both subcutaneous and systemic infections. Regarding infection by Tetraploa sp., only a few reports (a case of a cyst on the knee and two cases of keratomycosis) are cited in the literature (Cytopathology 2011). *Fusarium* A common soil fungus. It is found on a wide range of plants. It is often found in humidifiers. Several species in this genus can produce potent trichothecene toxins. The trichothecene (scirpene) toxin targets the following systems: circulatory, alimentary, skin, and nervous. Produces vomitoxin on grains during unusually damp growing conditions. Symptoms may occur either through ingestion of contaminated grains or possibly inhalation of spores. The genera can produce hemorrhagic syndrome in humans (alimentary toxic aleukia). This is characterized by nausea, vomiting, diarrhea, dermatitis, and extensive internal bleeding. Frequently involved in eye, skin, and nail infections (Hatcher*et al.,* 2006 and 2008). Pithomyces commonly grows on dead plants, soil, wood, and especially the dead leaves and grasses of livestock fodder. *Pithomyces chartarum* produces sporidesmin (a piperazinedione), a mycotoxin known to cause animal liver damage, and it causes facial eczema in cattle, sheep, and goats. In humans, it is considered a possible allergen, and a potential infectious agent in immunocompromised patients. It exhibits distinctive multi-celled brown conidia (Hatcher *et al.,* 2006; 2008). *Trichoderma* commonly found in soil, dead trees, pine needles, paper, and unglazed ceramics. It often will grow on other fungi. It produces antibiotics that are toxic to humans. It has been reported to be allergenic. It readily degrades cellulose (Hatcher *et al.,* 2006 and 2008).

Table 1. Seed born fungi isolated from *Moringa olifera* disease and their management

S. No	Name of fungus	Disease cause	Symptoms	Disease Management
1	*Alternaria solani*	early blight disease of tomato (*Solanum lycopersicum*)	Early blight occur on fruit, stem and foliage of tomatoes and stem, foliage and tubers of potatoes	Fungicides like mancozeb and chlorothalonil are the foundation of most early blight management programs (Kemmitt 2002)
2	*Chalara sp.*	Ash dieback is a lethal disease of ash trees (*Fraxinus spp*.)	Wilting and blackish discolouration of leaves, premature shedding of leaves, dieback of shoots, twigs and branches, necrosis of bark tissue, discrete necrotic cankers in the bark, diamond-shaped lesions on stems and a brownish to greyish discolouration of the inner bark and wood that often extends beyond the region of visible bark necrosis	fungicides and urea (Hauptman *et al*., 2014) (https://www.cabi.org; (https://www.brc.ac.uk)
3	*Fusarium roseum*	Fusarium Head Blight (FHB) or scab on Wheat	FHB visible in Wheat, Barley, Oats, Rye and some Forage grasses. FHB is best recognized by the bleaching of florets in the spike or head	Deoxynivalenol (DON) (Espinoza 2016)
4	*Gilmaniella sp.*	*Gilmaniella humicola* cause brownish necrotic spots on potato leaves	Usually begin with yellowish leaf spots which then turn brown; downy growth appears on underside of leaves	Fungicides (https://ausveg.com.au)
5	*Helminthosporium sp.*	Silver scurf, leaf blight, powdery mildew lesions on leaf blades	Greyish green, tan, or brown elliptical spots that appear on lower leaves and spread later to upper leaves. Leaf tissues turn yellow dark brown or white "net" blotches on the leaves	Thiabendazole (TBZ) Fungicide (https://en.wikipedia.org)
6	*Physarum sp.*	Cabbageclub, root disease and powdery scab tuber disease	Watery white, gray, cream to light yellow, red, violet, blue, green, or greasy purple-brown masses in round to irregular patches from 1 inch to 2 feet in diameter leaves.	Exopolysaccharides (EPS) (Keller 2010)
7	*Pithomyces chartarum*	Facial eczema in sheep and cattle	Spores of the *Pithomyceschartarum* contain the toxin sporidesmin, which damages bile ducts in the liver causing jaundice, photosensitisation (hence the name 'facial eczema'), loss of production and death in extreme cases	Zinc salts (Blaney 2005)
10	*Spegazzinia sp.*	Rust diseases	Colonies are considered relatively slow growing, and are brownish-black to black in colour. This saprobe (deriving its nourishment from non-living or decaying organic matter) is most commonly found in warm-temperate to tropical areas in soil and on dead leaves, stems, trees, and other various kinds of plant debris	Kitazin (0, 0-Diethyl-S-benzyl thiophosphate) Copper sprays or Sulfur powders to prevent infection of susceptible plants.

11	*Tetraploa aristate*	Cause keratitis, Phaeohyphomycotic cyst Allergic disease in human	Usually found in stems and leaf bases of many plants (https://www.latesting.com)	Fungicides
12	*Trichoderma harzianum*	Curb plant diseases fatal disseminated disease Biocontrol Agent for basal stem and Rot disease (Nusaibah 2019)	*Trichoderma harzianum* is a fungus that is also used as a fungicide. It is used for foliar application, seed treatment and soil treatment for suppression of various disease causing fungal pathogens. richodermaharzianum in inhibiting powdery mildew disease	controlling common soil-borne diseases like *Fusarium*, *Pythium* and *Rhizoctonia* on a wide range of crops including corn, soybeans, potatoes, tomatoes and cotton (https://www.arbico-organics.com)
13	*Verticillium* sp.	Verticillium species skin infection in a transplant patient	Chlorosis and necrosis of leaves, discoloration in stems and roots, and wilting on warm, sunny days. Severely diseased plants may be stunted or die (Terry 1989)	Fluconazole (Badreddine *et al*., 2019) amphotericin B, ketoconazole, itraconazoleand voriconazole (https://drfungus.org)

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PHARMACEUTICAL AND PERSONAL CARE PRODUCTS (PPCPs) IN WASTE WATER AND FRESH WATER SOURCES: DISTRIBUTION AND RELATED HEALTH CONCERNS

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ABSTRACT

Presence of pharmaceutical and personal care products (PPCPs) in wastewater and other water sources poses potential health threats and hazards in the ecosystem. Due to the heavy usage of these substances in the fields of agriculture, healthcare, and as personal care products, these pollutants are considered as pseudo-persistent because of their rapid replenishment in the environment. In the recent years, the widespread occurrence of PPCPs has resulted in great concern on their transformation, fate and risk in the environment. The present article reviews about sources of PPCP compounds in the environment, their distribution in aquatic environment and their effect on human health as well as aquatic life.

Keywords: Wastewater, PPCP compounds, Aquatic life, Water pollution, Health hazards.

INTRODUCTION

Pharmaceutical and personal care products (PPCPs) are the man made compounds used for health improvement of human and livestock through drugs, used in cosmetics and in agricultural industry for maintaining the health of plants (Nikolaou *et al.,* 2007). Scientific advancement in pharmaceutical therapies and types of personal care products has done much to improve the overall health of the world's population. But the widespread use of pharmaceuticals and other personal care products (PPCPs) has increased concerns about concentrations of these substances in the water cycle, including surface and ground waters, wastewater and drinking water due to untreated waste effluents in many areas of world. Approx. 10–90% of the administered dose of PPCPs are excreted from the human body as such, while the rest are excreted as metabolites and or in conjugated forms (Balakrishna *et al.,* 2017). The excreted PPCPs reach the wastewater treatment plants (WTPs), from where effluents are discharged as raw or in treated form into the groundwater, rivers, lakes, oceans, and soil. PPCPs have been detected in the environment throughout the world over last 40 years approximately but their wide distribution has been reported in past few years only. The unintentional presence of PPCPs in various compartments of the aquatic environment (e.g. water, sediments and biota), at different concentrations has the ability to cause detrimental effects to the aquatic organisms as well as to the human health which are increasing day by day. This is a major concern because PPCPs are extensively and increasingly used in human and veterinary medicine, resulting in their continuous release to the environment (Ternes *et al.,* 2002).

Now a days the several direct effects of PPCPs have been successfully demonstrated for aquatic and other terrestrial organisms and several human health diseases. Due to which, their presence in water are of major concern. Wide range of PPCPs has been detected in a variety of environmental samples at levels ranging from ng kg^{-1} up to g kg^{-1} fresh as well as in wastewater (Vajda *et al.,* 2008). These are widely detected in a trace levels in both the surface and ground water and have emerged as environmental contaminants with potentially detrimental effects. The effects of these chemical compounds on human beings, environment and the animals are negative, and these compounds show toxic effect at very low concentrations. Thus, there is an urgent need to determine the PPCPs concentration in various water resources, from wastewater to potable water. Proper treatment of these compounds is also necessary before disposing off into the environment. For this purpose, work had already started in some areas of the world where wastewater containing PPCP compounds are carried to wastewater treatment plants (WWTPs). In WWTPs, PPCPs are firstly treated and then eliminated by sorption or biodegradation; reformed due to conjugate cleavage or can pass

through the system without being affected. After the treatment PPCPs concentration is either decreased/increased or remains like that of raw sewage.

Sources, distribution of PPCPs in water resources

PPCP compounds can enter in our water bodies through various means. Industrial and sewage effluents, if not properly treated and added to natural water bodies can be the cause of presence of these compounds in water bodies (Fig 1). Direct disposal of domestic, hospital, hotel wastes in water bodies, seepage of these compounds from landfill sites to ground water resources, movement of these compounds from agricultural fields to surface water through runoff process, or though seepage to groundwater resources etc, are the major sources through which PPCP compounds can become a part of environment and cause threat to living beings directly or indirectly. Either intentionally or unintentionally, individual consumers are also an important source of PPCPs found in water. Consumers often dispose of unused prescription medications through domestic sewage system or directly in the environment as waste. Unintentional PPCP contamination of water by consumers occurs through the simple elimination of excreta from the body as drugs are not always fully metabolized by the body and also through bathing or showering, when soaps and cosmetic creams become a part of wastewater system (Klaschka *et al.,* 2013). As all the water resources finally mixes with sea so marine lives are severely affected by these emerging contaminants.

For last 20 years, the researches on distribution of PPCPs in existing drinking water resources are going on. Firstly, clofibric acid was detected in treated wastewater in Kansas City, US in 1976. Thereafter, various studies were conducted for analyzing such compounds throughout the world in various water resources as well as in the effluents of wastewater treatment plants. During 1999 and 2000, US Geological survey had analysed water samples, collected from wastewater treatments plants as well as the domestic water treatment plant, for analysing the presence of PPCPs. Around 95 PPCP compounds were identified in the collected samples (U.S. EPA 2012). Same type of research is going on worldwide for identification of PPCP compound concentration in water resources so that water treatment can be done in more efficient way for the benefit of both the human as well as aquatic life.

Pharmaceutical compounds

Meffe e*t al*., (2014) had identified occurrence of 161 emerging organic compounds (EOCs) in surface and groundwater sources of Italy and these identified compounds belong to the groups of industrials, pharmaceuticals, estrogens and illicit drugs. PPCPs in industrials waste occurring in both surface and groundwater with the highest concentrations up to 15×10^{6}ng/L. Concentrations of pharmaceuticals in surface water reported up to the maximum concentration of 3.59×10^{3}ng/L.

Based on available studies, carbamazepine (22-8200 ng/l) (a psychoactive), metoprolol (11800-35500 ng/l), atenolol (192-13800 ng/l) (antihypertensive), triclocarban (515-8880 ng/l) and triclosan (145-4890 ng/l) (antimicrobials), ibuprofen (834-4460 ng/l) and acetaminophen (4500-86800 ng/l) (analgesics), and caffeine (16-102840 ng/l) (stimulant), trimethoprim (3-4010 ng/l), sulfamethoxazole (3-2260 ng/l), ciprofloxacin 20-12900 ng/l), ampicillin (104.2 ng/l)), gatifloxacin (2.74 ng/l), sparfloxacin (22.49 ng/l), cefuroxime (3.42 ng/l) (antibiotic/ fungicide), amphetamine (238-4720 ng/l) (illicit drug), and saccharin (14-389000 ng/l) (artificial sweetener) are some of the important pharmaceutical compounds reported in India from domestic effluents (Balakrishna *et al.,* 2017). Most of these compounds are present many times higher in waste effluents than that present in countries like USA, Australia, Japan, Germany. Similar observations were made in case of hospital effluents (Akiba *et al.*, 2015), groundwater (Fick *et al.,* 2009), rivers and lakes (Mutiyar *et al.,* 2014). According to (Lapworth *et al.,* 2012), sulphamethoxazole, Ibuprofen, Carbamazepine, nonylphenol, bisphenol A, and caffeine are highly reported pharmaceuticals compounds in groundwater throughout the world. Triclosan, lipid soluble, broad spectrum antimicrobial agent has been detected at high concentration in USA, UK, South Korea, Japan, China. After chlorination of water, it has found more harmful due to toxic intermediate compound.

Fragrance

Fragrance ingredients (musks) have been utilized in various products such as cosmetics, detergents, fabric softeners, shampoos, perfumes and other scented personal care products throughout the world. There are mainly four main groups of synthetic musks used by different personal care product industries: nitro (musk ketone, musk ambrette, musk tibetene, musk alpha and musk moskene etc), polycyclic traseolide (ATII), celestolide (ADBI), fixolide/ tonalide (AHTN), versalide (ATTN), galaxolide (HHCB) etc) macrocyclic (ethylene brassilate, globalide (habanolide), ambrettolide, muscone, cyclopentadecanolide (exaltolide), velvione, civettone, etc) and alicyclic musks (cyclomusk, helvetolide and romandolide). These compounds are partially soluble in water, while their

octanol-water partition coefficients are relatively high (log K_{ow} range: 3.8 to 6.3) which indicate high bioaccumulation potential in adipose tissues of aquatic and terrestrial organisms (Osemwengie *et al.,* 2004). These compounds are also relatively persistent. (Liu *et al.,* 2014) has reported seven synthetic musks (SMs) and 17 siloxanes in anaerobic digested sludge samples in China which was ranging from 47.3 ng/g to 68.2 µg/g dry weight (dw). (Sun *et al.,* 2014) have reported synthetic musk ingredients such as AHTN (0.05 µg/l to 0.44 µg/l) and HHCB (0.45 to 4.79 µg/l) in the effluents of 40 wastewater treatment plants across the United States. In case of sludge, AHTN concentrations ranged from 0.65 to 15.0 mg/kg dw (dry weight) and HHCB concentrations were between 4.1 and 91 mg/kg dw. In Germany, polycyclic musks, HHCB and AHTN were found at concentrations ranging from <10 to 180 ng/ l and <10 to 70 ng/l, respectively in the Lippe River water (a tributary of the Rhine River, Germany) (Dsikowitzky *et al.,* 2002). Due to the presence of these compounds in water, the traces have been detected in fishes, human milk samples (Franke *et al*., 1999) and many other organisms. HHCB and AHTN were detected in wild and farmed shrimp from the USA and other countries at concentrations up to 762 ng/g lipid weight and 384 ng/g lipid weight respectively (Sapozhnikova *et al.,* 2010).

Sunscreen UV filters

Sunscreen products contain organic and inorganic UV filters which protect human skin against sunburn and cancer by absorbing UV radiation such as organic compounds that absorb UV rays (e.g. cinnamates, camphor derivatives, benzophenones) and/ or inorganic compounds (e.g. TiO_2 and ZnO), which act as chemical or physical filters preventing or limiting UV penetration (Giokas *et al.,* 2007). Organic UV filters include benzophenone-3 (BP-3), 4-methyl-benzylidene camphor (4- MBC), octocrylene (OC) and 2-ethyl-hexyl-4-trimethoxycinnamate (EHMC) etc. These compounds have been reported worldwide at various concentration in surface water (1–862 ng/l), ground water (55 ng/ l and 1980 ng/l at two different areas), waste water (1–8900 ng/l), sediments (3.2–870 ng/g dry weight), sewage sludge (260-970 ng/g dw), marine water (Bratkovics *et al.,* 2015) had reported 3700 ng/L of UV filters along the coastal areas of South Carolina in the USA. These compounds have shown tendency of bioaccumulation in fish, mussels, sea urchins, dolphins, breast milk and human placental tissues (Molins *et al.,* 2017). Butylparaben (BP), ethyl-hexyl-methoxycinnamate (OMC), benzophenone-3 (BZ) and 4-methylbenzylidene camphor (MBC), with the water solubility 207mg/l, 0.15 mg/l, 68.56 mg/l and 0.57 mg/l respectively, caused complete bleaching of coral species in the study conducted with *Acropora* spp. at a very low concentration (Danovaro *et al.,* 2008).

Plasticizers

Plasticizers have been used in products such as adhesives, inks, and cosmetics, munitions, industrial and lubricating oil, as well as solvents in perfumes and paints and additives in hair-sprays and insect repellent.Bis (2-ethylhexyl) phthalate (BEHP) also known as di-octyl phthalate or di-(2-ethylhexyl) phthalate (DEHP), bis (2-ethylhexyl) terephthalate (BEHTP) (an isomer of BEHP), bis (2-ethylhexyl) adipate (BEHA) are a family of plasticizers and dominate polymer production. Bisphenol A (BPA), 4,4´- (1-methylethylidene)- bisphenol, is widely employed as a monomer in the production of polycarbonate and some epoxy resins. There are many other plasticizers which have made our life very comfortable as these organic compounds are added to polymers to facilitate processing and to increase flexibility and toughness of the final product by internal modification of the polymer molecule (Barnabe *et al.,* 2008). These plasticizers can easily migrate from plastic products and can become a part of environment through waste disposal, domestic usages, industrial effluents etc. Due to this reason, these compounds have been reported in surface water, groundwater, wastewater etc (Fauser *et al.,* 2003).

Health effects

Due to the observation of PPCP compounds in freshwater resources as well as wastewater treatment plants, study of effect of these compounds on health of all the living creatures become important. These compounds work as endocrine disrupters by interfering in hormonal systems of humans and animals. Significant relations have been identified between endocrine disrupters and prostrate and breast cancer (Cizmas *et al.,* 2015). These PPCP compounds are harmful even at ppb level. Many studies are going on to analyse their effect on health of human as well as aquatic life and all the related living organisms (Boxall *et al* 2012). The contact of fish with these chemicals resulted in changes in sperm density, gonad size, male sex reversal, and other health issues (Parrott *et al.,* 2005). Pharmaceutical mixtures found suppressing cyano bacteria growth, increasing fish mortality, decreasing plankton diversity, and decreasing the growth of aquatic plants at concentrations of 60–100 ng/l. Bioactive pharmaceuticals and personal care products in surface waters also prompt concerns about human health effects, especially when considering life-long exposure. These are synthetic chemicals that block or mimic natural

hormones in the body, disrupting normal organ function. These compounds can affect human endocrine system even at very low concentrations. The common example of PPCPs such as synthetic estrogen commonly used in oral contraceptives may impact the reproduction of aquatic organism even at low concentration (Xu *et al.,* 2008).

The long-term exposure to high concentrations of DEHP can damage the liver and testicles, in mammals and cause death in aquatic species. Plasticizers can also influence the mobility and bioavailability of toxic substances such as polychlorinated biphenyls and metal ions by changes in their water or lipid solubility. Oxazepan, a psychiatric drug present in water resources has shown its effect in physiological process of European perch (Brodin *et al.,* 2013). BPA has the capacity to interact with humans and wildlife and can cause adverse effects. such as formation of additional female organs, enlarge accessory sex glands, morphological and functional gonadal dysfunction, and interference in the functioning of the endocrine system. BPA can be readily absorbed and metabolized by the skin via trans-dermal route (Zalko *et al.,* 2010). Exposure to triclosan has been reported causing thyroid function impairment, oxidative stress, endocrine disruption, liver carcinogenesis (Juliano *et al.,* 2017). UV filters also possess endocrine disruption capability if present in water resources. BP-3 has shown adverse effect on reproduction of aquatic organisms and human life as these compounds have been reported in human milk (Schlumpf *et al.,* 2008).

CONCLUSION

Due to the increased consumption of these PPCP compounds in day to day life, environmental risk on living organisms, including humans and animals, is increasing a lot. These compounds have been developed for making our life comfortable, so the products containing these compounds should be used in minimal quantity in a proper way. The waste containing these compounds

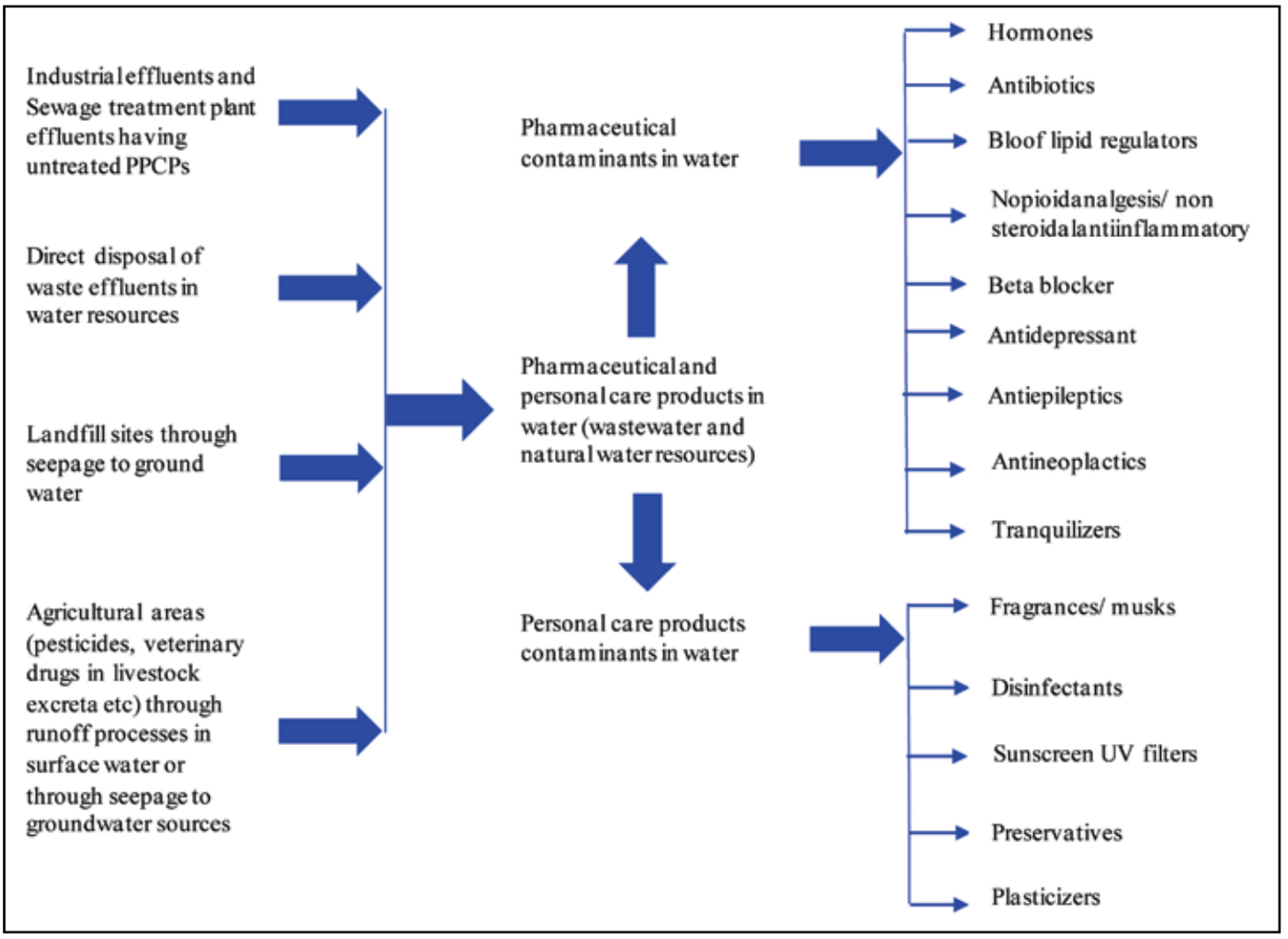

Fig. 1. Probable sources of PPCP compounds in wastewater and different categories of PPCP compounds in water resources

(industrial, domestic, sewage effluents etc) should be treated properly at point source so that environment is negatively affected. There is need to understand the status of distribution of these compounds and other hazardous chemicals in various water resources, and to develop better technologies for the treatment of waste at the point of their origin for sustainable and healthy environment.

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HIGHER GROWTH RATES OF SAXICOLOUS LICHENS IN ALPINE REGIONS OF WESTERN HIMALAYA- A CONSEQUENCE OF WARMING CLIMATE?

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ABSTRACT

Lichen species respond to changes in climatic conditions. The diameter growth rates of 8 lichen species viz. *Acarospora badiofusca*, *Circinaria calcarea*, *Dimelaena oreina*, *Physcia caesia*, *P. dubia*, *Protoparmeliopsis muralis*, *Rusavskia elegans* and *Xanthoparmelia Mexicana* were measured for the two consecutive years (2016 and 2017) with the help of digital vernier caliper in the alpine regions of Johar Valley located in Pithoragarh district, Uttarakhand, Western Himalaya. Lichen species *Xanthoparmelia Mexicana* showed highest diameter growth rate (3.39mm/year) while *Dimelaena oreina* showed the lowest growth rate (1.64mm/year). All the species showed higher growth rates as compared to their earlier reported growth rates. The study raises a question that - are these higher growth rates are a consequence of warming climate? To answer this question a detailed information about the growth rates of different lichen species from across the Himalayan alpine landscapes needs to be gathered. Further these growth rates can be correlated with the climatic data sets for better understanding of the responses of lichens to change in climatic conditions.

Keywords: Growth Rates, Himalaya, Johar Valley, Lichen, Warming.

INTRODUCTION

Lichens are very common organisms on planet Earth and are found in a range of habitats including the surfaces of rocks, bark of trees, soil and man-made objects. Lichens have long life spans and slow growth rates. Life span ranges from a couple of years for foliicolous lichens (Sanders *et al.*, 2002) to many centuries in the case of some polar and alpine species (Armstrong 2004). The crustose species typically grow only 0.1–2.0mm/year (Armstrong 2004) while most of foliose lichens grow with the rates of 0.5–4mm/year (Benedict e*t al.,* 1990). Sancho *et al.,* (2019) reported that most lichen species of the Antarctic tundra react positively to warming climate and negatively to cooling i.e. warmer climate is responsible for higher growth rates. Besides this, in a recent study greater warming rates have been observed in higher altitudes in general and western Himalaya in particular (Singh 2018). The alpine regions of western Himalaya are very less polluted as compared to urbanized low lands as well as the anthropogenic pressure also seems to be negligible. In this case climatic factors become more important for governing lichen growth and diversity and among various climatic factors temperature is one of the most important factors.

STUDY AREA AND METHODS

The study was conducted in alpine regions of Johar Valley that is located in Pithoragarh district in the state of Uttarakhand of western Himalaya. In the month of September 2016 and 2017 the lichen growth rates were measured on boulders spread from Milam village (N30°26.357′; E80°09.562′; 3462masl) to the snout of Milam Glacier (N30°27.952′; E80°06.702′; 3579masl). During recent years some lichenometric studies were conducted with the help of lichen growth rates in alpine regions of western Himalaya (Bisht 2018; Bisht *et al.*, 2018; Bisht *et al.*, 2019). 08 lichen species viz. *Acarospora badiofusca*, *Circinaria calcarea*, *Dimelaena oreina*, *Physcia caesia*, *P. dubia*, *Protoparmeliopsis muralis*, *Rusavskia elegans* and *Xanthoparmelia mexicana* growing on boulders were selected for growth rate measurement. The diameters of 10 specimens of each species were measured with the help of digital vernier caliper in 2016 and 2017 to calculate their annual diameter growth rate.

RESULT AND DISCUSSION

A total of 80 saxicolous lichen specimens belonging to 8 different species of lichens were measured (Fig.1).

The present lichen growth rates along with their previously reported growth rates are given (Table 1).

Fig.1. Diameter growth rate measurement of different lichen species **(A)** *Acarospora badiofusca*, **(B)** *Circinaria calcarea*, **(C)** *Dimelaena oreina*, **(D)** *Physcia caesia*, **(E)** *P. dubia*, **(F)** *Protoparmeliopsis muralis*, **(G)** *Rusavskia elegans* and **(H)** *Xanthoparmelia mexicana*

Table 1. Measurements of annual diameter growths of different lichen species in Johar Valley

Species	Family	Annual diameter growth of lichen specimens (mm)										Avg. Annual Growth Rate (mm/year)	Previous Growth Rates (mm/year)	Reference
		S1	S2	S3	S4	S5	S6	S7	S8	S9	S10			
Acarospora badiofusca	Acarosporaceae	2.12	2.20	2.73	2.74	2.98	3.15	3.27	3.29	3.58	3.62	2.97	1.60	Winchester 1984
Circinaria Calcarea	Megasporaceae	1.22	1.37	1.44	1.69	1.82	1.87	2.22	2.36	2.41	2.95	1.94	1.27	Winchester 1984
Dimelaena Oreina	Caliciaceae	1.02	1.16	1.35	1.39	1.47	1.62	1.98	2.06	2.15	2.21	1.64	0.30	Awasthim 2005
Physcia Caesia	Physciaceae	1.34	1.45	1.48	1.56	1.69	1.78	1.82	3.12	3.17	3.22	2.06	1.62	Hakulinen, 1966
Physcia Dubia	Physciaceae	2.20	2.25	2.42	2.61	2.75	2.92	3.21	3.67	3.80	3.88	2.97	2.50	Armstrong 1973
Protoparmeli-opsismuralis	Lecanoraceae	1.80	1.95	1.98	2.26	2.31	2.42	2.97	3.12	3.33	3.76	2.59	2.14	Winchester 1984
Rusavskia Elegans	Teloschistaceae	0.50	0.95	2.21	2.75	2.92	2.98	3.75	4.21	4.76	5.62	3.07	0.70	McCarthy and Smith 1995
Xanthoparmel-ia mexicana	Parmeliaceae	2.44	2.62	2.92	3.18	3.32	3.47	3.82	3.95	4.02	4.17	3.39	2.75	Armstrong 1973

Note: S = Specimen

Xanthoparmelia mexicana showed maximum annual diameter growth (3.39mm/year) followed by *Rusavskia elegans* (3.07mm/year), *Physcia dubia* (2.97mm/year), *Acarospora badiofusca* (2.97mm/year), *Protoparmeliopsis muralis* (2.59mm/year), *Physcia caesia* (2.06mm/year), *Circinaria calcarea* (1.94mm/year) and *Dimelaena oreina* (1.64mm/year). All the species showed higher annual growth rates as compared to their previously reported growth rates. *Rusavskia elegans* showed maximum variation in its growth rates (2.37mm/year) while *Physcia caesia* showed minimum variation i.e. 0.44mm/year. There are numerous environmental factors which influence the growth of lichens. These factors may be due to habitat conditions as well as climate. Rainfall, temperature, light intensity, frost injury, snow, aspect, slope, physical and chemical properties of rock, bird droppings, salinity, pollution etc. are responsible for lichen growth rates. Till date the responses of Himalayan alpine lichen vegetation to changing climate are poorly investigated and documented and it is well known that every taxon may not respond to climate change in the same manner. A particular climatic condition may be quite favourable for some, while at the same time it may be less suitable or unsuitable for the others. The temperature loving species may replace the cold adapted species and may dominate the high mountain summits. Only a few datasets dealing with lichen growth rates and climatic parameters are available from the alpine region of western Himalaya to correlate the past growth rates and climate with the present conditions. Hence, the impact of climate change on alpine lichen growth rates cannot be presented as lichens are very slow growing and it will take several years to infer the climate change impacts on lichen growth rates.

CONCLUSION

Present study concludes that the higher growth rates of lichens in alpine regions of western Himalaya could be due to greater warming rates. However, a detailed study from various alpine regions taking several lichen species into account along with environmental factors is needed for a generalized statement. Further there is scope for correlating lichen growth rates with temperature data for better understanding of the responses of lichen growth rates to warming climate. Lichens are likely to provide possibilities for future research that could contribute considerably towards a better understanding of drivers and impact of climate change.

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REGENERATION PATTERN OF TREE SPECIES ALONG AN ALTITUDINAL GRADIENT IN PITHORAGARH DISTRICT, WEST HIMALAYA

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ABSTRACT

Regeneration is an important process for maintaining biodiversity, however, several anthropogenic factors influence the pattern of regeneration in forest ecosystem of west Himalaya. The present investigation highlights, the regeneration pattern of dominant tree species namely *Pinus roxburghii*, *Querus leucotrichophora, Myrica esculenta, Pyrus pashia, Querus gluaca, Lyonia ovalifolia, Rhododendron arboreum* and *Terminalia chebula* along the altitudinal gradient (1000-1700m asl) of Pithoragarh district (Uttarakhand). Irregular distribution of the species recorded in the study sites, and maximum species showed "good" (55 %), "New" (22%), "Fair" (18%), "No" (3%) and "Poor" (2%) regeneration trend between 1000m and 1700m asl. At 1500m asl best regeneration was found with maximum species richness as compared to other elevations. However, most of the species are showing 'fair' regeneration, which needs an immediate attention for conservation. Therefore, their management and conservation strategies are required for future regeneration and their plantation will be helpful for biodiversity conservation.

Keywords: Regeneration, Tree species, Altitude, Pithoragarh district, West Himalaya

INTRODUCTION

Regeneration is a key process for the existence of any species in a forest community under varied environmental conditions and also an important indicator of sustainability of forest stock (Baland *et al*., 2010). This is cost effective natural process by which the plant species re-establish themselves and help in maintaining their diversity as well as genetic identity (Hanief *et al*., 2016), and also indicate possible changes in near future (Sharma *et al*., 2014). Presently, inadequate regeneration is the main problem of forests in hilly regions of Himalaya (Rawat *et al*., 2014), however, previous reports indicate that population structure and regeneration pattern of the tree species is influenced by several factors (Gairola *et al*., 2014). Many researchers, highlighted information on richness and diversity of forest ecosystems in the Western Himalaya (Rawal *et al.,* 1994; Dhar *et al*., 1997; Rawal *et al*., 2012; Lodhiyal *et al*., 2013; Singh *et al*., 2016; Negi 2019) however, more data on the regeneration pattern and population structure of diverse tree species along the altitudinal gradient is still required, particularly economically important tree species. This study generates base line data and pattern of species regeneration that will be helpful for developing strategies for future conservation to supplement the subsistence need of the local communities.

METHODOLOGY

The study was carried out along the altitudinal gradient (1000-1700masl) in different forest types of Pithoragarh district, Western Himalaya, Uttarakhand, India (Table 1).

Table 1. Characteristics of the study sites Pithoragarh district, west Himalaya

S. No.	Location	Latitude	Longitude	Altitude (masl)	Aspect
1	Gobrari	29°44'36.9"	080°09'21.4"	1000	SE
2	Tuniyar	29°48'35.9"	080°10'07.2"	1100	SE
3	Tapradhar	29°50'27.8"	080°09'36.5"	1200	NW
4	Gartil	29°47'03.0"	080°05'36.8"	1300	NE
5	Humkapita	29°51'17.6"	080°13'48.2"	1400	NE
6	Hattrap	29°47'14.0"	080°15'30.0"	1500	NE
7	Ankot	29°47'15.9"	080°14'33.0"	1600	Ridge top
8	Devradi pant	29°45'41.5"	079°54'53.1"	1700	SW

The quadrate sampling approach was followed and we laid down 105 sample plots for trees and saplings, and 350 plots for seedlings in the studied forests. Random vegetation sampling was conducted and 3 sample plots (50×50m) were marked. In each plot, 5 quadrats (10×10m) for enumeration of trees and saplings were laid and each individual 10×10m sub quadrates was further sub-divided into 1×1m for seedlings. Circumference at breast height (cbh at 1.37cm height from ground) was measured for trees. The tree population structure was developed based on density distribution across size classes. Individuals: >31cm CBH were considered trees, 10-31cm CBH as saplings and <10cm CBH as seedlings. The individuals of tree species were recorded from each quadrate and grouped in to seven girth classes (A: 0-10; B: 11-30; C: 31-60; D: 61-90; E: 91-120; F: 121-150; G>151cm). Class A and B represent seedling and sapling, respectively and Classes from C-G represented tree species. Relative density in a size class was calculated as a percentage of the total number of individuals in all size classes. The quadrat data were pooled for plots for calculation of various quantitative measures such as density, frequency, abundance, abundance/frequency ratio and Important Value Index (IVI) (Rawal *et al*., 2012; Rawat *et al*., 2014). The provenance value (PV) index was calculated for seedling by using the values of relative density (RD) and relative frequency (RF). The diversity (H') was determined using Shannon - Wiener index as $H= -\Sigma (ni/n)^2 \log2 (ni/n)$, where ni is the density of a species and n is the sum of total density of all the species of that forest. The Simpson's diversity index was calculated as D= 1- Cd, where D is Simpson's diversity and Cd is Concentration of dominance. Species richness was considered as number of species per unit area. The regeneration status of tree species was determined on the basis of population size of seedling, sapling and tree; (a) Good regeneration i.e. if number of seedling >sapling >adults, (b) Fair regeneration i.e. if number of seedling > or <sapling <adults, (c) Poor regeneration i.e. if the species was found as sapling, but no seedling (number of sapling may be more, less or equal that of adult) (d) No regeneration i.e. if individuals of species are present only as adults, and (e) New regeneration i.e. if individual of species have no adult but present as seedling or sapling (Hanief *et al*., 2016).

RESULTS AND DISCUSSION

The total 18 tree species belonging to 14 families were recorded from the study area from which 17 species belonged to angiosperm (16 genus, 17 species and 13 families) and 1 belonged to gymnosperm (1 genus, 1 species and 1 family). Ericaceae and Rosaceae (2 genus and 2 species respectively) were reported as dominant family followed by Fagaceae with 1 genus and 2 species (Fig. 1).

TREE, SAPLING AND SEEDLING LAYER

Tree density was recorded range 147-547indi/ha along the altitude (Table. 2) and *Quercus leucotrichophora* reported maximum tree density at 1200m asl. The highest IVI (300) was found in *Pinus roxburghii* at 1100m and 1700m, however, lowest (9.5) found at 1500m in *Prunus cerasoides*. The

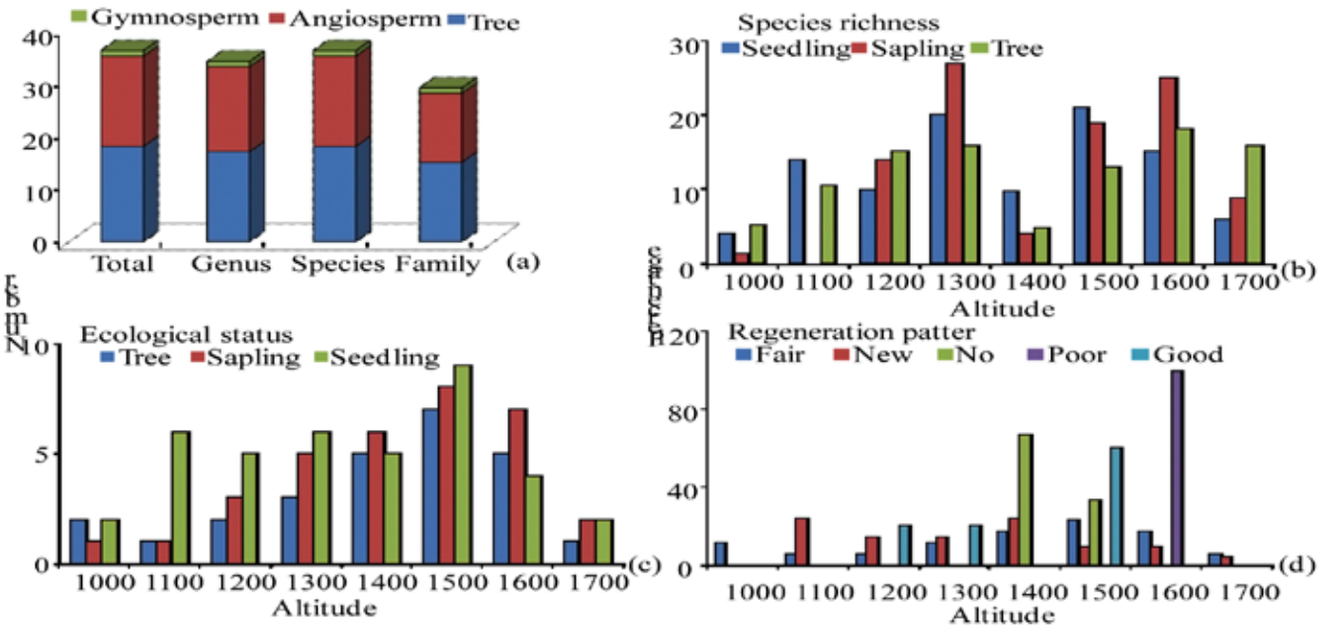

Fig. 1. Forest characteristics along the altitudinal gradient, West Himalaya

Shannon diversity index (H') range= 0.13 to 1.14 was reported maximum in *Myrica esculenta* (0.36) at 1300m followed by *Pinus roxburghii, Quercus leucotrichophora and Rhododendron arboreum,* respectively. Likewise, Simpson diversity index was varied from 0.41 to 3.93 and reported maximum in *Terminalia chebula* (0.99) at 1400m asl. Results reveal that sapling density varied between 7 and 447 indi/ha along the elevation range and was reported maximum in *Q. leucotrichophora* (213indi/ha) at 1300m. The lower altitude forest indicated highest IVI for *P. roxburghii* (1100m) and *P. pashia* (1300m). Similarly, sapling of *M. esculenta* (0.36) showed maximum diversity at 1300m and minimum found at 1700m in *P. roxburghii* (0.02). In terms of seedling density (range= 30-181indi/ha), was and reported highest in *Q. leucotrichophora* (66indi/ha) at 1300m as compared to others species. *P. roxburghii* showed maximum IVI in the lowest altitude (1000 m) and minimum in *A. nepalensis* (1400m). The 1300 m altitude was found good for seedlings of *M. esculenta* (0.36), *P. roxburghii* (1) which showed highest Shannon diversity index (H') and Simpson diversity, respectively.

Contagious distribution was shown by maximum species (63-88%) followed by random distribution (13-38%) and regular distribution (13%). The highest percentage of contagious distribution was shown by tree and sapling (50%). Random distribution highest shown by sapling (40%) and tree (23%) at 1600masl where as regular distribution was shown highest by tree (55%) at 1500masl. The tree species number varies in different forest as their seedling/sapling stages are concerned (Fig. 2). The overall seedling density ranged between 31-181indi/ha whereas sapling density varies from 27-407indi/ha. The maximum percentage of seedling (20%) was recorded at 1500masl and minimum (1%) at 1100masl. The highest percentage of sapling (27%) at 1300masl followed by (25%) at 1600masl whereas the maximum percentage of tree (18%) at 1600masl and minimum (5%) at 1000 and 1400masl.

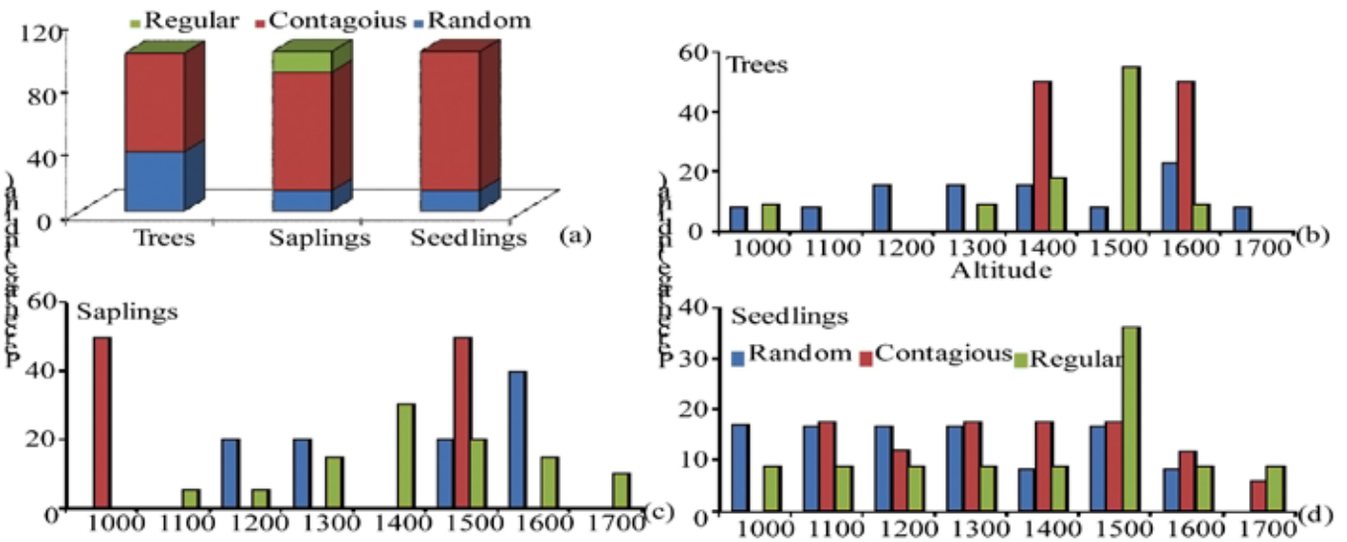

Fig.2. A/F ration of studied forest sites along the altitudinal gradient, West Himalaya

Table 2. Phytosociological analysis of tree species along the altitudinal gradient

	Parameters					
Altitude (masl)	**Density (indi/ha)**	**Frequency**	**A/F Ratio**	**Simpson diversity**	**Shannon diversity**	**Dominant species (IVI values)**
Tree						
1000	160	87	0.043	0.42	0.14	*P. roxburghii* (286.3)
1100	327	100	0.033	0	0	*P. roxburghii* (300)
1200	460	107	0.093	0.41	0.13	*Q. leucotrichophora* (272.3)
1300	500	187	0.103	2.12	0.72	*Q. leucotrichophora* (150.9)
1400	147	100	0.187	2.47	0.83	*P. roxburghii* (175.3)
1500	393	227	0.157	3.93	1.14	*Q. gluca* (133.2)
1600	547	173	0.183	2.76	0.72	*Q. leucotrichophora* (161.6)
1700	500	100	0.050	0	0	*P. roxburghii* (300)
Sapling						
1000	27	13	0.067	0	0	*T. chebula* (200)
1100	7	7	0.017	0	0	*P. roxburghii* (100)
1200	227	80	0.090	0.82	0.26	*Q. leucotrichophora* (244.8)
1300	447	227	0.120	3.27	0.51	*Q. leucotrichophora* (121.4)
1400	73	53	0.097	1.91	0.52	*A. lebbeck* (73.4)
1500	313	140	0.257	4.69	1.39	*Q. gluca* (85.4)
1600	407	207	0.200	3.94	1.12	*Q. leucotrichophora* (120.2)
1700	153	60	0.037	0.38	0.08	*P. roxburghii* (174.1)
Seedling						
1000	81	29	0.093	0.43	0.15	*T. chebula* (200)
1100	117	90	0.460	3.37	0.73	*P. roxburghii* (100)
1200	90	75	0.307	2.87	0.90	*Q. leucotrichophora* (244.8)
1300	177	131	0.443	4.72	1.41	*Q. leucotrichophora* (121.4)
1400	87	72	0.357	0.66	0.88	*A. lebbeck* (73.4)
1500	181	139	0.403	5.11	1.51	*Q. gluca* (85.4)
1600	127	106	0.230	3.27	0.11	*Q. leucotrichophora* (120.2)
1700	30	29	0.073	0.50	0.22	*P. roxburghii* (174.1)

POPULATION STRUCTURE AND REGENRATION PATTERN

A total of 1542 free-standing live individuals (DBH>1cm) were identified belonging to 7 species, 6 genera, 6 families. *Q. leucotrichophora*, *P. roxburghii* and *M. esculenta* were the most abundant, accounting for 36.12%, 33% and 19%, respectively, of the total number of the free standing individuals and identified as dominated species in the forest community. The DBH classes of all species in the sample plot were unimodally distributed, with young trees more abundant than older trees and 59.27% of the individuals were in the DBH class <10cm; indicating abundant recruitment beneath the forest canopy. However, *Q. leucotrichophora*, and *P. roxburghii* had a higher capacity for natural regeneration than rest of the identified species. According to the DBH class of tree species the distribution of *Q. leucotrichophora*, and *P. roxburghii* was unimodal and discontinuous, similar to that of all species in the sample plots, evident discontinuous unimodal distributions, with abundant smaller trees and distinct size deficiencies (2cm<DBH<8cm and 3cm<DBH<10cm), suggesting an adequate number of seedlings, but a lack of saplings under the canopy. A sharp decrease at a DBH of 11-30cm indicated that all the studied species *Q. leucotrichophora*, *P. roxburghii, M. esculenta, T. chebula, R. arboreum, L. ovalifolia, P. pashia* saplings have high mortality under the forest canopy. All the studied spp. at an elevation gradient of 1000-1500m had a low survival rate between the seeding and sapling stages. The presence of sapling and tree stage (DBH<90cm) were exhibited in *R. arboreum* at

an altitude of 1600m and *P. roxburghii* at 1700m, respectively (Fig. 3).

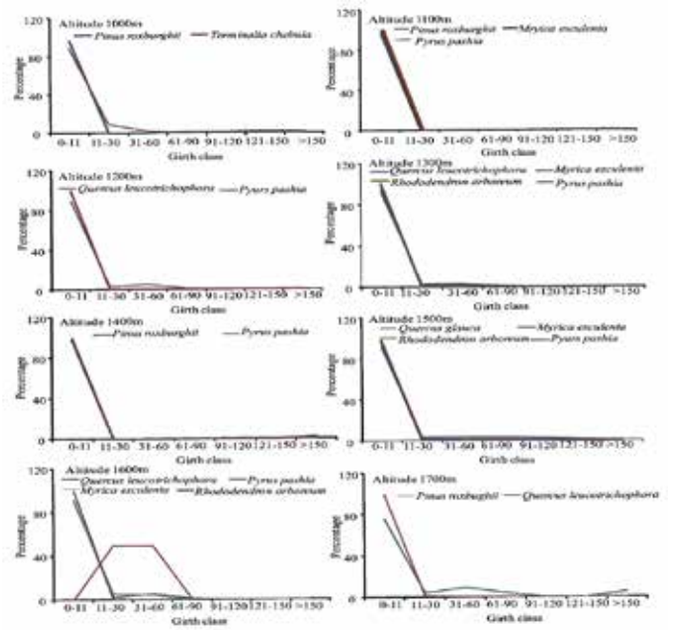

Fig. 3. Population structure along the altitudinal gradient, West Himalaya

Similarly, *P. roxburghii* showed maximum tree density (500indi/ha) at 1700m (Table. 3), however, sapling density of *Q. leucotrichophora* (213indi/ha) was recorded highest at 1300 m and seedling density of *P. roxburghii* (91indi/ha) recorded maximum at 1100m elevation. In the study area, maximum species showed "good" (55 %), "New" (22%), "Fair" (18%), "No" (3%) and "Poor" (2%) regeneration trend at 1000m to 1700m (Fig. 4; Table 3). *R. arboreum,* in north east (NE) facing aspect at 1500m elevation showed "good" regeneration, however, "poor" was found in ridge top of 1600m elevation. *M. esculenta* was reported "fair" regeneration at 1300m, 1500m and 1600m. However, "new" regeneration at 1100m elevation from south east (SE) facing aspect recorded in *M. esculenta*. "New" regeneration was found in *P. pashia* in the elevation range of 1100m to 1600m. However, "no" regeneration was reported by *T. ciliata*, *B. variegata* and *P. cerasoides*.

Altitude is one of the most important determinants of tree distribution due to its direct impact or microclimate of the habitat (Rawal *et al.,* 1994). In the western Himalaya, along the altitudinal transect, distinct changes in vegetation types are reported (Gairola *et al*., 2008). The forest health depends on the potential regenerative status of species composing the forest stand in space and time (Jones *et al*., 1994), and the species distribution pattern indicates its adaptability to various environment and forest communities mainly depends on the ecological characteristics of locations, species diversity and regeneration pattern (Gairola *et al*., 2014). Researchers also reported that regeneration status of tree species of any forest is determined by recruitment of saplings and seedlings (Dhar *et al*., 1997; Pant *et al.,* 2012). The outcomes of the study supported by earlier investigations (Pant *et al.,* 2012; Singh *et al*., 2016). In the study, most of the species had contagious distribution, few species had shown random distribution and very few species showed regular distribution. However, in the mid elevation range (1500-1600m) showed maximum regular distribution of trees and saplings. Similar kind of trends also reported in Garhwal Himalaya (Gairola *et al*., 2010; Singh *et al*., 2016). The study reported highest species richness in NE facing aspect of forest of *Q. glauca* (1500m) and three species namely, *Q. leucotrichophora, M. esculenta* and *P. pashia* showed new regeneration at 1100m in the SE aspect (1100m). The poor regeneration was recorded for *Q. glauca* and *R. arboreum* at the ridge top of 1600m, and *T. ciliate*, *B. variegata* and *P. cerasoides* showed no regeneration. The overall status of regeneration of the tree species is unsatisfactory and alarming situation which may affect the population size and forest composition in near future. Few species reported fair regeneration which might be due to anthropogenic pressure such as firewood collection, grazing, poor biotic potential of tree species which either affect the fruiting or seed germination or successful conversion of seedling to sapling stage. Regeneration of the species is also affected due to environmental factor such as temperature, rainfall, moisture content, soil characteristics, aspect, altitude, etc (Gairola *et al*., 2014; Pant *et al*., 2017; Negi 2019). The economically important species those produce wild edibles and other products need to be given prioritize in regeneration and protection of forest that will also serve the purpose of biodiversity conservation in the region.

Table 3. Regeneration status of tree species along the altitudinal gradient, West Himalaya

Altitude (m asl)		Density (indi/ha)							
		Pinus roxburghii	*Quercus leucotricophora*	***Myrica esculenta***	***Pyrus pashia***	*Quercus gluaca*	*Lyonia ovalifolia*	*Rhododendron arboreum*	*Terminalia chebula*
1000	SD	79	-	-	-	-	-	-	3
	SP	0	-	-	-	-	-	-	27
	TR	153	-	-	-	-	-	-	7
	RS	Fair							Fair
1100	SD	91	5	**9**	**6**	-	-	-	-
	SP	7	-	-	-	-	-	-	-
	TR	327	-	-	-	-	-	-	-
	RS	Fair	New	**New**	**New**				
1200	SD	21	54	-	**7**	3	5	-	-
	SP	-	193	-	-	20	13	-	-
	TR	-	440	-	-	20	-	-	-
	RS	New	Fair		**New**	Fair	New		
1300	SD	15	66	**52**	**13**	-	23	**9**	-
	SP	60	213	**147**	**7**	-	20	-	-
	TR	13	333	**153**	-	-	0	-	-
	RS	Good	Fair	**Fair**	**New**		New	**New**	
1400	SD	58	11	-	**8**	-	-	-	8
	SP	7	7	-	-	13	-	-	33
	TR	100	0	-	-	-	-	-	20
	RS	Fair	New		**New**	New			Fair
1500	SD	-	14	**49**	**5**	35	21	**37**	-
	SP	-	47	**67**	**7**	100	20	**53**	-
	TR	-	53	**67**	-	220	7	**33**	-
	RS		Fair	**Fair**	**New**	Fair	Good	**Good**	
1600	SD	-	64	**25**	**29**	-	9	-	-
	SP	-	173	**153**	**7**	20	33	**7**	-
	TR	-	380	**133**	-	13	13	**7**	-
	RS	-	-	**Fair**	**New**	Poor	Fair	**Poor**	
1700	SD	47	5	-	-	-	-	-	-
	SP	147	7	-	-	-	-	-	-
	TR	500	-	-	-	-	-	-	-
	RS	Fair	New						

(Whereas: RS-Regeneration status; SD-Seedling; SP-Sapling; TR-Trees)

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IMPACT OF POLLUTION ON THE HEALTH OF RIVER GANGA IN UPPER HIMALAYAN FOOTHILLS

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ABSTRACT

This research article reviews, critically analyzes and finally identifies the pollution crisis looming large over the most magnificent, historical, revered, benevolent, faithful, lifeline for billions globally and highly valuable river Ganga- the cultural and rich heritage of our country, playing pivotal and indispensible roles in human life and civilization. Further, several reasons of pollution and related water quality deterioration in Ganga on biotic and abiotic components of the environment have been given based on literature review. Study reveals that pollution scenario in Ganga river reflects a dark picture and alarms to mitigate it urgently by devising meaningful and effective strategies.

Keywords : River Ganga, Historical perspectives, Water pollution, Upper Himalayan regions, Public health, Metal toxicity, Biotic and Abiotic communities.

INTRODUCTION

Water is the most important resource needed for growth, development and sustenance of life on earth. It is evident from the fact that nearly 79% of earth is occupied only by water. Similarly, 79% water is found in our body. So is the importance of water for us and the associated communities. Ganga- the most important river in India, is the illuminating source for human civilization and millions depend on this great river for physical and spiritual sustenance. People have immense faith in the healing and rejuvenation powers of Ganga. It is unarguably the most sacred river in India and is deeply revered by the people of this country and beyond. Due to the ample availability of water throughout the year, accounting for 25% of Indian water resources, Ganga has played a significant role in the growth of Indian civilization and economy (Paul *et al.*, 2013). Ganga is the 30th longest river in the world, covering a basin area of 861,404 km^2 (Rahaman 2009). Ganga basin is among the most heavily populated areas in the world with an average density of 520 persons/km^2 (Das *et al.*, 2012). The basin houses and supports the lives of more than 400 million people in India, Nepal, and Bangladesh (Gopal 2000) and has very rich heritage, cultural and religious values.

Considering the water discharge into the sea, this river occupies the third largest river status across the globe. The river system drains about one fourth area of Indian subcontinent. Ganga river water is used routinely for drinking and outdoor bathing by millions of people who take a holy dip at least once a year throughout the course of the river, from Gangotri to Ganga Sagar, owing to its socio-religious significance (Rehana 1996).

HISTORY, ORIGIN AND IMPORTANCE OF GANGA

Himalaya is the origin source and home of major Indian rivers including Ganga and Brahmaputra. Bhagirathi is the source stream of Ganga. It emanates from the Gangotri glacier at Gaumukh situated at 3,892m from mean sea level. This river occupies an unique position in the cultural ethos of India. Legend says that the river has descended from heaven on earth as a result of the long and arduous prayers of king Bhagirath for the deliverance of soul to eternity of his sixty thousand ancestors burnt to ashes by the curse of Kapil Muni. From times immemorial, Ganga has been India's river of faith, devotion and worship. Millions of Hindus consider its water as the most sacred.

The people carry treasured Ganga water all over India and abroad because it is "holy" water and known for its "curative" properties (Paul 2017) besides, destroying the sins committed in life and beyond and deliverance of soul form the pains of

birth and death. However, the river is not only a legend but also a life support system for the people of India. Alaknanda, Dhauliganga, Pindar, Mandakini and Bhilangana find their ultimate home in Ganga and are considered as the sisters of Ganga. At Devprayag confluence, Alaknanda joins Bhagirathi and thus it becomes Ganga. It travels about 2525km on her journey destination to the sea. Ganga basin is a part of the composite Ganga-Brahmaputra-Meghna basin draining 1,086,000km² in China, Nepal, India and Bangladesh. Nearly 79% area of Ganga basin is in India. It is the largest river basin in the country, constituting 26% of the country's land mass and supporting about half of Indian population. Ganga drains a basin of extraordinary variety in altitude, climate, land use, flora and fauna, social and cultural life.

Besides, Ganga commences its journey on the way to sea- the ultimate destination, along with the main larger rivers like Yamuna, Ramganga, Gomti, Ghaghara, Gandak, Kosi and Kali-East and sub tributaries such as Chambal, Sindh, Betwa, Ken, Tons (beyond Five States), Sone and Kasia-Haldi. The surface water resources of Ganga (its long term mean annual flow volume upon entering the ocean) have been estimated as 525 billion cubic meters (BCM). Noteworthy is to mention that the average population density in Ganga basin is 520 persons per square km as compared to 312 for the entire country. Further, Ganga has immense values for Indian people in terms of densely populated basin (inhabited by 37% of Indian population). Effective draining of about half of the states of north India, irrigating 47 % of the total cultivable land in India, being the major source of navigation and communication since ancient times etc., are furthering its importance.

POLLUTION SCENARIO OF GANGA IN INDIA: CAUSES, SEVERITY AND CRISIS

Recently, pollution increase is being noticed in the least inhabited stretches like Upper Himalayan regions as a result of rapid industrialization, urbanization, use of chemicals, fertilizers and pesticides etc. Water borne diseases, mainly diarrhea, become more panic and severe when water bodies get densely contaminated and polluted. It was stated in the year 2012, during the meeting of Ganga Basin Authority that every day 29,000 trillion litres of wastes, dirty and polluted water and effluents are drained in the river Ganga. Moreover, domestic household wastes and municipal sewage sludge wastes containing nearly all types of pathogenic coliform bacteria are considered as the biggest cause of about 85% pollution of river Ganga. Ganga water at Rishikesh has shown the presence of all types of *pathogenic coliform bacteria,* many times more than the recommended permissible limits. Rishikesh is situated on the bank of holy river Ganga but around 20% of population does not have sewer lines and hence dirty domestic waste water is drained in Ganga amounting to around 85% of pollution specially the bacterial pollution. In Rishikesh, from Tapovan to Shyampur, around 18 drains directly discharge in to Ganga. Triveni Ghat- the heart of Rishikesh, witnesses the merger of the biggest drain of the city (earlier known as Saraswati Stream), containing dirty household domestic and municipal sewage sludge wastes in the river Ganga. Due to all these ill impacts, there is an alarming increase in the number of patients of diarrheal diseases, mainly bacterial diarrhea, in and around Rishikesh city.

Similarly, in Haridwar district, 42 million litres of wastewater/ sewage is drained in Ganga every day and nearly 30 million litres of wastewater/ sewage is drained in Ganga every day from hilly districts of Garhwal Himalayan regions like Uttarkashi, Tehri, Chamoli, Rudraprayag and Pauri. The seventeen towns in Chamoli district alone drain in Ganga every day approximately 11.00 million litres of wastewater/sewage. In report of 2011-12, CAG declared the water of Yamuna, Ganga and Hindan as the home of diseases in Uttar Pradesh. It is noteworthy to mention that every day 860 million litres of sewage/ domestic waste is being drained in river Ganga water in Himalayan region is given in Table 1.

Table 1. Showing the details of domestic/household wastewater discharge in river Ganga from Garhwal Himalayan region

Districts	City/ Towns	Sewer/ domestic waste discharge (million litres daily- MLD)
Uttarkashi	41	13.76
Rudraprayag	2	0.36
Tehri	5	5.44
Dehradun/ Rishikesh	4	11.97
Pauri	1	2.66
Haridwar	6	39.54

(Source; Dainik Jagran, Page 01, 3 December, 2016).

Industrial effluents and sewage/domestic wastes entering the water bodies are among the main sources of environmental toxicity damaging the aquatic biota and deteriorating the water quality (Tripathi 1993; Sinha *et al*., 2012; Sinha *et al*., 2016). For example, data collected from Government District Hospital and Nirmal Ashram Hospital from Rishikesh (both from OPD & IPD) clearly proved the panic and severity of diarrheal diseases. In Government District Hospital of Rishikesh, nearly 1400 patients with diarrheal complaints reported during July-September, 2012 and above 98% of them were found suffering from bacterial diarrhea. Further, the observations made at Nirmal Ashram Hospital of Rishikesh demonstrated that nearly 960 patients with diarrheal complaints reporting to Hospital during April - August, 2012, were found suffering from bacterial diarrhea.

DOCUMENTATION OF GROUND REALITY OF RIVER GANGA WATER POLLUTION AT RISHIKESH

Fig.1. (A & B) showing direct drainage of domestic/city wastes in river Ganga at Swargashram, Rishikesh & Picture **(C)** showing direct drainage of domestic wastes/ city wastes in river Ganga at Chandreshwar Nagar, Rishikesh.

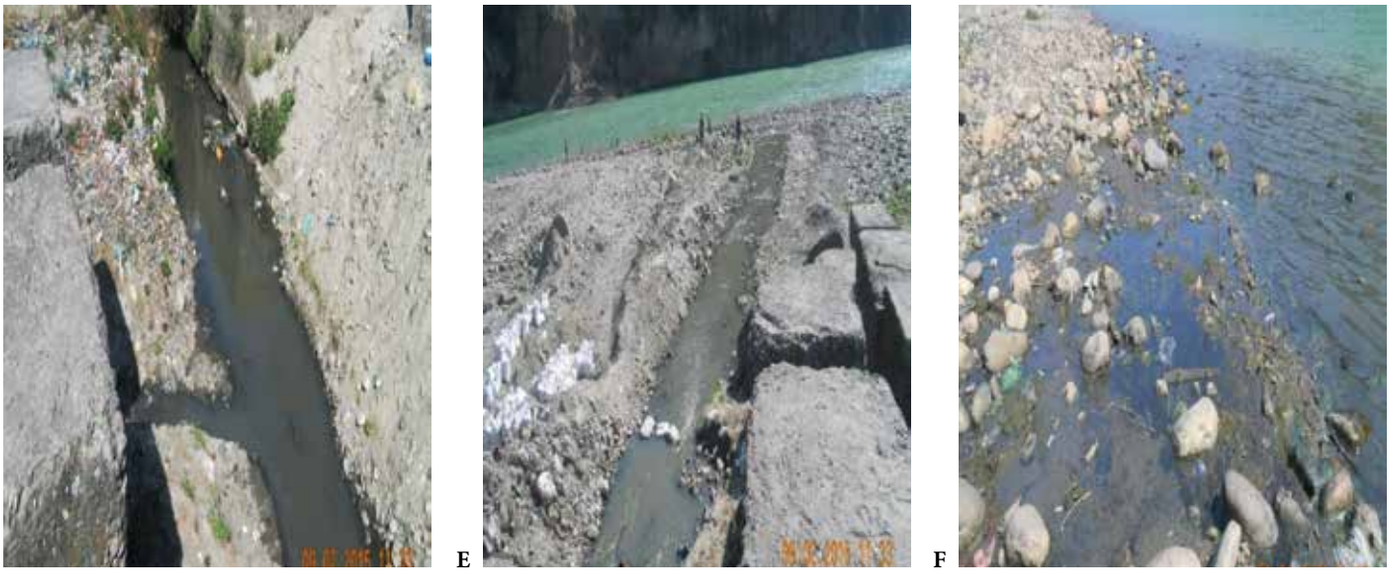

Fig.1. (D, E and **F)** showing direct drainage of city wastes/domestic wastes in river Ganga at Chandreshwar Nagar, Rishikesh.
Note *how badly the city domestic wastes are contaminating and intoxicating the larger area of river Ganga water at Chandreshwar Nagar, Rishikesh.*

The river water pollution due to heavy metals, in terms of toxicity, is one of the serious threats posed in the most of the metropolitan cities of India and other developing countries. These heavy metals are of serious concerns due to not readily degradable nature and accumulation in the animal as well as human bodies through the food chain (Parveena *et al.,* 2010). Major pollutants found in water include volatile, biodegradable and recalcitrant organic compounds, toxic metals, plant nutrients, suspended solids, microbial pathogens and parasites (Bitton 1994; Sinha *et al*., 2016).

This pollution load in Ganga water is harmful to a variety of faunal diversity reported between Haridwar to Farakka (Sinha 2014). The 87 species of zooplankton and 83 species of fishes were found. Zoological Survey of India reported 375 species of fish including 34 Indian major carps (*Labeo rohita, Catla catla, Cirrhinus mrigala*, and *Labeo calbasu*), large catfishes (*Aorichthys aor, A. seenghala, Wallago attu, Bagarius bagarius*), feather backs (*Notopterus notopterus, N. chittala*) and murrels (*Channa marulius, C. punctatus*) from Ganga water (Rahman *et al.,*2012).

CONCLUSION

This article presents an overview of the prevailing scenario of pollution in Ganga, its causes, severity and crises. Further, the details on sources and discharge of sewer and other wastes, coming from several sites in Upper Himalayan regions, have been put forth particularly in Rishikesh. Based on the foregoing deliberations, it becomes evident that the river Ganga is facing pollution problems from various sources. Therefore, measures like stopping the direct discharge of sewer lines, establishing functional treatment plants and sustaining the usual water flow throughout, maintaining natural biological and physicochemical properties of water are strongly recommended. Efforts to minimize the pollutant load, cleaning targets and launching the effective result oriented awareness programmes can be other approaches to combat and minimize the pollution threats.

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PERSPECTIVE ON HIMALAYAN SPRING WATER: A QUINTESSENTIAL RESOURCE

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ABSTRACT

Spring water resources are the natural assets which Himalayan states are bestowed with, and Mandi is one such district in Himachal Pradesh, India. The perception based study indicated that changing precipitation patterns attributed to climate change impacts, catchment degradation, unrestricted landuse, ignorance and inadequate regulations are adversely impacting the spring discharge and creating water scarcity to people of the Mandi district. This has definite social, cultural, religious and environmental implications on livelihood of the people. Therefore, scientific and indigenous knowledge should be incorporated to formulate sustainable plans for the water security of mountain inhabitants.

Keywords: Springs, Himalaya, Climate change, Water Security, Perception.

INTRODUCTION

Civilization has always laid their habitations near the available water sources. Sustainable social and economic upliftment worldwide quintessentially depends on availability of fresh water resources. Among all the freshwater resources, groundwater sufficiently meets the demand of domestic, agriculture and industrial sectors. Groundwater is considered to be less contaminated in comparison to other water resources that is being over explored on the recent decades concern over water management even in the selected locations of Himalayan region.

In the Himalayan region springs have been playing an important role in the daily lives of rural communities and urban towns. The significance of springs in the life of mountainous areas especially Himalayan regions is more prominent than rest of the region in the country. Studies conducted on springs in Kashmir Himalayas (Jeelani *et al.,* 2015, Bhat *et al.,* 2015), Sikkim Himalayas (Tambe *et al.,* 2012), Kumaun Himalayas (Valdiya *et al.,* 1989, 1991, Negi *et al.,* 2002, Ansari *et al.,* 2015), Nepal Himalaya (Shrestha *et al.,* 2018), Uttarakhand (Shivanna *et al.,* 2008), Himachal Pradesh (Kumar *et al.,* 2012; Thakur *et al.,* 2018) reputed that spring flow is diminishing which is of prime importance in the area for agricultural, social - economic and tourism activities. Climate change, unrestricted land use, overwhelming pressures of population growth, disturbances in spring catchment areas and inadequate regulations has led to depletion in these spring water resources. Decreasing and drying spring discharges not only lead to migration of the people, reduction in economy as well as change in ecology but also sabotage the social, cultural and religious relevance. In Mandi district of Himachal Pradesh, major projects of domestic water supply system are based on springs, hence it is essential to study the current status of spring water resources and perception of local people. There is a paucity of data on springs in Himalayan states of India in general, and Mandi district in particular especially on social, cultural and environment aspects which refrain the civil authorities to formulate sustainable plan for spring water management. This paper point out the role of springs for social, cultural, economic and environmental needs, and the imminent threats to the sustainability of springs by anthropogenic and natural factors, which is affecting the overall socioeconomic wellbeing of the people in the study area.

STUDY AREA AND METHODOLOGY

Mandi district is a densely populated and centrally located district of Himachal Pradesh. The district is entirely hilly, except a few isolated patches of small and fertile valleys. The district, with its headquarter at Mandi town, lies between 31°13' and 32° 05' north latitudes and 76°37' and 77°25' east longitudes. The district has a total geographical area of 3,950 Km^2. There are 6 towns and 3,338 villages in the district. There are 9 tehsils (Sadar, Thunag, Sundernagar, Sarkaghat, Padhar, Jogindernagar, Lad Bhraol, Karsog and Chachyot). The study area under

investigation (Barot valley and Seraj valley) lies in Padhar and Thunag tehsil. The district has a population of 9,99,777 persons with a population density of 253 persons Km^2 (Census 2011). The major sources of irrigation are small water channels or the Kuhls in the district and an area of 12608 ha is brought under irrigation by various sources like canals, tanks, wells and other sources. A sizeable part of the cultivated area of the district is not having any assured irrigation facilities and the agriculturists have to depend on the vagaries of weather. Under the various plans, the construction of Kuhls and lift irrigation schemes are being taken up in the district.

This study was carried out in Barot and Seraj valleys of District Mandi. For collection of information on knowledge and awareness regarding the status of spring water resources, the survey was conducted in the rural areas across 43 spring locations. Information pertaining to springs and their social, economic and cultural relevance were collected through Participatory Rural Appraisal (PRA's) technique (Fig.1). The interactive PRA techniques employed to ascertain the required information using a semi structured questionnaire and pre tested schedule (45 respondents) and subsequently compiled and presented in this article.

Fig. 1. Participatory Rural Appraisal on spring status

RESULT AND DISCUSSION

Springs play an important role in the socio-economic development of the people in the study area. Springs at village level fulfil the demand of water supply for the livelihood of people in the absence or dysfunction of public water supply. Benefits drawn from these prime water resource are plenty in terms of domestic use, livestock use, and agriculture use and tourism sector. Out of total respondents (45 people) interviewed in the study area, majority of respondents stated that spring water quality is best for drinking water except during monsoon when rainfall - runoffs mixed with the spring discharge. Respondents believe that spring water is best quality water as they rely on it as purest portable water. Among the meteorological parameters, respondents considered precipitation (snow and rainfall) as major contributor for changing regime of springs. Some functional and abandoned springs are depicted in (Fig.2) and (Fig.3).

Integrating experience with traditional knowledge of communities and scientific technique is must to understand the dynamics of the springs so that spring water can be harvested sustainably.

Springs are considered to be sacred from religious and cultural point of view, and has always been preserved on this pretext that they have religious value and cultural affiliation. As Himachal is known as abode of gods, water resources such as rivers, lakes and springs are also worshiped as mountain deity with firm beliefs. Respondents of the study area listed out the above mentioned cultural and religious significance of the springs in their life. It is also observed that the advent of public water supply distribution system is important reason which leads to abandoning the springs in villages, and on the lines of "sacred grooves concept" religious and cultural attachment can be promoted for protection and revival of abandoned

Fig. 2. Functional springs used for various purposes in the study area

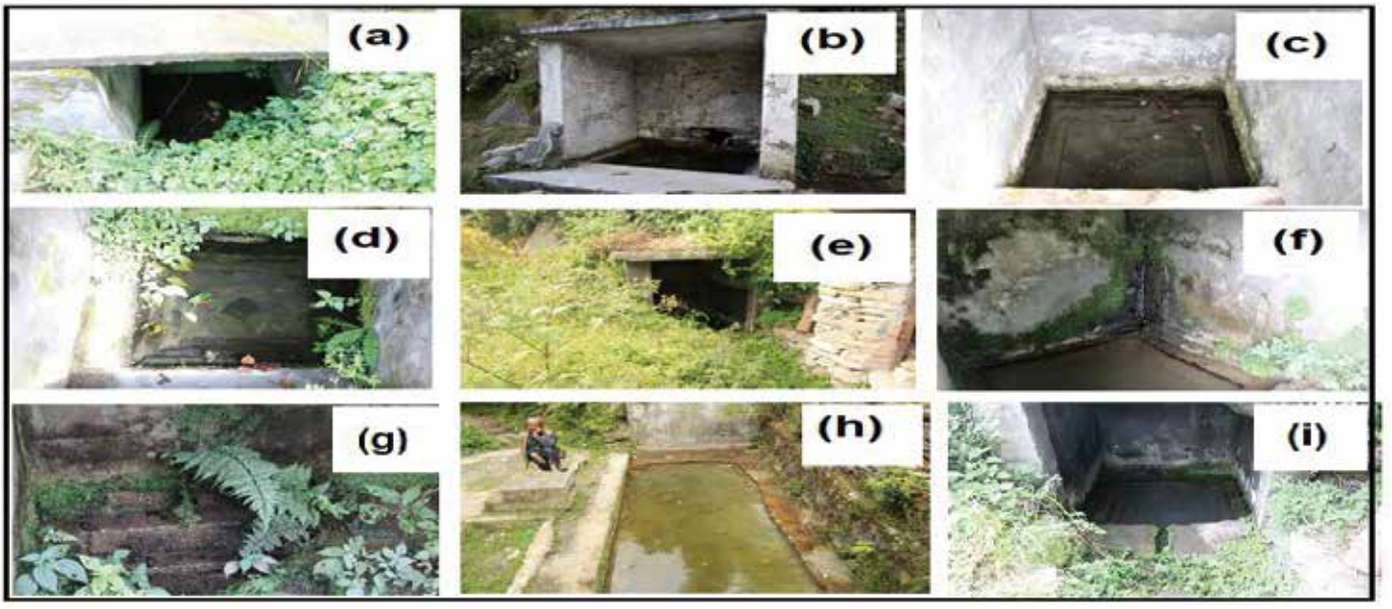

Fig. 3. Abandoned springs in the study area

springs. Demise of springs are caused first by ignorance and unrestricted land use and then by the overwhelming pressure of population growth, disturbances in spring catchment area and inadequate regulations. It is essential to reduce the negative impacts on the springs from various human induced and natural factors and create awareness among the local residents for spring sanctuaries and spring shed development. Respondents further added that spring water health is directly connected with forest cover and precipitation to have perpetual flow throughout year.

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SOIL NUTRIENT STATUS OF BHABHAR AND HILL AREAS OF UTTARAKHAND

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ABSTRACT

Soil is the most important and precious resource for food production. The increase in world population places continuous pressure on the soil resource to grow more and more food for the growing population. The per capita arable land is reducing every year due to increased population, land degradation and competition for non-agriculture land use. Due to enhanced production of food grains accompanied with imbalanced use of nutrients the intrinsic capability of soil to supply nutrients including micronutrients is reducing over the years. In Bhabhar area of Uttarakhand soils nutrient deficiency problems were more pronounced compared to soil of hilly area due to intense cropping. Application of balanced plant nutrients is thus the only solution to increase soil productivity for maintaining/enhancing the overall soil productivity. However soil nutrients status knowledge is must to determine the soil nutrients application roles. This study provides soil nutrients status of Nainital and Pauri Garhwal districts of Uttarakhand.

Keywords: Bhabhar Soil, Micronutrients, Hill farming, Cropping pattern

INTRODUCTION

Physical determinants, like steep and rugged topography, are the primary factors that have influenced hill agriculture in the Uttarakhand. Agriculture is the primary and biggest source of income in rural parts of Uttarakhand and provides employment to approximately 70% of the population. Hill agriculture is an age-old phenomenon in Uttarakhand and appears to be a complex production system which is mostly dependent upon the monsoon and winter rains. The rainfall distribution is quite varied from one region to another. On an average, the *Tarai - Bhabar* plains receive 168cm annual rainfall. Climate is largely governed by elevation, slope, direction of mountain ranges and their position in relation to the snow-clad peaks. The annual average temperature in the region generally varies from 17°C in the hills to 35°C in the plains.

The different pedo-ecological zones in Uttarakhand, over which the soils are developed also had a great impact on cropping patterns and crop production. For example, the *Tarai*, Siwaliks and *Duns* (<900m), in general, have alluviums which are rich in nutrients and therefore fertile and productive for crop farming. Throughout the study region, there is a large variation in soil types and their distribution from one place to another. With increasing altitude, the soil depth also decreases which intern leads to the erratic distribution of nutrients and other solutes in soils of the Bhimtal Nainital and Pauri districts of Uttarakhand. The major problems in this area are the low Soil moisture holding capacity and limited root zone. In this article an attempt has been made to present the nutrients status of the soils of the Bhimtal (Nainital) and Pauri districts in the Uttarakhand.

MATERIALS AND METHODS

Several surface soil samples (0-15 cm depth) from ten sites of Bhimtal (Nainital) and Pauri districts (Table 1 and 2) comprising *Bhabhar* and Hill area of Uttarakhand were collected from the rice-wheat based cropping system to know the physico-chemical properties of soil using standard methods. Soil samples were brought to the laboratory air dried, processed and analyzed for physico-chemical, chemical, physical and biological parameters after passing through 2mm sieve. The pH and EC were determined in 1:2 soils: water ratio and after half an hour of equilibrium, using digital pH meter (Jackson 1967). The organic carbon content in soil was determined by following the modified (Walkley *et al.,* 1934) method as described by (Jackson 1967). Available nitrogen was determined by alkaline potassium permanganate method (Subbiah *et al.*, 1956).

Available phosphorus in soil was extracted by using sodium bi-carbonate extractant (0.5 M $NaHCO_3$) adjusted to pH 8.5 (Olsen *et al*., 1954). Available potassium in soil mainly refers to exchangeable + water soluble K. The exchangeable K constitutes the major portion of available potassium except in saline and saline sodic soil. Available K was determined by neutral ammonium acetate (1N NH_4OAc; pH 7) method outlined by (Black 1965). Available sulphur content was estimated by extracting the soil with 0.15 percent $CaCl_2.2H_2O$ solution as described by (Williams *et al.,* 1959). Zn, Cu, Mn and Fe were analyzed with an atomic absorption spectrophotometer at wavelength 213.7nm, 324.6nm, 279.5nm and 248.7nm, respectively. Available Boron in soil was determined following method of (Berger *et al.,* 1936) and designated as hot water soluble boron or available boron. Categorization of soil in to low, medium and high status of nutrient content were done following (Singh *et al.,* 1999).The dehydrogenase activity of soil was determined using the method listed by (Casida *et al.,* 1964). Biological activity of a soil is the function of number of organisms present in soil and their physiological efficiency. Monitoring of dehydrogenases, which are respiratory enzymes and integral part of all soil organisms, will give a measure of biological activity of soil at a given time. The amount of dehydrogenase activity was expressed in terms of µg TPF 24 h^{-1} g^{-1} soil.

Soils of Uttarakhand

Uttarakhand is a mountainous state where about 90% area falls in the hill region and only 10 per cent is in the plains. These two distinct physiographic regions have different soil groups. The hill region consists of three outward successions of mountains *viz*. Greater Himalayas, Lesser Himalayas and Shiwalik ranges in decreasing order of height. These hills possess very little leveled land. Soils of the hill region are characterized by their diversity due to parent rocks, elevation, slope and aspect. They are generally shallow, gravelly, impregnated with unweathered fragments of parent rocks, occurring as a thin layer of a few centimeters at high elevations to about 2 meter deep in the valleys or depressions. In contrast, the plain area of the state has deep and highly productive soils The soils are developed form alluvium deposited by the two major river of the state i.e. the Ganga, the Yamuna and their tributaries. The soils of Haridwar, U.S. Nagar and lower part of Nainital district represent the Gangetic plain. These soils are very deep, highly productive and intensively cultivated to wheat, rice, sugarcane etc. These soils occur on three different landforms *viz*. piedmont plain (locally known as *Bhabhar*), *Tarai* and old alluvium. *Bhabhar* soil constitutes a narrow belt in U.S. Nagar and lower part of Nainital district covering 0.72m ha. The soils are deep, well drained, neutral or slightly alkaline, coarse-loamy/fine-loamy, and with deep, well drained, neutral to slightly acidic coarse-loamy, very fragmental and fine-loamy of sandy soils. At places, deep, excessively drained soils occur. The major constraints of the soils of piedmont plain are the low moisture holding capacity and limited root growth zone. *Tarai* soils are found in U.S. Nagar and lower part of Nainital district in continuation of *Bhabhar* soils. The soils are very deep, well drained, slightly alkaline and coarse-loamy/fine-loamy. The other soils in this tract are coarse-loamy (calcareous) and fine loamy. These soils are rich in organic matter, plant nutrients and have fairly good water holding capacity. In *Tarai* belt problem of wetness, overflows and places of erosion are observed. *Tarai* soils are one of the most productive soils in the country. Rice, wheat, sugarcane, lentil, mustard etc. are the principal crops grown on these soils intensively.

Land form wise soil nutrient status Bhabhar (Piedmont plain):

It is the region south of the Lower Himalayas and the Siwalik Hills where the alluvial grade merges into the Indo-Gangetic Plains. Thirty initial soil samples (0-15cm depth) from different villages from the area were collected and analyzed for initial nutrient status (Table 1).

Table 1. Initial soil samples analysis for basic properties of the selected villages in Bhabhar

Parameter	District wise											
	Dogra		Halduchaur+ Gangapur		Dhanpur		DPPP		Nathupur		Average	
	n=3		n=2		n=2		n=15		n=8		n=30	
pH	6.96		6.68		6.52		6.57		6.57		**6.72**	
EC (dSm^{-1})	0.158		0.32		0.56		0.15		0.13		**0.26**	
O.C (%)	1.49	**H**	1.01	**H**	1.28	**H**	1.39	**H**	1.13	**H**	**1.269**	**H**
Av.N (Kg/ha)	192.3	**L**	141.9	**L**	131.1	**L**	159.0	**L**	147.3	**L**	**154.3**	**L**
Av. P(Kg/ha)	12.6	**M**	20.6	**M**	28.9	**H**	29.2	**H**	19.5	**M**	**22.16**	**M**
Av.K(Kg/ha)	196.2	**M**	94.6	**L**	98.9	**L**	113.3	**L**	109.6	**L**	**102.5**	**L**
Av.S(Kg/ha)	58.5	**H**	47.9	**H**	70.6	**H**	43.6	**H**	65.4	**H**	**57.2**	**H**
Zn (ppm)	3.73	**H**	0.83	**M**	2.06	**H**	1.71	**M**	2.75	**H**	**2.21**	**H**
Fe (ppm)	25.17	**H**	23.45	**H**	31.2	**H**	42.6	**H**	45.3	**H**	**33.5**	**H**
Cu(ppm)	3.58	**H**	1.84	**H**	4.67	**H**	2.61	**H**	1.62	**H**	**2.86**	**H**
Mn(ppm)	3.43	**M**	2.25	**M**	6.65	**H**	9.69	**H**	8.23	**H**	**6.06**	**H**
B(ppm)	1.30	**M**	1.97	**M**	1.30	**M**	2.29	**H**	1.45	**M**	**1.66**	**M**
Dehydrogenase (µg TPF/ ml/24hr/g soil)	32.7		13.3		22.15		104.4		38.4		**42.1**	

The soil of this region is neutral in reaction with normal electrical conductivity i.e. 0.26dSm^{-1}. The average organic carbon content of the *Bhabhar* soil was high (i.e. 1.27%) might be due to high application of FYM. The available nitrogen content of the soil was low with the low mean nitrogen value i.e. 154.3kgha^{-1}. may be due to poor quality of applied FYM to the soil. Available phosphorus varied from medium to high range with the average value 22.2 kgha^{-1}. Available potassium status was low most of the villages studied except in Dogra (102.5kgha^{-1}). The available sulphur content (mean value 57.2kgha^{-1}) was high.

Micronutrient status of selected villages varied from medium to high. The average value for Zn (2.2ppm), Fe (33.5ppm), Cu (2.86ppm), Mn (6.1ppm) were high except for B. The mean boron content was 1.7 ppm. The mean dehydrogenase activity of selected village soils was 42.1µg TPF/mL/24hr/g soil.

Hill area

Sixty four initial soil samples (0-15cm depth) from different villages from the hilly area were collected and analyzed for initial nutrient status of the soil (Table 2).

Table 2. Initial soil samples analysis for basic properties of the selected villages in Hills

Parameter	District wise											
	Jantwal		Nainital Bhurjala		Amritpur		Kausani		Pauri		Average	
	n=21		n=12		n=9		n=2		n=20		n=64	
pH	6.73		6.88		6.33		5.83		5.86		**6.38**	
EC (dSm^{-1})	0.11		0.16		0.10		0.91		0.55		**0.36**	
O.C. (%)	2.71	**H**	2.51	**H**	1.06	**H**	2.90	**H**	1.70	**H**	**2.17**	**H**
Av.N (Kg/ha)	198.9	**L**	204.8	**L**	160.2	**L**	564.4	**M**	294.1	**M**	**284.4**	**M**
Av. P (Kg/ha)	46.0	**H**	51.6	**H**	17.5	**H**	39.2	**H**	77.3	**H**	**46.3**	**H**
Av.K (Kg/ha)	266.0	**M**	283.0	**H**	233.3	**M**	443.5	**H**	209.8	**M**	**287.1**	**H**
Av.S (Kg/ha)	46.8	**H**	32.8	**H**	52.5	**H**	282.3	**H**	48.4	**H**	**92.5**	**H**
Zn (ppm)	5.05	**H**	6.03	**H**	2.12	**H**	3.42	**H**	2.11	**H**	**3.74**	**H**

Fe (ppm)	58.4	**H**	27.8	**H**	41.1	**H**	31.8	**H**	-	-	**39.7**	**H**
Cu (ppm)	4.80	**H**	3.24	**H**	1.05	**M**	0.99	**H**	-	-	**2.52**	**M**
Mn (ppm)	7.70	**H**	10.7	**H**	5.37	**H**	15.61	**M**	-	-	**9.84**	**H**
B (ppm)	2.16	**H**	1.93	**M**	1.78	**M**	2.41	**H**	1.15	**M**	**1.88**	**M**
De hydrogenase (µgTPF/ ml/24hr/g soil)	411.2		316.5		76.8		41.2		52.5		**224.5**	

The soil of this region is neutral in reaction (pH 6.38) with normal electrical conductivity i.e. 0.36 dSm^{-1}. The average organic carbon content of the hill soil was higher than *Bhabhar* soil (i.e. 2.17 %) might be due to low temperature and accumulation of organic material in the soil. The available nitrogen content of the soil was low to medium low with the medium mean nitrogen value i.e. 284.4$kgha^{-1}$. Mean available phosphorus and sulphur content of the soil falls under high category whereas; available potassium varied from medium to high with the average high status of potassium content i.e. 287$kgha^{-1}$. Micronutrient status of selected villages (except Pauri) varied from medium to high in hilly area. The average value for Zn (3.7ppm), Fe (39.7ppm), Mn (9.8ppm) were high except for Cu (2.52ppm) and B (1.9ppm). The mean copper and boron content were under medium category. Hill soils were also analyzed for soil enzymatic activity from the different villages and found wide variation with mean de-hydrogenase activity (224.5µg TPF/mL/24hr/g soil). The wide variation may be due to the variation in microbial activity in the hill soils.

CONCLUSION

This study reveals that uneven distribution of nutrients is widespread in *Bhabhar* and hill soils of Uttarakhand. Their availability especially associated with specific soil, crop/ or their properties. It was observed that besides heavy application of farm yard manure deficiencies of many nutrients have also occurred in most of the soil samples. As the pressure on the land is increasing day- by- day due to increase in population, the soil fertility status need to be maintained. to ensure the that agriculture sector continues to supply food for the growing population.

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COMPARATIVE VEGETATION ANALYSIS OF MIXED OAK FORESTS TO DISTURBANCE REGIME: CASE STUDY IN CENTRAL HIMALAYA

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ABSTRACT

The forest is a fundamental natural resource that provides goods and services for many aspects of human development. Traditionally, forests have been a provider of energy for community demands, protection and a habitat for various animal and plant species. In addition to these tangible benefits there has been a growing recognition of the more intangible services provided by the forests. On a grand scale, forests cover more than 1/3rd of the earth's land surface and are the most important carbon pool in terrestrial ecosystem, containing some 80% of all global above-ground carbon stored in biomass (Waring *et al.,* 1998). Recent literature emphasizes that different stresses may produce contradictory changes in plant characteristics (Chapin1991a; Warring,1991; Schulze1991) . In particular, stresses produced by direct damage to tissues, e.g. lopping of branches, may affect trees differently from stresses produced by shortage of resources (Chapin 1991b).The current study shows the variation among the tree density in the studied Oak forest as the presence or absence of lopping stress.

Keywords: Aspect, Banj oak, Lopping, Vegetation analysis

INTRODUCTION

India is recognized as one of four 'mega diversity' centers of Asia and as one of ten largest forested areas in the world that owes partly to the Himalaya. The Himalaya although cover only 18% of the geographical area of India, account for more than 50% of the India's forest cover, and 40% of the species endemic to the India sub-continent (Maikhuri *et al.*, 2000). Various steps have been implemented, for the conservation of biological resources in the Indian Himalaya under the protected area network by establishing 3 biosphere reserves, 18 national parks and 71 wild life sanctuaries (covering 9.2% are of the Indian Himalaya). Enforcement in these protected areas has created a lot of conflicts between local people and protected area managers due to restrictions imposed on the traditional usufruct rights of the local people. These conflicts are causing major hurdles to achieve the goal of biodiversity conservation for which the protected areas have been setup (Gadgil *et al.*, 1993; Maikhuri *et al.*, 2000).

Banj oak (*Quercus leucotrichophora*) forests (Forest Sub-Type 12/ Class. as per (Champion *et al.,* 1968) are evergreen high forests of trees of large girth but have medium heights, rarely over 25m and usually with large branching crowns festooned with mosses, ferns, aroids and other epiphytes. In damp ravines and other favorable sites, there may be an appreciable mixture of deciduous trees contributing to the main canopy. The Banj oak forests are exposed to damage or destruction through human begins altitudinal exploration for settlement and cultivation. The species is coppiced regularly near habitations for getting young shoots for quality fodder, which gives a decidedly different appearance from the original undisturbed tree form. Lopping is extremely prevalent and combined with fuel and a charcoal demand has led to the disappearance of the forests over large areas in the past (Sharma *et al.,* 2007). Excessive forest use produces stress on trees, reduces their productivity, and eventually kills many of them, further reducing forest cover. Scientists have yet to identify the level of forest exploitation that is sustainable without eventual deforestation (Zobel *et al.*, 1995).

METHODOLOGY

The study area is situated in Nainital district (Uttarakhand), between latitudes 28°-30°N , and Longitude 78°-81° E, and covering an area of 3860km^2 (Table 1).

Table.1. Description of study sites

Site No.	Elevation (meters)	Aspect
(1)-Kailakhan	1950	Southern (S.A.)
(2)-Manora	1930	Norhern (N.A.)
(3)-Land's End	2100	Northern (N.A.)
(4)-Land's End	2110	Southern (S.A.)
(5)-Ayarpatta	2200	Northern (N.A.)
(6)-Ayarpatta	2200	Southern (S.A.)

Methodology

The quadrates method (count method) of sampling was used for assessment of vegetation of Oak forests. To study the forest community 10 quadrates are laid out inside the forest in all the forest areas and the observation recorded were name of species, CBH and number of individuals of the species. The number (density) of seedlings of any species can be considered as the regeneration potential of that species. A/F ratio was used to assess the distribution pattern of the species. Distribution pattern indicated that most of plots species are distributed contagiously (clumped) followed by randomly sampled plots IVI is used to evaluate the importance of tree species in any ecosystem which reflects the sum total of relative frequency, relative study and relative dominance (basal cover) of a species.

Table. 2 Comparative Vegetation analysis of forest of site 1 Kailakhan forest (Southern Aspect) and Site 2 Manora forest (Northern Aspect)

SN	Species (site1+2)	Density (individuals per 100m^2)		Frequency (F) (%)		Abundance (A)		A/F Ratio		IVI	
		Site 1	Site 2	Site 1	Site 2	Site 1	Site	Site 1	Site 2	Site 1	Site 2
1	*Quercus leucotrichophora*	5.9	3.7	100	70	5.9	5.28	0.059	0.075	196.84	76.79
2	*Rhododendron arboreum*	1.0	1.5	50	50	2.0	3.0	0.04	0.06	43.62	48.20
3	*Cupressus torulosa*	0.6	2.9	50	60	1.2	4.83	0.024	0.080	31.63	52.71
4	*Myrica esculenta*	0.4	0.9	40	50	10	1.8	0.025	0.036	23.17	28.95
5	*Cedrus deodara*	0.3	0.3	20	20	1.5	1.5	0.075	0.075	3.56	24.82
6	*Aesculus indica*	0.1	-	10	-	1.0	-	0.10	-	1.17	-
7	*Pyrus pashia*	-	0.2	-	10	-	2.0	-	0.20	-	11.98
8	*Lyonia ovalifolia*	-	0.1	-	10	-	1.0	-	0.10	-	9.52
9	*Prunus cerasoides*	-	0.2	-	10	-	2.0	-	0.20	-	13.45
10	*Ficus numeralis*	-	0.2	-	10	-	2.0	-	0.20	-	12.11
11	*Pinus roxburghii*	-	0.1	-	10	-	1.0	-	0.10	-	11.35

Table 3. Vegetation analysis for seedlings and saplings of site 1 Kailakhan forest (Southern Aspect) and Site 2 Manora forest (Northern Aspect)

Sl. No.	Species (site1+2)	Density (individual per 100m^2)		Frequency (F) (%)		Abundance(A)		A/F Ratio	
		Site 1	Site 2	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2
1	*Quercus leucotrichophora*	1.7 (7.7)	-	80 (100)	-	2.125 (7.7)	-	0.026 (0.077)	-
2	*Rhododendron arboreum*	0.3 (0.4)	-	20 (20)	-	1.5 (2.0)	-	0.075 (0.1)	-
3	*Cupressus torulosa*	-	0.4	-	40	-	1.33	-	0.0332
4	*Myrica esculenta*	0.4 (4.4)	-	20 (50)	-	2.0 (8.8)	-	0.10 (0.176)	-
5	*Cedrus deodara*	0.2 (0.1)	-	10 (10)		2.0 (10)		0.20 (0.1)	
6	*Aesculus indica*	-	0.3	-	30	1.5		-	-
7	*Pyrus pashia*	-	1.9	-	70	-	3.33	-	-
8	*Lyonia ovalifolia*	-	1.2	-	40	-	4.0	-	-
9	*Prunus cerasoides*	-	0.8	-	40	-	2.33	-	-
10	*Ficus numeralis*	-	0.7	-	40	-	2.33	-	-
11	*Fraxinus micrantha*	-	0.5	-	30	-	2.50	-	-
12	*Acer oblungum*	-	0.3	-	30	-	1.5	-	-

Note- Figures in parentheses are the values for seedlings

Table 4. Vegetation analysis of site 3 land's end (northern aspect) and site 4 land's end (southern aspect)

SN	Species (site3+4)	Density (individual per 100m²))		Frequency (F) (%)		Abundance(A)		A/F Ratio		IVI	
		Site 3	Site 4	Site 3	Site 4	Site 3	Site 4	Site 3	Site 4	Site 3	Site 4
1	*Quercus leucotrichophora*	3.6	6.9	100	100	3.6	6.9	0.036	0.069	251.9	269.99
2	*Quercus floribunda*	0.4	0.1	40	10	1	1	0.025	0.1	48.08	9.10
3	*Cornus macrophylla*	-	0.3	-	10	-	3	-	0.3	-	11.82
4	*Cupressus torulosa*	-	0.1	-	10	-	1	-	0.1	-	9.02

Table 5. Vegetation analysis of site 5 Ayarpatta (Northern aspect) and Site 6 Ayarpatta (Southern aspect)

SN	Species (site5+6)	Density (individual per 100m²)		Frequency (F) (%)		Abundance(A)		A/F Ratio		IVI	
		Site 5	Site 6	Site 5	Site 6	Site 5	Site 6	Site 5	Site 6	Site 5	Site 6
1	*Quercus leucotrichophora*	10.1	0.3	100	20	10.1	1.5	0.101	0.075	280.42	21.45
2	*Quercus floribunda*	0.2	3.1	10	100	2	3.1	0.2	0.031	10.26	233.77
3	*Acer oblungum*	0.1	-	10	-	1	-	0.1	-	9.29	-
4	*Cupressus torulosa*	-	0.2	-	20	-	1	-	0.05	-	25.59
5	*Cornus macrophylla*	-	0.1	-	10	-	1	-	0.1	-	9.84
6	*Lyonia ovalifolia*	-	0.1	-	10	-	1	-	0.1	-	9.31

RESULTS AND DISCUSSION

Vegetation analysis for trees of site 1 (Kailakhan forest) and site 2 (Manora peak): The forest of the study area is close canopied and has a dense under story of mainly *Arundinaria falcata*. In the trees located in the southern aspect, *Q. leucotrichophora* is the dominant species having an IVI of 196.84. The density of *Q. leucotrichophora* is 5.9 (individual per 100m²). Followed by *Rhododendron arboreum* and *Cupressus torulosa*. In comparison to this the forest of the study area is fairly open and mainly consists of *Q. leucotrichophora* and *C. torulosa. Q. leucotrichophora* is again a dominant species having density of 3.7 / (individual per 100m²) and IVI of 76.70 (approximately 60% less than Kailakhan site). Majority of trees found are stunted and signs of lopping are present.

Vegetation analysis for sapling and seedling of site 1 (Kailakhan forest) and Site 2 (Manora peak):

Q. leucotrichophora has the highest sapling and seedling density of 1.7/ (individual per 100m²) and 7.7 (individual per 100m²) respectively. Thus it can be concluded that the regeneration potential of *Q. leucotrichophora* is good and the forest will maintain itself, in comparison to this in the Manora site *Q. leucotrichophora* had the highest sapling density of 5.6 (individual per 100m²) followed by *Myrica esculenta* i.e. 3.9 (per individual per 100m²). This is because the canopy is open, easy light penetration, thus seedlings can grow easily. This site also experiences disturbances in the form of lopping, regular scrapping for fodder, and grazing by cattle. This may be the reason for the absence of seedlings in the site. Thus the site requires immediate protection for the survival of the forest.

Vegetation analysis for trees of site 3 Land's end (Northern Aspect) and site 4 Land's end (Southern Aspect): The forest of the studied area is moderately open canopied and has a under story of mainly *Arundineria falcata*. The dominant tree species is *Q. leucotrichophora*. The density is 3.6 (per individual per 100m²) and the IVI is 251.9. and the forest of the second studied area is closed canopied. The main dominant tree species is *Q. leucotrichophora*. In comparison to the northern aspect, in the southern aspect the density of the tree species is 6.9 (individual per 100m²) and the IVI for the species is 269.99.

Vegetation analysis for trees of site 4 Ayarpatta (Northern Aspect) and site 5 Ayarpatta (Southern Aspect): The forest of the studied area is closed canopied. The main dominant tree species is *Q. leucotrichophora*. The density of the tree species is 10.1 (individual per 100m²) and the IVI of the species is 280.42. In comparison to this, the forest of the studied area in southern aspect is open canopied. The co-dominant tree species was *Q. floribunda*. The density of the tree species is 3.1(individual per 100m²) and the IVI is 233.77.

Vegetation analysis for site 5 and site 6: The forest of the study site was moderately close canopied and *Q. leucotrichophora*

shows highest density of 10.1 (individual/100m^2) for site 5 and *Acer oblangum* and *Lyonia ovalifolia* shows minimum density of 0.1 (individual/100m^2), respectively and in comparison to the southern aspect, northern aspect shows higher density and the IVI value for northern aspect was 299.97 and for southern aspect was 299.96.

CONCLUSION

This study shows the variation in results among the forest sites, the closed canopied sites shows much vegetation than the open canopied sites, thus presenting a database for the proper management of the forests having the history of anthropogenic disturbance. The study also shows that there is no significant difference in species composition of the forests located at altitudinal variation from 1950 to 2200m. However in each altitude, the aspect shows variation in the species encountered. Thus on the basis of density and (IVI). *Q. leucotricophora* was found to be the most important and dominant species in all the forest stands studied in the present study, which requires consequent care and protection for its existence as it is the prime species which harbors rich under canopy diversity. The intervention can be taken us as developing the area as potential eco-tourism site where the controlled tourist flow can be encouraged along with sustainable conservation strategies for the existing species.

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HUMAN INTERFERENCES ON HIMALAYAN BIODIVERSITY IN UTTARAKHAND WITH PARTICULAR FOCUS ON WILD ANIMALS

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ABSTRACT

Himalaya is our greatest and most precious heritage. It is one of the richest ecosystems owing to its biological diversity. The floral and faunal diversity of Himalaya greatly varies with varied rainfall, climatic and geographical conditions, temperature, altitudinal and latitudinal variations, soils etc. and accordingly making this region the home land for rare plant and animal species. The biological resources of this region are of diversified nature as there are about 35000 species of flora and fauna available in this region. It also serves as abode for majority of biological resources including some of the rarer ones. However, these rich biological resources are depleting rapidly throughout the world because of unethical, immoral, dishonest and above all, unsustainable approaches used by human beings such as blasting, dumping of debris, digging, excavation of the mountain sides, widening of roads and construction of houses, drainage of domestic and industrial wastes/ effluents and massive deforestation for the construction of dams, roads etc. Natural and man caused calamities like forest fires, landslides, soil erosion etc. are causing severe ecological devastations in Himalayan regions. The exponential growth of human population has fuelled the excess increase in the process of industrialization, urbanization, transportation, more and more needs for the food and shelter in the form of houses which eventually cause the huge destruction to environmental balances through climate change. These disturbances to Himalayan ecosystems further speed up the microclimatic changes thereby increasing its impact on human health and livelihood, besides, the floral and faunal biodiversity. Thus, conservation, protection and enrichment of natural resources and Himalayan biodiversity, including wildlife diversity, is one of the prominent global accountabilities of mankind for self and the generations ahead. This research article suggests ways and means for bringing balance and harmony to the distorted ecological relations.

Keywords: Himalayan Ecology, Eco-biodiversity, Natural Habitat, Wildlife, Himalayan Ecosystem, Wild Animals and Human Conflicts

INTRODUCTION TO HIMALAYAN ECOLOGY

Himalaya is a gift of Nature for entire living beings including human beings. The geological, climatic and altitudinal variations in the hotspot areas contribute immensely to the biological diversity of mountains in all the four directions (Sharma 2012). The diversity of altitude, rainfall and soil conditions generates a variety of distinct plant and animal communities or eco regions. Besides, the mighty Himalaya is the homeland of nearly 1500 glaciers covering an area of about 33000km^2. A large number of biological resources, both floral and faunal species along with agricultural plant resources, is housed in Himalaya. The unethical, unsustainable, greedy and dishonest approaches of human activities restlessly gear up the ecological devastations in this region. Such ecological disturbances micro-climatically cause increasing detrimental impacts on lives and livelihood of people.

OVERVIEW OF HIMALAYAN BIODIVERSITY

Himalayan floral and faunal diversity varies immensely with the several prevailing topography and climatic conditions from one region to another. Himalaya, the youngest mountains in the world and accordingly being acutely fragile, represents as the natural treasure of biodiversity (Chopra 2009). Any change in the climate here affects the people ecologically,

socially, economically, culturally and spiritually with increasing catastrophes viz., mass wasting, cloud bursts, avalanches etc. (Kumari *et al.*, 2009). Forests- the natural habitats and wealth of biodiversity, are severely fragmented, isolated and degraded at many places resulting in the huge loss of wild prosperity and life in Himalaya. In this direction, further researches were being carried out on massive deforestation caused losses to endemic biodiversity in Indian Himalaya (Pandit *et al.*, 2007). The sustenance of forest ecosystem is of paramount significance for environmental conservation endeavors. Any degradation in natural and healthy relations of biotic and abiotic components of forest adversely affects various systems, such as water resources, agriculture, biodiversity, healthcare system including human health, environment and the climate. Several types of health complications including causation of various diseases had been observed in earlier researches conducted in Hindu Kush Himalayas (Ebi *et al.*, 2007).

IMPORTANCE OF BIODIVERSITY

Biodiversity is essentially required for the maintenance, sustenance and betterment of people including many more aspects (Fig. 1).

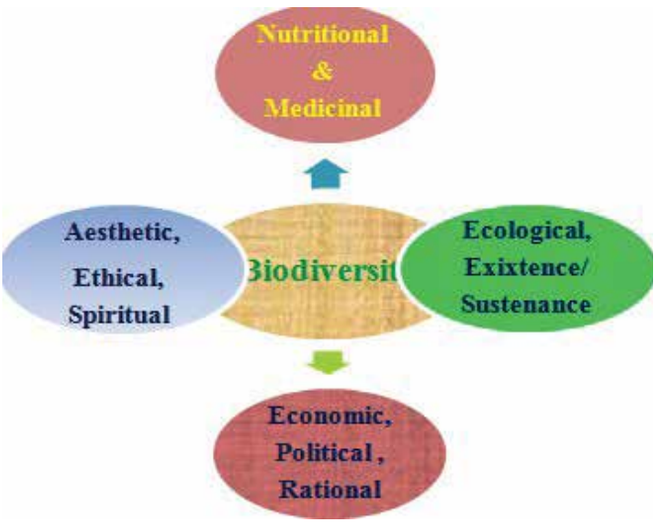

Fig. 1 showing the values of biodiversity

It serves as the source of food, medicines, pharmaceutical drugs, fibers, rubber, timber etc. The healthcare products as neutracares and neutraceuticals are being provided by the rich and prosperous biodiversity to satisfy our health demands. It serves as the natural reservoir of therapeutically rich substance with profound medicinal properties. There is an ever increasing scope for using more and more diversified plants/ herbs being used as drugs and pharmaceuticals being used throughout the world and in traditional medicines, ayurvedic medicines more than several thousands of plants/ herbs are being used with pronounced degree of clinical efficacy (Sood *et al.,* 2015). The diversity of organisms also provides many ecological services free of charge that are responsible for maintaining the health of ecosystem.

Biodiversity is essential both at resource utilization levels and individual species levels as well with a focus on sustenance. The healthier ecosystem services are imperative to control and manage gaseous pool and its natural composition in atmosphere. The climate is being regulated by forest and oceanic systems. Further, pest control through natural ways, pollination in plants by insects and birds, enrichment and conservation of soil from erosion and corrosion, storage and purification of water, the live saving oxygen, photo-synthetically significant carbon dioxide and also the nutrient cycling, etc. are the precious services rendered by the biodiversity. Alterations and subsequent depletion in biodiversity may initiate unforeseen detrimental consequences in ecosystem culminating to disastrous impacts on agriculture and human health (Sood *et al.*, 2015). It is immensely significant in providing many industrial raw materials like fiber, oil, dyes, rubber, water, timber, paper and food etc. The ecosystem services offered in eastern Himalaya are playing pivotal roles in improving the economic status and subsequently enhancing the welfare of the people (Sandhu *et al.*, 2014). Biodiversity further increases the recreational and amusement activities like bird watching, fishing, trekking, tourism etc. and thus indirectly helping in reducing the mental stress. Recently (Maikhuri *et al.,* 2019) performed researches on community response for coping the climatic changes to enhance and strengthen the adaptability, in central Himalaya of Uttarakhand, India and stressed upon the needs of such studies to be undertaken at larger scale for the benefit of the people and the environment. Several effective measures, like bio-reserves, national parks and sanctuaries, Zoological and Botanical Gardens, have been practiced since long in the past to promote and conserve the biodiversity. Rich biodiversity is an indication of developed economic status of country.

PROMINENT ANIMAL FAUNA OF HIMALAYAN REGION

The Asian elephant, tiger, nil gai, wild boar, sambar, chital, barking deer, leopard including snow leopard and jackal, beer etc. (Mishra *et al.*, 2009) are the important mammals in Himalayan regions.

ANTHROPOGENIC ACTIVITIES AND THEIR IMPACTS ON BIODIVERSITY

The consistent pressure being exerted, due to ever increasing human population, urbanization, construction of roads and hydroelectric power dams and immense anthropogenic interventions on Himalayan regions affecting adversely its natural flora and fauna. Various factors responsible for adversely damaging Himalayan biodiversity have been depicted here (Fig. 2).

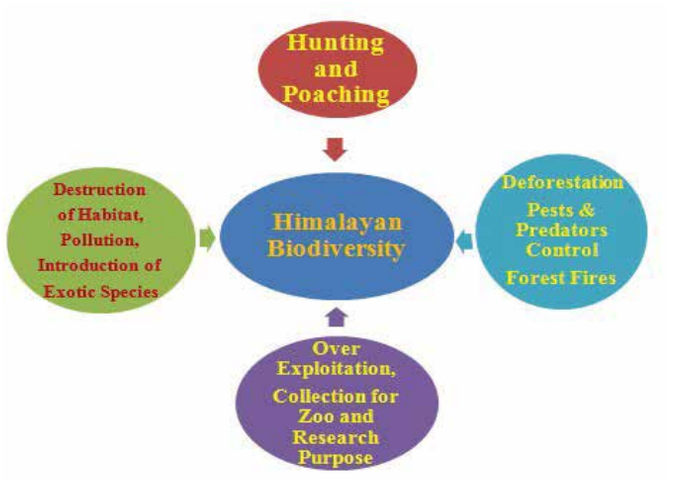

Fig. 2 showing various factors and causes adversely damaging Himalayan Biodiversity

The unlawful and unethical activities of human beings every now and then are restlessly putting the natural ecosystem of Himalaya in extreme degree of crisis and damages. These activities all together force the living beings to adapt to cope up such changes, move on for migration to other safer places, may surrender to predation, starvation and diseases culminating to death. The destruction of natural habitat causes severe losses to avian and mammalian populations which results in the form of extinction of many of them (Sayer *et al.*, 1991). The human interventions in private and buffer zones of wild animals are compelling mainly the large mammals to go wild and furious for human beings, in terms of causing causalities/ fatalities and property losses, by intensifying the shifting the patterns of human wildlife conflicts in Nepal Himalayan regions (Acharya *et al.*, 2016). Such behavioral and attitudinal alterations are found responsible for enhancing the leopards' attacks and fatal/brutal losses to the people in Uttarakhand (Sondhi *et al.*, 2016). The lust for making more money from trading of wild animals is proving even far more disastrous for wildlife of all types including the wild animals and even for the existence and sustenance of human beings. Accordingly, depletion and loss of wild fauna is alarmingly dangerous and reasons and strategies to mitigate this crisis must be chalked out and implemented. It is noteworthy to mention that Himalayan regions harbor a rich faunal diversity (Table 1).

Table 1. showing the diversified prevalence and dominance of several faunal groups in India and Himalayan regions

Faunal Group	No. of species in India	No. of species in Himalaya	%age Prevalence of Himalayan Fauna in Indian Context
Mammals	434	300	69.12
Birds	1232	977	79.30
Reptiles	462	176	38.10
Amphibians	312	105	33.65
Fishes	2641	269	10.19

(Source: Singh 2013)

Hunting: Since the dawn of human civilization, man started hunting the wild animals to fulfill his requirements for food, cosmetics, pharmaceuticals, recreational purposes, perfumes etc. (Chandrakar 2012). Further, the hunting of rhino for horns, tigers for bones and skin, musk deer for musk with profound medicinal values, elephant for ivory, gharial and crocodile for their skin are the sole reasons for never ending activity of hunting- the climax of brutality. Poaching of Indian tiger has gone up because of the increasing demand from pharmaceutical industries. It has accelerated the poaching of Indian tigers for fetching the consumption of about 100 tigers per year. For making huge money, smuggling of tiger bones and skins is a more profitable business.

Hunting, in fact, is one of the most prominent factors for depletion of wild lives including wild animals. Poaching has remained another main cause for increased killing of leopards in India. It may be envisaged by the fact that in 2010 only, 54.87 % of the 328 leopard deaths, across the country, were reported due to poaching. Poaching and illegal trade in animals are

projected around 2 billion to 3 billion US dollars. It is largely accountable for unethical extinction of animal species. Kansky *et al.,* (2014) pointed out the main factors turning the attitude of large mammals in causing conflicting brutal fatalities and injuries to human beings and found the unwanted interferences of human beings responsible for such famines. Further, animals like primates including monkeys, chimpanzees and rabbits, dogs, cats etc. are being used and sacrificed for research purposes worldwide because of their closure anatomical, genetic and physiological resemblances to human beings which eventually bring down immensely their population.

Pollution: It is yet another factor of biodiversity loss. The normal and healthy composition of ecosystems are being disrupted and altered by introduction of the toxic wastes, chemicals like heavy metals, pesticides, hospital garbage, detergents, industrial effluents etc. Toxic chemicals disturb the food chain, food web thereby adversely affecting the ecosystems. Fatal consequences like acid rain, ozone depletion and global warming etc. are known to affect adversely both the plant and animal species threatening to their survival. Likewise, noise pollution is also considered as one of the significant causes of wildlife disturbance.

Deforestation: It is one of the important causes of loss of wildlife population. In our country, the present scenario of deforestation is 13,000km^2 annually which itself is sufficient to show the alarming and gloomy picture of future forests and the richness of our biological diversity fate. It has been anticipated that nearly 100 species every day would be diminishing due to alone deforestation in coming years. Besides the above stated factors, the other ecological factors such as distribution range, degree of specialization, position of the organism in the food chain, reproductive rate, outbreaks of diseases etc. are found immensely responsible for the depletion, leading to extinction, of wildlife including the wild animals (Jayasankar 2015). Table 2 lists out the man made causes of killing of wildlife in Rajaji National Park (Uttarakhand).

Table 2. Killing of wild animals by human beings in Rajaji National Park

Elephant	27%
Sambar	37%
Cheetal	27%
Wild boar	4%
Leopard	3%
Goral	1%
Python	1%

(Source: Singh et al., 2001)

Modern activities of human beings have troubled and accordingly hindered the natural habitats basically reserved for the wild animals. The ever growing needs for more and more food, clothings, shelter etc. are immensely responsible for shattering the normal fabrics of wildlife and the rich biodiversity. Further, the enhanced tourism and ecotourism related actions are proving as the worst weapons of destruction to natural ecosystem. Adventure tourism related acts further deteriorate this never ending loss of biodiversity by more and more uses of vehicles causing severe noise pollution responsible for even abortions of pregnant wild animals besides, making them furious and irritating towards human beings and their related assets. Road facilities are also accountable for increased brutal killings as a result of road mishaps causing irreparable damage to the natural habitat of birds and animals from wild area. Further, menace like forest fire troubles the life and safety of wild animals and causes huge loss to natural biodiversity.

SOME REMEDIAL MEASURES TO CONSERVE BIODIVERSITY

Keeping in mind the foregoing facts, it becomes imperative to minimize the conflicting and fatal fighting between wild animals and the human beings. The pressing demand to declare wild life area as protected/prohibited zone for frequent and common entry of people, for any purpose, appears quite logical and meaningful. Human interferences must be stopped immediately in wildlife habitats. Making Himalayan wildlife ecosystem more prosperous and rich, in terms of various components, also requires special attention. Stringent enforcement of various legal measures like wildlife protection act for prevention of hunting, poaching and smuggling of wild animals is emergent need of the hour. Further, the provisions for strict punishment to culprits of wildlife including wild animals must be implemented. In order to make wild animals safeguarded, there is a dire need to construct the flyovers on national corridors of wild animals including railway tracks, national/state highways etc. We should not ignore the crawling, slow jumping and moving animals while planning the effective measures for protecting the wild animals. Thus, construction of under pass on national /state highways, railway tracks etc. are mandatory. Devising and enforcing the strategic measures to prevent forests from fire is in reality the urgent most need of the hour. Awareness programs for ensuring public participation must be launched at larger scale. Further, it is highly required to aware the people, make them feel about significance of wild animals and developing attitude of compassion. Curriculum must be designed accordingly so that the students at under graduate and post graduate levels may be

made familiar with the techniques of protection of wild animals and the wildlife at large.

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FARMER VULNERABILITY TO AGRICULTURAL RISKS IN THE INDIAN CENTRAL HIMALAYAN REGION

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ABSTRACT

Practicing traditional agriculture, in the small patches of traced fields, is the main occupation and the major option of livelihoods of about 70% population living in the rural area of the Indian Central Himalayan Region. However, the output from traditionally grown cereals is considerably less that leads to malnutrition and food scarcity. The area under arable land, production, and yield of crops is decreasing and thus agriculture is at risk in the rural areas. This study analyzes farmer vulnerability to agricultural risks in the Indian Central Himalayan Region. A case study of nine villages of the Eastern Nayar River Basin, Pauri district, Uttarakhand was conducted. The villages are located between 900 m and 2100 m altitude along the high slope gradient. The household-level survey was carried out and a purposive random sampling method was employed with a 52.6% sample size. We observed that the major drivers of decreasing production and yield of crops are growing population, high climate variability, erratic rainfall, warming of the river valleys and mid-altitudes, small landholdings, fragile landscape, and wildlife that are damaging corps. Climate-smart agriculture, agricultural intensification, selection of crops in different altitudes, and adequate market, irrigation, and transportation facilities can cope with agricultural risks.

Keywords: Farmer vulnerability, landholdings, cereals, agricultural risks, Eastern Nayar River Basin, ICHR.

INTRODUCTION

Agriculture is one of the major sources of livelihoods for the most vulnerable and rural poor people (Kauti 2009). However, rural farmers continue to face more challenges– poor infrastructure, poverty, poor policies– that impede agricultural productivity. Further, climate change is experienced as a major challenge to agriculture recently (ROK 2001). It causes negative impacts on farming systems and livelihoods (IAASTD 2008). Although smallholders have been adapting agriculture to the changing climate since time immemorial yet, they are still vulnerable to climate change and variability (IPCC 2001). As estimated, about 450-500 million smallholder farmers constitute a significant portion of the world's population, representing 85% of the world's farms (Nagayet 2005). These farmers are also estimated to represent half of the hungry people worldwide (Sanchez *et al.*, 2005). Further, smallholder farmers are facing numerous risks to their agricultural products such as pest and disease outbreaks, extreme weather events, and market shocks, which often undermine their household food and income security (Morton 2007). They are directly depending on agriculture for their livelihoods thus, any reductions to agricultural productivity can have significant impacts on their food security, nutrition, income, and well-being (Mcdowell *et al.,* 2012). Apart from these impacts, climate change will also have negative impacts on the main cereals such as rice, maize, and wheat, upon which the smallholder farmers are dependent (Bandooni 2017). It will further have impacts on disease outbreaks and high intensity and frequency of disasters which will lead to poor yields, crop failure, and livestock mortality (Kevan 1999). Therefore, there is an urgent need for identifying adaptation measures so that the farmer's vulnerability to agricultural risks can be reduced.

Agriculture is the main basis of livelihood of about 70% of the rural population in the Himalayan countries, however, more than 90% of the farmers are marginal (Partap 1998). On account of the potential productivity of crops and soil fertility, it is declining and consequently, the farmers are facing food shortages (Jodha *et al.,* 1993). It is, therefore, necessary to explore all possible ways of increasing the sustainable productivity and carrying capacity of the farming systems to improve the

livelihoods of marginal households. In the Indian Central Himalayan Region (ICHR), the phenomena of high growth of population (19.17%: 2001-2011), low production and low per ha yields of subsistence crops (28.0q) and traditional modes of farming (69.45%) are reported and of course, the phenomena of climate change have together led to food insecurity. As a result, food scarcity, malnutrition, and out-migration are very common phenomena. A majority of rural people do not get sufficient nutrition in their diet; consequently suffering from nutrition deficiency-related diseases (Pant 1996). Cultivation of traditional subsistence cereals is based upon the centuries-old practices carried out on the narrow patches of the terraced fields (Sati 2004). Production and per ha yields from traditionally grown subsistence crops are considerably low. Further, high landscape fragility and slope gradient restrict the possibility of expansion of arable land and the use of modern innovation in the agricultural land (Sati 2012). Further, farming has become unsustainable due to increasing food needs as well as the pressure of the population on the limited arable land (ICIMOD 1996). The major thrust of this paper is to analyze farmer vulnerability to agricultural risks in the case study villages in Uttarakhand. It further examines landholdings, arable area, production and yield of crops and raise questions that what are the major drivers of decreasing arable land, production, and yield of crops. The authors suggested climate-smart agriculture, selection of suitable crops according to climate and altitude, transfer of land to the cultivation of cash crops, agricultural intensification and adequate irrigation, market, and transportation facilities for the management of agricultural risks and control out-migration.

METHODOLOGY

STUDY AREA

Uttarakhand state of the central Himalaya is divided into two divisions, Garhwal in the west and Kumaon in the east. It has five altitudinal or vertical zones – *Tarai* and *Doon* plains, Shivalik ranges and the river valleys, middle Himalaya, the highlands (including alpine meadows), and the Great Himalayan ranges, which is snow-clad. The Ganges system originates from the Great Himalaya and provides ample water to the upstream and downstream river basin. The whole ICHR region is home for faunal and floral resources and feasible climatic conditions. Agro-climate varies from tropical to subtropical, temperate, cold, and alpine where several crop races/cultivars grow.

The case study villages are located in the Eastern Nayar Basin, Pauri district, Garhwal Himalaya between 900m (lowest), and 2100m (highest) altitude– in the river valleys, middle altitudes and the highlands. The upper reaches of the basin have cold climate even during winter, the area remains covered by snow. Meanwhile, the valley regions are hot during the summer season. Generally, temperature decreases along with an increase in altitudes. Climate variability along with erratic rainfall and warming of valleys and mid-altitudes is high. Pine (*Chir*) forests are found in the valley and lower mid-latitudes (up to 1600m), mixed oak forests in the upper middle-altitudes and the highlands (1600m to 2400m) and coniferous forests – deodar, fir, and spruce in the highlands (2400m to 2800m). Small patches of alpine pasture are found above 2800 m where the rural people migrate with their migratory animals for summer pasture. Climate is highly variable. High rainfall and drought situation prevail.

In the selected villages mainly, traditional subsistence cereals grow and among them millets –*Mandua* (*Eleusinecoracana* or finger millet), *Jhangora* (Barnyard Millet), wheat, and paddy are prominent. However, the yield from these crops is insufficient to meet household food demand. An average literacy rate in the surveyed household is 87.5% with the highest literacy 98% in Gudinda village and the lowest literacy 75.2% in Bhandeli village. The sex ratio is high (1044). The population is aging as about 18% population is above 60 years. Rural-urban migration has been increasing for the past two decades. An exodus population (average 20%) has out-migrated from these villages to the urban areas within and outsides the state. Out-migration has led to land abandonment and as a result, the area under arable land has decreased and consequently, production and yield of crops have also decreased.

Data collection and survey methods

This study is inductive, using both qualitative and quantitative approaches. A case study of nine villages of the Eastern Nayar River Basin of ICHR (Table 1) was conducted. A total of 168 households (HHs) were surveyed from nine villages. The authors employed a random sampling method to select households and the sample size was between 27% (minimum) and 100% (maximum) with an average of 52.6%. A structured questionnaire was used to collect data on population, literacy, family size, sex ratio, and migration. Further, time-series data (2000-2017) on area, production, and yield of the major crops were gathered through a household level survey. We interviewed 168 heads of the households of the age group 45-55 years. The education level of these heads of households is between high school and graduate. The family size of the households varies from 3.5 persons (lowest) to 6 persons (highest) with 4.7

people average. The interview questions were mainly related to climate change, its implications on farming, water resources, and the health and livelihoods of the rural population. Several questions on how to manage agriculture risk under climate change and growing population were asked. Data were analyzed using correlation and regression methods. Data on migration, education, and area, production, and yield of crops was correlated with altitudes of the villages. An agricultural risk model was developed.

Table 1. General information of surveyed villages

S. No.	Villages	Altitude (m)	Total HH	Surveyed HH	Surveyed HH (%)	Family size	Literacy (%)	Migration (%)
1	Dangu	900-1100	35	18	51.4	4.5	83.1	20.2
2	Gudinda	1000-1200	31	18	58.1	4.5	98.8	20.9
3	Sera	1100-1200	24	16	66.7	4	91.3	20
4	Kandhlekha	1300-1500	8	8	100	3.5	90.8	46.4
5	Bhandeli	1300-1600	75	22	29.3	5.5	75.2	20.8
6	Ghodiyana	1400-1600	32	18	56.3	4.5	89.5	18.9
7	Kaproli	1500-2000	100	27	27	6	85.9	6.7
8	Bhainswara	1600-1900	25	14	56	3.5	93.2	22
9	Museti	1600-2100	94	27	28.7	6	79.5	7.5
Average		900-2100	424	168	52.6	4.7	87.5	20.4

Source: Household-level survey

RESULTS

Characteristics of smallholder farming

The landholding is small. Further, the land is fragmented, terraced, and fragile. Landholdings are comparatively bigger under food grains (subsistence crops) than pulses and oilseeds and fruits and vegetables. It is because a large number of marginal farmers are cultivating cereals. However, pulses and oilseeds and fruits and vegetables grow in smallholdings. About 12% of households have >1ha landholdings under food grains whereas, under pulses and oilseeds, 5% of households have >1ha landholdings. Only 3% of households have >1ha landholdings under fruit and vegetable crops. It depicts that a large number of households grow food grain.

Buffalo, cow, and oxen are the main livestock reared here. In the study villages, 78% household rear cow, 76% rear buffalo, and 54% rear oxen. Chicken farming is growing as 35% of household rear them. Goat and sheep are also reared in the village by 20% and 16% of households, respectively. Agriculture is the main source of income of 52% of households followed by the service sector with 26% and labor 16%. Rural-urban migration has become common. There are many urban migration hotspots. The highest number of people from these villages has out-migrated to the Delhi NCR region (46.3%) followed by Dehradun (19.5%). In defense, about 23.4% of people are working. Others include teachers, drivers, hotel personnel, and seasonal workers who constitute 21.9%population. The authors analyzed the reason for migrating and noticed that out of total migration, 54.4% of people have migrated for the job. Migration due to marriage obtains a 22.7% population. For education, 10.6% of people have out-migrated and for other reasons, about 12.3% of people have out-migrated (Table 2).

Table 2. Characteristics of smallholder farming systems in the case study villages

Category (Altitude)	Surveyed households (n)	Landholdings/ Variables	% of households
Total area under food grain (900 m – 2100 m)	168	<0.2 ha	19
		0.2-0.4	17
		0.4-0.6	22
		0.6-0.8	16
		0.8-1	14
		>1 ha	12
Total area under pulses and oilseeds (900 m – 2100 m)	168	<0.2 ha	28
		0.2-0.4	26
		0.4-0.6	23
		0.6-0.8	10
		0.8-1	8
		>1ha	5
Total area under fruits and vegetables (900 m – 2100 m)	168	<0.2	32
		0.2-0.4	24
		0.4-0.6	21
		0.6-0.8	11
		0.8-1	9
		>1ha	3
Livestock ownership	168	Goat	20
		Chicken	35
		Sheep	16
		Cow	78
		Buffalo	76
		Ox	54
		Calf	32
Source of income (Persons in %)	786	Agriculture	52
		Service	26
		Labour	16
		Others	06
Migration hotspots (Persons in %)	320	Dehradun valley	19.5
		Delhi NCR	46.3
		Defense	23.4
		Others	21.9
Reason of migrating (Persons in %)	320	Job	54.4
		Education	10.6
		Marriage	22.7
		Others	12.3

Source: Household-level survey by authors

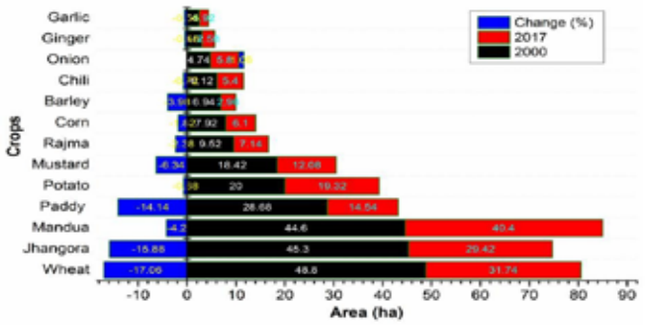

Fig. 1. Area under major crops; (*Source*: Primary data collection by authors)

Area, production, and yield of major crops

Area under major crops and change

Wheat, Jhangora (Barnyard Millet), Mandua (Finger millet), paddy, potato, mustard, Rajma (Kidney beans), corn, barley, chili, onion, ginger, and garlic are the major crops grow in the study villages. Wheat occupies the highest area (48.8 ha) among all the crops followed by the two millets – *Jhangora* (46.5 ha) and *Mandua* (44.6 ha), and paddy 28.68 ha (Fig.1). Potato (20 ha) and mustard (18.42 ha) further followed them. Other crops *Rajma*, corn, barley, chili, onion, ginger, and garlic occupy less than 10 ha. In 2017, the area under all crops in comparison to 2000 has decreased, except for onion, under which area has increased from 4.74 ha in 2000 to 16.98 ha in 2017. The area under wheat has decreased by 17 ha followed by *Jhangora* (16 ha) and paddy (14 ha). Other crops also got a decrease in the area however it is comparatively less.

Production of major crops

Time series data on production of the major crops show that production of *Jhangora* (69.98t) is the highest (Fig.2) in 2000 followed by potato (59.7 t), *Mandua* (54.9t), and paddy (35.72t). Barley (34.35t), wheat (25.96t), and mustard (10.79 t) have substantial production. Other crops have less than 21 t production. In 2017, the production of crops has decreased enormously such as *Jhangora* (about 29 t), potato (19t), barley (32 t), and paddy (19 t). Wheat has decreased to 17.68 t whereas *Mandua* has decreased to 47.06 t. Similarly, the production of other crops has decreased substantially.

Yield of major crops

The yield of the major crops has shown a decreasing trend (Fig.3) between 2000 and 2017. In 2000, the yield of barley was the highest (4.95t/ha) followed by potato (2.99t/ha), *Jhangora* (1.54 t/ha), paddy (1.25 t/ha) and *Mandua* (1.22 t/ha). Other crops

have less than 1 t/ha yield. In terms of yield of crops in 2017 except mustard, wheat, and *Rajma* which yield has increased, the yield of other crops has decreased substantially. The highest yield is decreased under barley crops followed by potato.

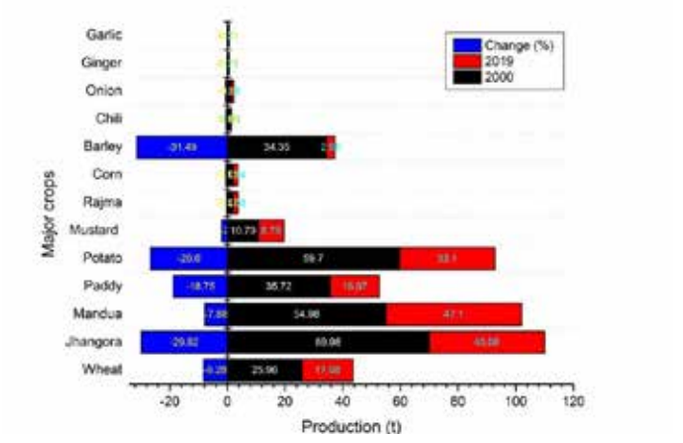

Fig. 3. Yield of major crops; (*Source*: Primary data collection by authors)

Declining area, production and yield

Area, production, and yield of the maximum crops in the study villages have decreased largely. The area under barley, which is the major crop in the highland, has decreased (57.3%) followed by paddy (49.3%), *Jhangora* (35.1%), and Wheat (34.9%). Other crops also registered a substantial decrease (eg. Soya bean 21.6%). A small proportion of land has increased under onion. Similarly, the production of all crops has decreased with the highest decrease in barley (91.7%) followed by paddy (52.5%) chili (48.7%), ginger (46.1%), and potato (44%). Other major crops in which production has decreased are *Jhangora* (42.8%), garlic (33.3%), and wheat (31.9%). Production of the rest of the crops has also decreased enormously. In terms of the yield of the major crops, it has decreased substantially. Except for mustard, *Rajma,* and wheat crops in which yield has increased from 24.3% to 4.9%, the yield of other crops has decreased. The major crops barley, potato, *Jhangora,* paddy, *Mandua,* chili, and ginger registered the highest decrease in their yield/ha (30% to 84%). The yield of other crops decreased by less than 30%. One of the reasons for the decrease in the area of wheat and Jhangora is damage from wildlife. The increasing trend of climate variability during the last one and half decades has decreased crop production and yield and as a result, the land has abandoned. Farmers also perceived that warming of valleys and middle-altitudes has reduced the area and production of various crops. This has resulted in exodus rural-urban migration and abandonment of arable land. Change in food habits is also among the reason for the declining yield of traditional crops.

Livestock population and change

Data on livestock population goat, sheep, cow, buffalo, oxen, and calf shows an enormous decrease between 2000 and 2017 (Fig.4) except the hen population. In terms of the number of livestock, goat ranks first with 1,180 numbers in 2000 followed by a hen (396), sheep (361), cow (313), buffalo (281), oxen (238) and calf (103). The highest decrease was noticed in the oxen population (45%) followed by cow (44.1%) goat (35.4%), buffalo (33.5%), calf (33.5%), and Sheep (13.9%).

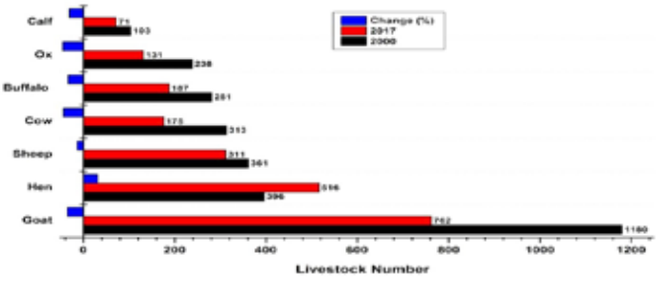

Fig. 4. Livestock population and change; (*Source*: primary survey by author)

High climate variability

Climate data of the last 15 years (2000-2014) – rainfall (mm) and temperature (°C) of Mukteshwar town (Kumaun hill of Uttarakhand), located at 2,200 m altitude, was collected from the Meteorological center, Dehradun and shown in Fig.5. It shows that variability in rainfall ranges from 900 mm (minimum) in 2001 to more than 1,700 mm (maximum) in 2012. Similarly, rainfall varies from year -year, and the variation is very high. The average rainfall during the period was 1,377 mm. It has been noticed from the data that average rainfall is increasing. Temperature varies from 13.59° C minimum (2013) to above 15.51° C maximum (2012), although, the average temperature during the period was stagnant, which was 14.29° C. It has been noticed that in 2000, rainfall was above 1,600mm whereas, the temperature was about 13° C. On the other hand, rainfall was about 1,100mm in 2012, the temperature was about 15° C. High variability in climatic conditions has resulted in extreme events such as cloudburst triggered flash floods, debris flows, and landslides. Consequently, a substantial proportion of crops have damaged by heavy and erratic rainfall. Further, droughts and flash floods due to a tremendous increase and decrease in rainfall and temperature have decreased crop area, production, and yield.

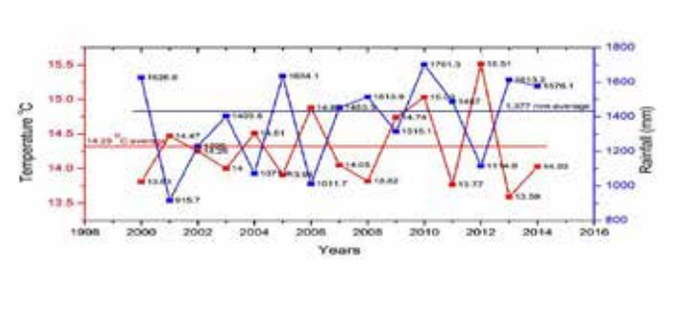

Fig. 5. Rainfall (mm) and temperature (°C) in Mukteshwar (*Source*: Meteorological Centre, Dehradun)

Household-level food availability

Household-level food availability was analyzed of all crops in the case study villages (Fig.6). It is important to note that the output from agriculture is subsistence in nature even the production is not sufficient for the whole year. Production of all crops in total surveyed households was divided by the total number of households at the village level and food availability at household level was determined. Food availability is the highest (6648.1kg) in Museti village and lowest (461.4kg) in Dangu village It means that crop production is higher in high altitude villages. However, food availability as a whole is very less, which leads to food scarcity and further causes for large out-migration. The slope gradient is another cause of low production, therefore, food availability in Ghodiyana village (1400-1600m) is less than Bhandeli village (1300-1600m).

Peoples' perception of agricultural risks and livelihoods

Interviews of 168 heads of households of nine villages were conducted and 14 questions were asked on climate change and its impact on agriculture/horticulture, crop diversity, water, health, irrigation, livelihoods, livestock population, and milk production (Table 3). These heads of households are of age between 45 and 55 years and all of them are well educated. Most of them are aware of climate change (64.9%) and they perceived (56.5%) that agricultural production and water sources (86.9%) are decreasing due to climate change. Climate change has also a negative impact on health (89.9%), crop diversity (85.1%), livestock population (73.2%), and milk production (70.2%). Only 36.3% population sells agricultural products, which is too less in number.

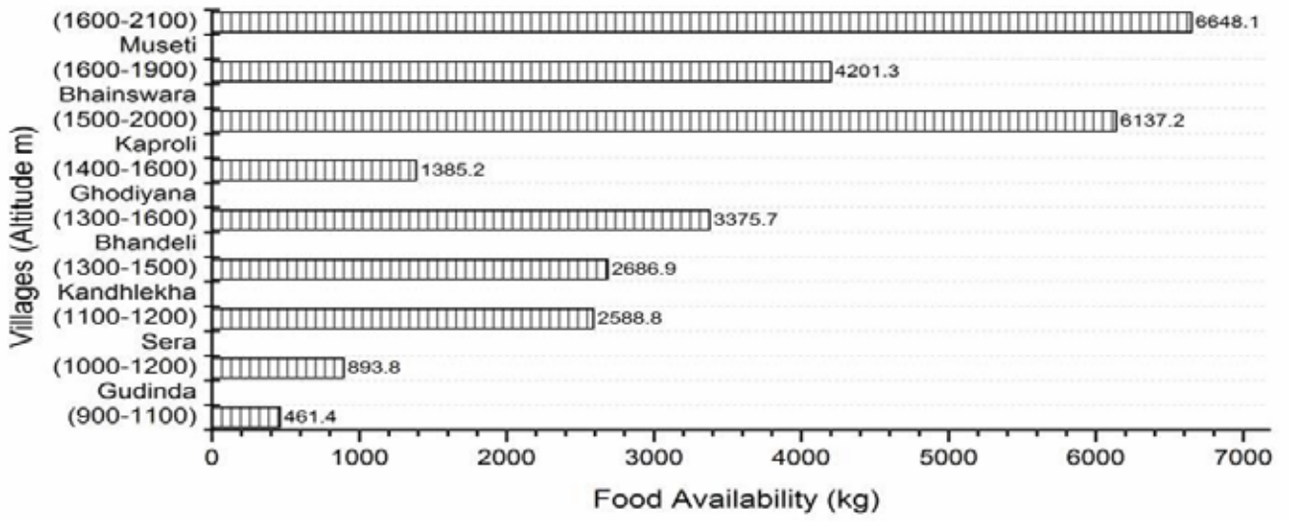

Fig. 6. Household-level food availability (kg) (*Source*: primary survey by authors)

Table 3. People's perception (%) on climate change and its implications (n=168)

S. No.	Questions	% of household	
		Yes	No
1	Do you know about climate change?	64.9	35.1
2	Is agricultural production decreasing due to climate change?	56.5	43.5
3	Are water sources decreasing?	86.9	13.1
4	Has climate change impacted on health negatively?	89.9	10.2
5	Is crop diversity decreasing?	85.1	14.9
6	Is the livestock population decreasing?	73.2	26.8
7	Is milk production decreasing?	70.2	29.8
8	Is government support enough to providing livelihoods?	88.1	11.9
9	Is drinking water sufficient?	56	44
10	Is agricultural production sufficient to support livelihoods?	25.6	74.4
11	Is water sufficient for irrigation?	28.6	71.4
12	Do you sell agricultural products?	36.3	63.7
13	Is there any change in horticultural production?	12.5	87.5
14	Is government support in combating climate change?	12.5	87.5

Source: Primary data collection by authors

Agricultural risks management model

We developed a model for agricultural risk management (Fig.7). Agricultural risk management has three major components such as climate-smart agriculture/horticulture, sustainable livestock farming, and infrastructural development. Each component has several sub-components that support agricultural risk management. We proposed the selection of crop cultivars/races according to agro-climatic conditions along the altitudinal gradient, crop diversification, and intensification, organic farming, adequate irrigation facilities, cultivation of fruits and vegetables, and soil conservations as the major sub-components of climate-smart agriculture and horticulture. The sub-components of sustainable livestock farming are conservation of pastureland and fodder tree, farming of both indigenous and hybrid animals, and cooperative farming. Infrastructural development is quite essentials for agricultural risk management. Adequate market and transportation facilities, construction of cold storage, employment generation through small-scale industries, and governmental supports will also serve as the most important sub-components of infrastructural facilities.

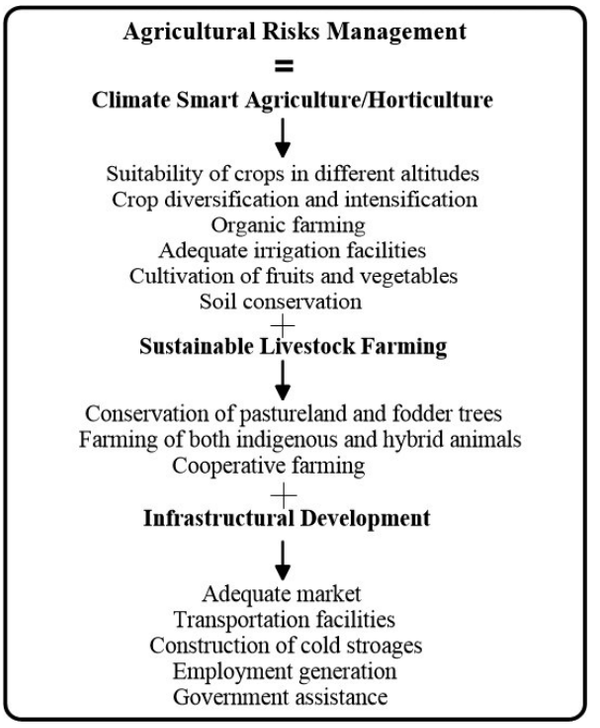

Fig. 7. Agricultural risks management model

DISCUSSION

The ICHR is facing acute food insecurity problems because of declining crop area, production, and yield and as a result, about 40% of people are living under the poverty line. A case study of nine villages depicts that crop area of all the 14 crops has decreased by 24% which has resulted in a decrease in crop production (39%) and consequently decreases in yield of crops i.e. 0.42t/ha (average). A decrease in area, production, and yield vary from crop to crop and village to village according to their economic status and location, respectively. The villages, which are located in the highlands, grow millets with high agro-biodiversity. Cropped area, production, and yield of barley, wheat, *Jhangora*, paddy, and potato have decreased largely. During the recent past, food habit of people has largely changed and people preferred wheat and paddy in place of these millets/cereals and therefore their area, production, and yield have decreased. A decrease in area, production, and yield of crops are large in the mid-altitude and the river valleys' villages than to the highland villages. We observed that warming impact on the lower altitude is much higher than in the highlands. Climate data of the region shows that the highland villages receive less temperature and it has substantial humidity that keeps the atmosphere cool so that crops can grow even in the adverse

situation. Besides, household-level food availability is high in the highland villages therefore out-migration from the highland is comparatively less.

The livestock population has been decreasing. Cow population has decreased by 44% during the last 18 years. Similarly, oxen, buffalo, goat, and sheep population have also decreased substantially. Because, livestock is the second important option of the livelihoods in the rural areas and it also assists agricultural practices, declining its population has led to food scarcity. In the past, every household had two or >2 dairy animals now their number has decreased enormously. Therefore, the quantity of milk and milk products has decreased.

Government initiative to develop agriculture sustainably is not so much effective. Infrastructural facilities in the study villages are considerably less. They are not well-connected by road or other means of transportation. Growing population, decreasing arable land and low production and yield of crops have paved a way to food scarcity, which has further led to exodus rural-urban migration. From the study villages, >20% population has been out-migrated and most of them are migrated for the job. It denotes that agriculture, which was the main occupation and source of income during the past, has decreased and a large population prefers working in the tertiary sector. An exodus out-migration from the villages has led to land abandonment and thus, arable land, production, and yield of crops have decreased. All these driving forces lead to agricultural risks. Coping with it, several drives have been initiated at government and farmers' levels such as large changes in cropping pattern from subsistence cereals to wheat and paddy, fruits and off-season vegetables, and cultivation of medicinal plants. However, all these initiatives could not be succeeded to the desired extent.

This study revealed that although, agriculture is the mainstay of people of the study villages in particular and ICHR in general, yet output from it is substantially low. The area of arable land, production, and yield of the major crops have decreased during the last decades. Livestock population has decreased and as a result, the marginal farmers are facing acute problems of food scarcity, and malnutrition and agriculture as a whole are at risk. The rate of out-migration is increasing and arable land has abandoned largely. Policy measures for managing agricultural risks are required to be framed and implemented. We suggest herewith some key measures to combat agricultural risks. First of all, crop suitability and productivity index should be implemented so that agricultural sustainability can be attained. It means that crop races/cultivars should grow according to climate, landscape, and altitude. Climate-smart agriculture is the key solution for managing agricultural risks. Because of limited arable land, agricultural intensification can be practiced. Crop diversity of cereals, fruits and vegetables, and household level food availability, which is high in the highlands, should be maintained. Further cultivation of potato in the highlands and onion in the mid-altitudes and the river valleys will reduce agricultural risks. Cash crops, mainly potato, onion, garlic, and ginger are the most suitable crops in the agro-ecosystems of case study villages, which need to given importance. Subtropical fruits like orange and lemon and temperate fruits like walnut and apple can grow in lower-middle and highlands, respectively. Tomato, eggplants, cauliflowers, cabbage, capsicum, spinach, and other leafy vegetables can be grown in the village. Apart from all these measures, adequate market and cold storage facilities, transportation and irrigation facilities should be provided that will reduce agricultural risks and combat climate change. Adequate food should be supplied to poor rural people through the public distribution system to reduce food scarcity. Crops should be insured at the government level so that the marginal farmers can cope with food scarcity, mainly during the situation of crop failure. The government should develop a mechanism to purchase crop products from the farmers at the market rate. The market should be provided for milk and milk products so that the income and livelihood of the marginal farmers can be enhanced.

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RAINFALL TRENDS (1998-2018) OVER THE CHORABARI GLACIER IN MANDAKINI RIVER BASIN, UTTARAKHAND, INDIA

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ABSTRACT

The snow-glacier fed Himalayan water resources are supplying water to more than 800 million people, and are largely regulated by the precipitation system. Deep understanding of the Himalayan watershed dynamics is much needed in the current changing climate scenario to ensure the future water availability. Thus, the present study aims to identify the precipitation pattern (trend and periodicity) over one of the glacierized catchment of Central Himalaya (Chorabari Glacier catchment, Mandakini River basin, Uttarakhand). Multi temporal rainfall records (past two decades: 1998-2018) extracted from satellite measurements (NASA-TRMM) were used. The precipitation varied between 1015.7-1932.3 mm a^{-1} during the study period with a mean of 1405 mm a^{-1}. The multilevel decomposition technique of discrete wavelet transform (Mallat algorithm and Daubechies 9 wavelet), and nonparametric Sen's slope method and Mann-Kendall test were used to analyze the dataset. Results suggested that during post monsoon and monsoon season, the amount of rainfall was decreased and it was increased in winter and pre monsoon seasons. Accordingly, the annual amount of rainfall over the Chorabari Glacier catchment was increased in past two decades with the periodicity of 2, 4, 8 (in general) and 16 (in particular) years. This represented that seasonal pattern of rainfall is changed substantially and shifted towards the non-monsoonal months. Changes in the precipitation pattern will result in enhance melting of snow/glacier mass which in turn subsequently harmful for the Himalayan snow-glacier fed watersheds.

Keywords: Himalayan glacier, Climate change, Rainfall trends, Wavelet transform

INTRODUCTION

Dynamics of snow-glacier fed Himalayan watersheds (Third Pole), which are the sources of many rivers, are majorly controlled by the precipitation (snowfall and rainfall) system (Kesarwani *et al.,* 2015; Mala *et al.,* 2019). The Himalayan watersheds are known as winter-summer accumulation type due to the influence of Western disturbance (west-east) and Indian summer monsoon (south-west) (Kesarwani *et al.,* 2015). Several recent studies (Randall *et al.,* 2007; Meenu *et al.,* 2013) suggested that atmospheric temperature is rising and precipitation patterns are continuously changing due to variations in the climate. Thus, it is important to understand the mechanism and pattern of the Himalayan precipitation system at regional to local scale. Generally, rainfall is measured locally using rain gauges. However, rainfall over a large spatial scale can be computed with the help of satellite technologies (e.g. radar systems and earth-observing satellites) and climate models (AOGCM, CMIP5, GCMs, CORDEX, etc.) using the ocular observations. Such approaches are cost effective and being widely used to estimate the seasonal rainfall on the global scale (Huffman *et al.,* 2001; Joyce *et al.,* 2004). However, challenges are there while using the products of climate models due to their larger spatial resolution, downscaling issues and ignorance of topographical boundaries. Moreover, assessment of the multi temporal climatological dataset in terms of forecasting, trend analysis, dimension deduction, etc. is also typical. Use of wavelet transform is the most suitable technique to analyse the long-term rainfall dataset (Holman 2005). This technique is also suitable for the theoretical aspects (Mala *et al.,* 2018) and widely used in the various science & technology fields *viz.,* wave propagation, seismology, data encoding, pattern recognition, fault detection, analysis of medical images, etc. (Debnath & Shah 2015).

The present research work aims to analyse the rainfall trends over the Chorabari Glacier catchment of Mandakini River basin (Uttarakhand, India) during past two decades (1998-2018). Multi temporal rainfall records (1998-2018) extracted from

satellite measurements (NASA-TRMM; spatial resolution: 0.25° × 0.25°) are used in this study.

STUDY AREA

The Chorabari Glacier valley (latitudes N 30°41' to 30°48' and longitudes E 79°1' to 79°6') comprises catchment area of 63.8 km² in the Mandakini River basin (1,657 km²), upper Ganga catchment, Garhwal Himalaya, Uttarakhand (Fig. 1). In this valley, two well constrained valley glaciers (Chorabari and Companion glaciers) and four unnamed small glaciers (including ice apron, hanging glaciers, glacierete and cirque glacier) are identified covering an area of about 16 km² (25 % of total area). The Chorabari is the largest glacier (length - 7.5 km; area - 6.66 km²) in the valley and can be considered as representative glacier of the valley (Kesarwani 2015).

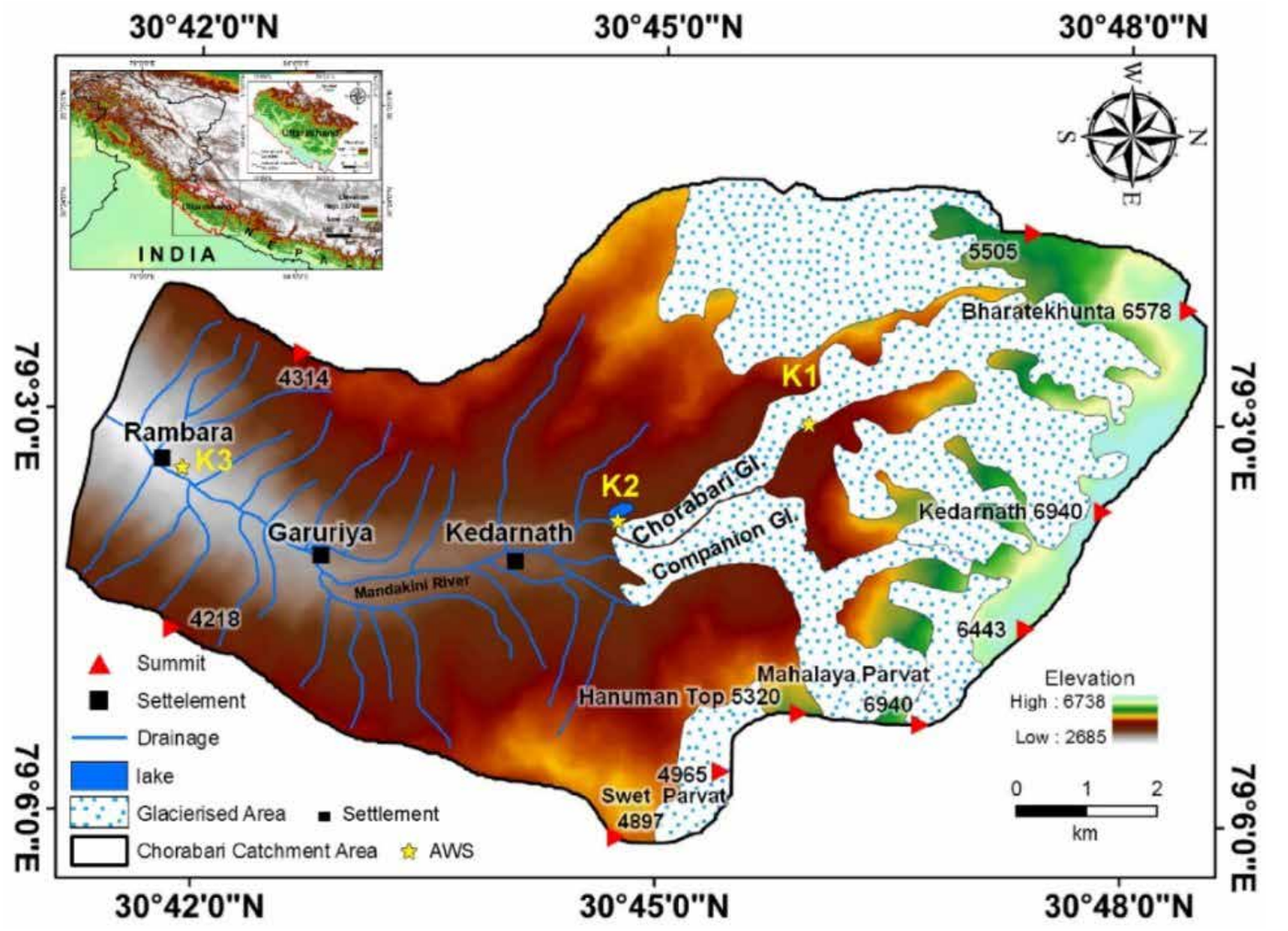

Fig. 1. Upper Mandakini basin with location of the Chorabari Glacier catchment, Mandakini River basin, Uttarakhand, India (background image: SRTM DEM of 90.0 m spatial resolution, source: Kesarwani, 2015).

MATERIAL AND METHODS

Rainfall Data Acquisition

Multi temporal rainfall records (1998-2018) of the Chorabari Glacier catchment extracted from satellite measurements (NASA-TRMM) are used (Fig. 2). The data series is alienated as per the hydrological year (01 November to 31 October of the following year) and classified into three categories - (i) monthly, (ii) seasonal, and (iii) yearly. The seasonal classification of the dataset is further divided into four categories - (i) Post monsoon (November and October of the following year), (ii) Winter (December, January and February), (iii) Pre monsoon (March, April and May) and, (iv) Monsoon (June, July, August and September).

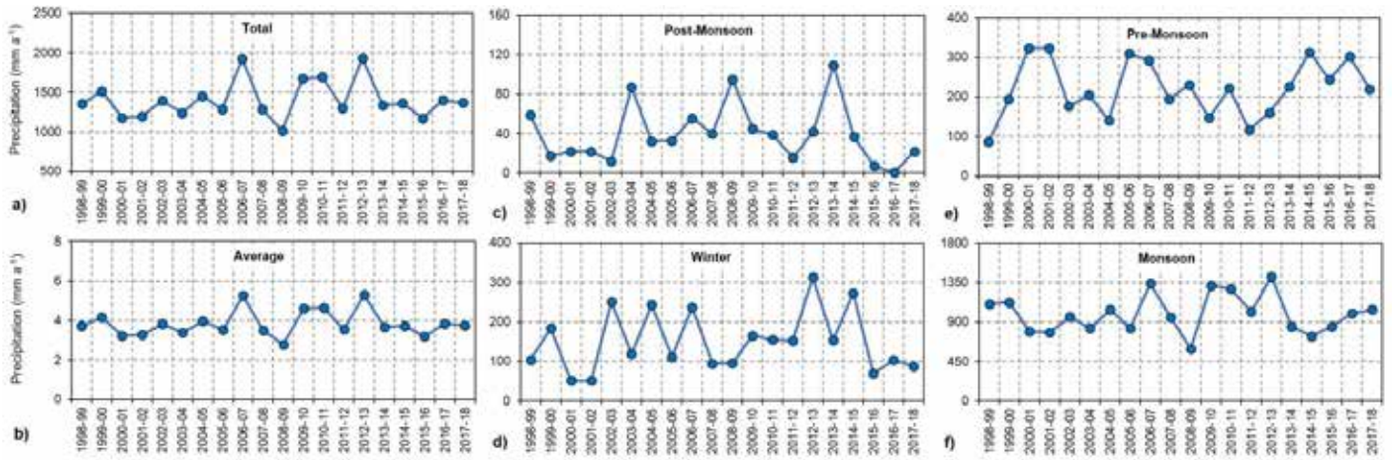

Fig. 2. (a) Yearly, (b) average and (c-f) seasonal distribution of rainfall records extracted using NASA-TRMM satellite measurements (spatial resolution: 0.25º) for the Chorabari Glacier catchment (Mandakini River basin) during the hydrological year (01 November to 31 October of the following year) of 1998 to 2018

Trend Analysis

The multilevel decomposition technique is applied over the long-term rainfall records obtained from the NASA-TRMM for the dimension deduction and removal of noise in signal, and trend analysis. The discrete wavelet transform (DWT) of a signal requires selection of a suitable mother wavelet and an appropriate level of decomposition. In the DWT, the wavelet coefficients of a time series $f(t)$, whose response occurs at discrete integer time steps can be obtained as follows (Deobnath 2002)-

$$W_{\Psi} f(m,n) = (\mathrm{f}, \Psi_{\mathrm{m,n}}) = \sum_{m,n\in} f(t)\overline{\Psi(a_o^{-m}t - nb_o)}dt$$

where, **Z** is the domain of integer numbers; m and n are the factors of frequency and time, respectively and $\overline{\psi(.)}$ is the complex conjugate of the stretched form of mother wavelet $\psi(\mathrm{t})$ (wavelet function of time). Multilevel one-dimensional wavelet decomposition function is used for the discrete wavelet analysis of spatial observations of rainfall at 2^{n} (dyadic translation fluctuations), where n is the level of detailed components.

The detailed and approximate coefficients obtained from the wavelet decomposition of rainfall time series are used to reconstruct the time series of various combination of detailed and approximate components. Different combinations of reconstructed detailed component series levels (D1, D2, D3, ..., Dn) and approximate component at highest level (A_n) have been analysed for significance of trends. The information deduction from decomposed components requires the reconstruction of signal in form of time series. Inverse discrete wavelet transform for signal reconstruction is performed as:

$$x(\mathrm{t}) = \mathrm{A_n}(\mathrm{t}) + \sum_{i=1}^{n} \mathrm{D_i}(\mathrm{t})$$

Statistical Analysis

To ascertain the presence of statistically significant trend in climatologic variables *viz.* rainfall, nonparametric Sen's slope method (SSM) and Mann-Kendall test (MKT) are used. Sen's slope method will be helpful in identifying the magnitude of trend in rainfall dataset. The positive value of Sen's slope estimator coefficient indicates an upward (increasing) trend and negative value indicates the downward (decreasing) trend. However, MKT will be helpful in identifying the significance testing of trend. In present study, null hypothesis in MKT is tested as 5 % level of significance. A positive value of Mann-Kendall coefficient indicates an increasing trend, while a negative value of coefficient indicates the decreasing trend of the considered time series.

RESULTS AND DISCUSSION

Analysis of Rainfall Records

In the Chorabari Glacier catchment, the precipitation varied between 1015.7-1932.3 mm a^{-1} during 1998 to 2018 (20 years) with a mean of 1405 mm a^{-1}. Over the 20 years of dataset, 2008-09 received a minimal rainfall (1015.7 mm a^{-1}) reflected the drought conditions. However, 2012-13 received the highest rainfall (1932.3 mm a^{-1}) indicated the flood conditions in the study area. Normalization of rainfall records suggested that total 14 years (1998-99, 2000-01, 2001-04, 2005-06, 2007-09, 2011-12 and 2013-18) received less rainfall then average, and

remaining 06 years (1999-00, 2004-05, 2006-07, 2009-11 and 2012-13) received higher than average rainfall. In the seasonal cycle, rainfall in post monsoon varied between 0.53-109 mm a^{-1}, 50-312 mm a^{-1} in winter season, 87-324 mm a^{-1} in pre monsoon and 594-1417 mm a^{-1} in monsoon season.

Rainfall Trends

Wavelet analysis of discrete wavelet transform (Mallat algorithm and Daubechies 9 wavelet) is performed on the NASA-TRMM rainfall records observed during 1998-2018 (based on monthly sum). The arbitrary noise present in the original series (S) is reduced by and by as the decomposition level is increased (Fig. 3). Rainfall records based on the monthly sum are decomposed into maximum approximation value (A6) and six detailed components (D1-D6). Each level of detailed component represents the dyadic translation fluctuations (n).

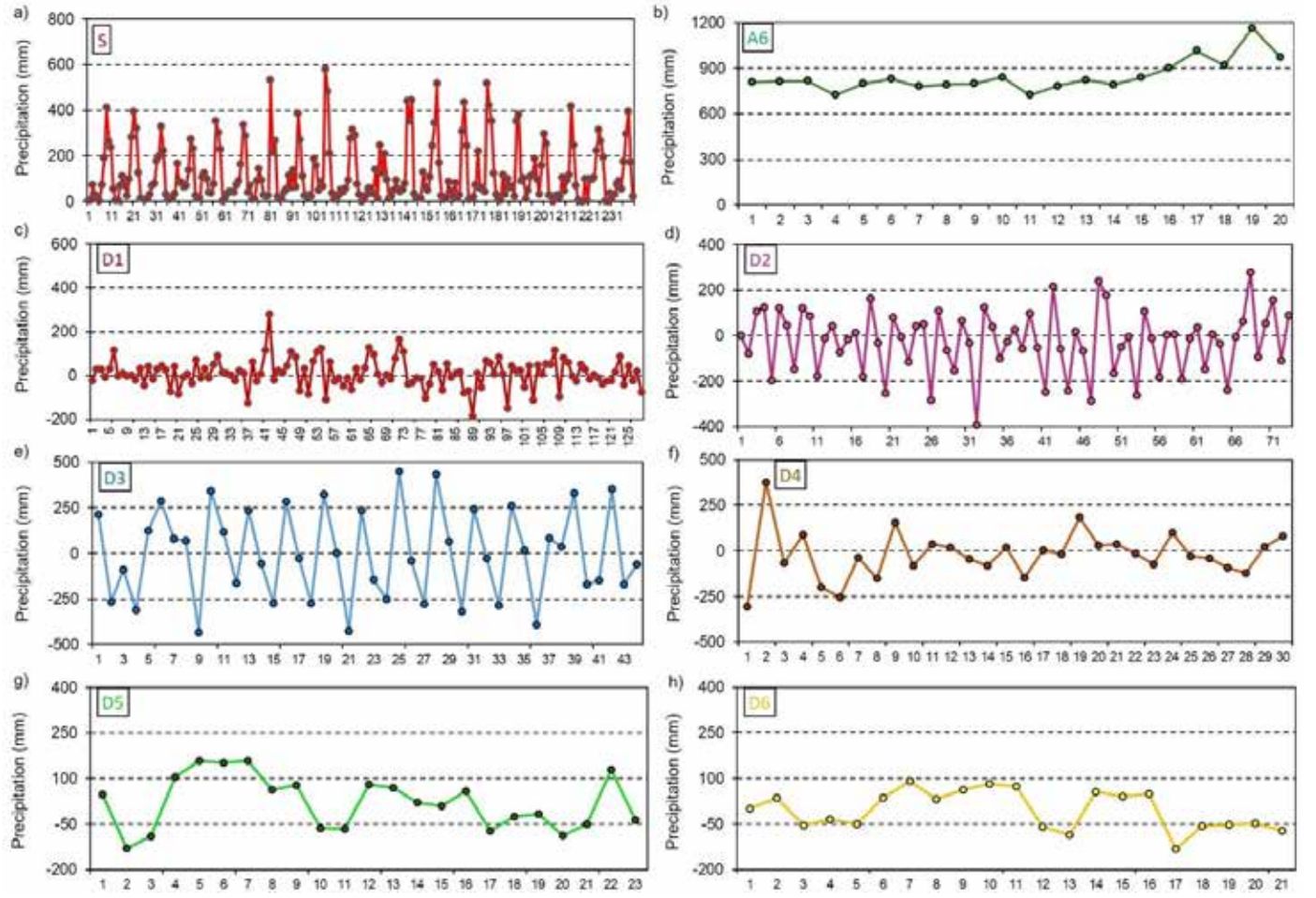

Fig. 3. (a) Analysed yearly (based on monthly sum) NASA-TRMM rainfall records (S) using wavelet multilevel decomposition techniques on different levels – (b) maximum approximate series (A6) and (c-h) detailed series (D1 to D6). The highest approximate series (A6) depicts the clear trend (sharp spikes, bumps or discontinuity) of the dataset as the noise level is decreased. Similarly, the highest detailed series (D6) represent the clear trend.

Table 1. Results of Sen's slope method (SSM) and Mann-Kendall test (MKT).

Category	SSM	MKT	Indicator
Post Monsoon (Nov and Oct of the following year)	-9.59	-0.49	↓
Winter (Dec, Jan, Feb)	0.41	0.88	↑
Pre Monsoon (Mar, Apr, May)	8.30	0.49	↑
Monsoon (Jun, Jul, Aug, Sep)	-1.79	-0.42	↓
Annual (Nov to Oct of the following year)	2.62	0.88	↑

In the statistical analysis, both Sen's slope estimation method (SSM) and Mann-Kendall test (MKT) are showing almost similar trends (either both are in upward or downward directions) in the seasonal and annual series (Table 1). Analysis of sesonal series indicate that there was an increasing trend of rainfall in the winter (SSM: 0.41; MKT: 0.88), pre monsoon (SSM: 8.30; MKT: 0.49) and annual (SSM: 2.62; MKT: 0.88) series. However, rainfall in the post monsoon (Sen's Slop: -9.59; MKT: -0.49) and monsoon (SSM: -1.79; MKT: -0.42) seasons were decreasing

(Table 1). Results represents that seasonal pattern of rainfall is changed considerably and shifted towards the non-monsoonal months (snowfall period).

Moreover, to identify the periodicity of rainfall over the study area, transformed series (detailed and maximum approximation) and various combinations of detailed and maximum approximation series are further analyzed in terms of MKT. A comparative analysis is performed among the original series with detailed series (D1-D6), original series with maximum approximate series (A6), and original series with combination of detailed series including maximum approximate series (D1+A6 to D6+A6). The original series (S) shows a positive trend (MKT: 0.79), which again confirms an increasing trend to rainfall over the study area during 1998 to 2018. Increasing trend of rainfall are also found in the D4 (MKT: 0.86) and A6 (MKT: 2.76). In the combination series of D1-D6 with A6, only D6+A6 shows an increasing trend (MKT: 1.98). However, D1-D5 with A6 indicate a decreasing trend with MKT values of -4.86, -4.48, -4.34, -2.29, and -0.21, respectively. The positive value of D4 (MKT: 0.86) is much closer to the original series (MKT: 0.79). This represents that a periodicity of 2, 4, 8 (in general) and 16 years (2^4 as per the dyadic translation fluctuations, where n (decomposed level) = 4) (in particular) in the rainfall trend over the Chorabari Glacier catchment during the study period.

CONCLUSION

In the present research work, multitemporal rainfall records (past two decades: 1998-2018) extracted from satellite measurements (NASA-TRMM) over the Chorabari Glacier catchment (Mandakini River basin), Uttarakhand, India were analysed. The precipitation varied between 1015.7-1932.3 mm a^{-1} during the study period with a mean of 1405 mm a^{-1}. The multilevel decomposition technique of discrete wavelet transform (Mallat algorithm and Daubechies 9 wavelet) was applied on the rainfall dataset to reduce the arbitrary noise for trend identification. Further, nonparametric Sen's slope method and Mann-Kendall test were used to identify the magnitude and significant testing of rainfall trend. Harmonic analysis of transformed series (detailed and approximate) with original series and combinations of detailed and maximum approximation series with original series, were also used to identify the periodicity of the rainfall. Results suggested that during post monsoon and monsoon season, the amount of rainfall was decreased while it was increased in winter and pre monsoon seasons. Accordingly, the annual amount of rainfall over the Chorabari Glacier catchment was increased in last two decades and the periodicity in the rainfall trend is observed to be 2, 4, 8 (in general) and 16 (in particular) years. This indicate that seasonal pattern of rainfall is changing considerably and shifting towards the non-monsoonal months, which in turn, subsequently resulting the enhanced melting of the snow/glacier mass present in the catchment. The study will be helpful in identifying the behaviour of the Himalayan Cryosphere/water resources fluctuations under the changing climate scenario.

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CULTURAL AND LIVELIHOOD INTERDEPENDENCE ON THE FORESTRY RESOURCES IN THE BUFFER ZONE OF NANDA DEVI BIOSPHERE RESERVE, A NATURAL WORLD HERITAGE SITE IN UTTARAKHAND

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ABSTRACT

Nanda Devi National Park and Valley of Flowers National Park form the core zones of The Nanda Devi Biosphere Reserve (NDBR) in Uttarakhand which represent high diversity, endemism and representativeness. These two parks are surrounded by a large buffer zone comprising Reserve Forests, Community (Van Panchayat) forests and Civil Soyam forests. Over 15,000 people live in the Biosphere Reserve, many among which practice transhumance due to harsh climate during winter. The present study was conducted in the buffer zone of NDBR in the Niti Valley of Joshimath block of Chamoli district. A workshop was conducted with the inhabitants of Reni, Lata and Tolmavillages which lie just outside the Nanda Devi National Park, the core zone of NDBR. Information was gathered through structured questionnaires about the various commodities such as wild fruits, vegetable, spices, medicines etc. for which they are dependent on nearby forest area. Changes in the scenario after the notification of Nanda Devi National Park and inclusion of this region into the buffer zone of NDBS were discussed. Their cultural and religious dependence on the forestry resources were also discussed in the workshop. The team also undertook day trips in the villages of Reni, Lata, Malari and Niti and interviewed the local people. The information gathered was complemented by secondary information from literature review. It was found that they rely heavily on the biodiversity of the reserve which they use for variety of their needs including food, fodder fuel, medicine, building material and religious rituals. Closure of trade with Tibet after the Indo-China conflict (1962) followed by the restrictions imposed by the Biosphere has impacted the traditional patterns of resource use (and economic mainstays) of subsistence farming, forest extraction, and livestock grazing.

Keywords: National park, Core zones, Niti valley, Bhotiyas, biodiversity.

INTRODUCTION

The Nanda Devi Biosphere Reserve (NDBR) in Uttarakhand is one of three biosphere reserves in the Indian Himalaya, the other two being Kanchengdzonga Biosphere Reserve in Sikkim and Cold Desert Biosphere Reserve in Himachal Pradesh. NDBR is spread over an area of 5860 Km^2 with two core zones viz. the Nanda Devi National Park (625 Km^2) and the Valley of Flowers National Park (88 Km^2). The two core areas together constitute a World Heritage site inscribed by UNESCO in 1992 and the reserve was included in the UNESCO's world network of Biosphere Reserves in 2004. The core zones are securely protected for conservation of biodiversity, monitoring minimally disturbed ecosystems, and undertaking research and other low-impact uses such as ecotourism and education. They represent high diversity, endemism and representativeness. Covering 712.10 Km^2 area, these two parks are surrounded by a large buffer zone of 5148.57 Km^2 which encompasses a wide range of elevation and habitats (https://whc.unesco.org/en/list/335). Though the buffer zone is not well defined and any notification in this regard is yet to come, an area of 10 Km^2 from the boundary of core zones is conveniently taken as buffer zone (Fig 1). It comprises Reserve Forests, Community (Van Panchayat) forests and Civil Soyam forests. The Buffer zone is used for cooperative activities compatible with sound ecological practices, including environmental education, recreation and research. The buffer zone of NDBR includes 47 settlements spread over an elevation range of 2200-3400 m asl and dispersed in patches of forest matrix in Chamoli, Pithoragarh and Bageswar districts of Uttarakhand. The NDBR buffer zone is home to 19 communities (five permanent and 14 transhumant settlements). From geomorphologiacal point of view, the buffer zone occupies the whole Alaknanda and

Rishi Ganga rivers catchment areas (sub-catchement areas of the Ganga river system) that is encircled by high Himalayan peaks including the Nanda Devi, which is India's second highest peak. The transition area of 546 Km^2 with 55 villages forms a "cushion" of the buffer zone and the same activities take place here as in the buffer zone (http://www.unesco.org/mabdb/br/brdir/directory/biores.asp?mode = all&code = IND + 04). The transition area is mostly inhabited by Schedule tribes, Schedule Castes, Brahmins and Rajputs (http://www.unesco.org/mabdb/br/brdir/directory/biores.asp?mode = all&code = IND + 04). A large area of NDBR lies above tree line and is covered with snow for more than 6 months in a year (Saxena *et al.,* 2010).

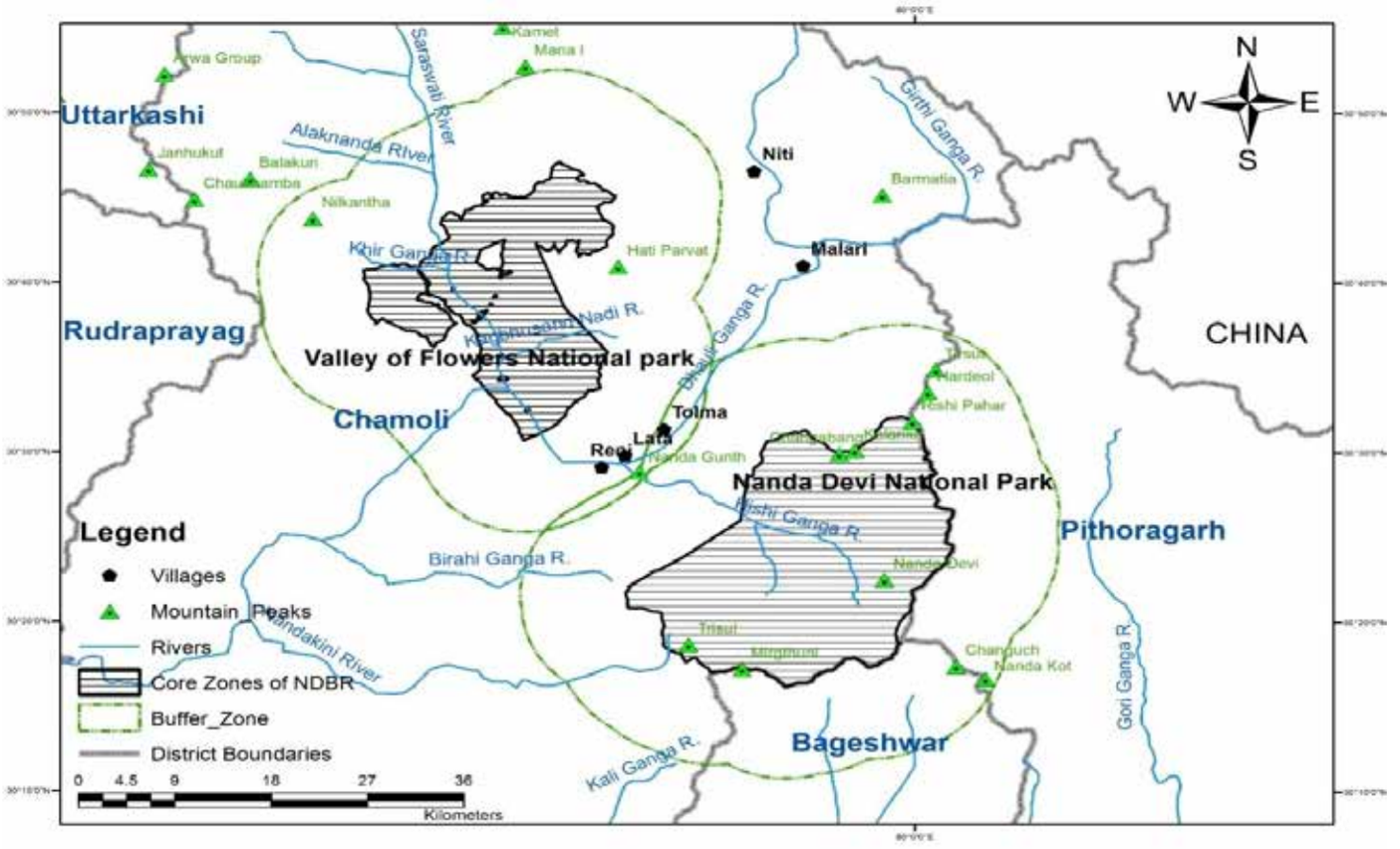

Fig. 1. Map showing Core and Buffer Zones of Nanda Devi Biosphere Reserve, villages surveyed, important streams and mountain peaks

Over 15,000 people live in the Biosphere Reserve which mainly belong to two ethnic groups, the Indo-Mongoloid (Bhotia) and Indo-Aryan. A defining characteristic of the Bhotiya is the practice of transhumance, or migration between summer and winter villages to use grazing land and grow crops. Transhumance is generally considered good for the environment as it takes advantage of seasonal resources. The centuries old occupation of the Bhotiya community was trade with the Tibet. During the summer months, while few members of the community would embark on their journey of the season towards Tibet converting their winter villages into trade facility, the rest would stay in the upper villages cultivating crops and medicinal herbs (for subsistence, trade and cash). Using pack goats as the means of transport they carried goods from the plains to Tibet. The main occupation of Malari and Niti villages was trade while the villages downstream like Reni and Lata assisted in the trade. While trade continued, Malari was the hub of activities. With the closure of trade with Tibet after the Indo-China conflict (1962), the Bhotiya community opted for other sources of livelihood. The pack goats were sold and the focus became sheep, woolen products and agriculture. Cultivation of medicinal plants, sheep farming, apiculture and horticulture became the main sources of income. They still practice marginal subsistence agriculture, rear cattle for milk and sheep for woolbut the livestock population particularly sheep and goat has been reduced considerably in the past few decades. Also about 50% pastures were included in the core zone and hence became un-accessible for people to use for their livestock (Nautiyal 1999). The growing popularity of the Nanda Devi Sanctuary as a mountaineering destination provided ample alternative employment opportunities for the

villagers till 1982 when the area was notified as a national park with a complete ban on mountaineering and grazing in the core zone, which includes the Nanda Devi peak.

The present study was conducted in the buffer zone of Nanda Devi National Park in the Niti Valley of Joshimath block of Chamoli district. The valley gets its name from the last upstream village 'Niti' located near the Indo-Tibetan border. The Nanda Devi was a wildlife sanctuary declared as early as 1939, which was upgraded to a national park in 1982. In 1988, this Park housing the Nanda Devi peak (7,816 m) became the core zone of the Nanda Devi Biosphere Reserve (NDBR). Free from any anthropogenic pressure, it is surrounded by a buffer zone of 1611 Km^2 that includes humanized landscape (http://www.forest.uk.gov.in/pages/view/158-nanda-devi-national-park). In geomorphological terms, it occupies the entire catchment area of Rishi Ganga, a tributary of the Dhauli Gangariver.

METHODOLOGY

A workshop was conducted near Lata village (30˚29'41" N and 79˚42'10"E, 2070m asl). This area is the birth place of Chipko movement and lies at the periphery of the Nanda Devi National Park, the core zone of NDBR. About 80 villagers from nearby villages viz. Reni, Lata and Tolma participated in the workshop. Information was gathered through structured questionnaires about the various commodities such as wild fruits, vegetable, spices, medicines etc. for which they are dependent on nearby forest area for sustenance or trade. Changes in the scenario after the notification of Nanda Devi National Park and inclusion of this region into the buffer zone of NDBS were discussed. Their cultural and religious dependence on the forest resources were also discussed in the workshop. Following this, detailed discussions were held with Dr Sunil Dutt Kaithola, Director, Mountain Shepherds Initiative and Dhan Singh Rana, Ex-Gram Pradhan, Lata village and leader of Chhino-Jhapto Andolan. The team also undertook day trips in the villages of Reni, Lata, Malari and Niti and interviewed the local people in their households. Individuals interviewed in the villages were all adults, with a majority being above 40 years of age and at the time of the interviews, they were involved in farming, weaving and domestic household caretaking. These trips also allowed to further explore temples, forest resources, river drainages, and other points of interests. The information gathered was supplemented by secondary information from literature review. Articles and previous case studies about the Buffer zone of the Nanda Devi Biosphere Reserve were reviewed in relation to function and conservation of ecosystem, forest resources including medicinal plants, traditional knowledge, biosphere management and conflict with people. Demographic Profile of these villages Census 2011 is given in Table 1.

Table 1. Demographic Profile of the villages surveyed in the Buffer Zone of NDBR in the Niti valley

Name	No of Households	Total Population (No.)	Male Population (No.)	Female Population (No.)	Scheduled Castes population (No.)	Scheduled Tribes population (No.)	Literate Population (No.)	Illiterate Population (No.)
Raini	48	145	106	39	4	70	120	25
Tolma	74	429	299	130	16	135	323	106
Lata	84	305	145	160	1	302	175	130
Niti	29	47	22	25	0	46	37	10
Malari	1076	1933	1427	506	74	911	1574	359

RESULTS

There are 25 villages in the Niti valley and besides Bhalgaon, all the villages are inhabited by members of the Bhotia schedule tribe (Kainthola *et al.,* 2006). Bhotiyas, the local inhabitants, historically were traders, with livestock husbandry as their subsidiary occupation. Until 1962, they used to carry wheat, rice, buckwheat and all sorts of items of daily need such as utensils, jaggery, edible oil and fabrics etc. to Tibet as Tibetians were unable to grow grains because of unfertile land and harsh climatic conditions and practiced only cattle rearing which included sheep, goats, yalks and horses. Bhotiyas used to barter these items with lake salt, wool, pashm (wool from a special kind of Goat in very high altitudes) and sohaga (Sodium borate, which is found in the beds of salt lakes and was mainly used for soldering in gold jewelry). People of Niti valley totally used the lake salt brought from Tibet which was considered healthiest for consumption, sea salt was not at all in use at that time. Bhotiyas follow Hindu religion whereas Tibetians are Buddhists and hence there were no cultural ties between them; they only had trade relations.

People lived in their high elevation settlements in summer and

move down in winters to their settlements at lower elevations acquired from Garhwali communities on informal share-cropping terms that were not recognized in the formal land right system put in place by 1960. With the loss of customary cultivation rights in their winter settlements coupled with the loss of income from trade and from wild biological resources due to legal protection of these resources, local people seem to have intensified agricultural land use in an attempt to compensate for the losses. Woolen handlooms and traditional beverage production units are the traditional cottage industries. Marketing (barter system) within village operates on a very small scale but is a crucial determinant of resource flows. People now have more inclination towards cash crops. Livestock (particularly goat/sheep), raw medicinal and aromatic plant products (both collected from wild and cultivated), woolen handloom products and traditional beverages are the major export items and salt, sugar, oils and consumer products the major import items (Saxena *et al.,* 2010).

Wild Plant Resources

Some of the medicinal herbs collected for trade and ethno botanical purposes are: Keedajadi, Atees, Gandranu/Choru, Laljari/ Balchar, Hatajari, Kutki/Kaduwi, Ban-Kakri etc. Deodar, Surai and Kail are the fuelwood species that the villagers use. Apart from taking the cattle for regular grazing, they also collects fodder from the forest. Some of the most commonly fodder species thus collected are kameru, saginu, Purakh, Khod, Kumayu, Chriya, etc. The people also consume some wild vegetables like Puyonu, Chandra, Barmau, Lingura, Kandali etc. The wild fruits in the region are Jamun, Ghenu, Hisalu, Darbhau, Bedu, Chulu etc. Decoctions made of wild Thuner bark and sheel podi leaves are consumed in their daily routine. Dhoop and agarbatti for religious rituals are made using aromatic wild plants like Masi, Tagar, Bhitaru, Nair and Purchu. A list of wild plant resources of the region used for fodder, fuelwood, medicines, decoction, fruits, vegetables, spices and religious ceremonies are given in Table 2.

Table 2. Wild plant resources of the region

Uses	Common name	Scientific name
Fodder	Baanj	*Qurercus leucotrichophora*
	Chamla	*Desmodium elegans*
	Kaanchula	*Acer ceasium*
	Kabasi (BhotiyaBadam)	*Corylus jecqmontii*
	Kaimu (Shahtoot)	*Morus serrata*
	Sakina	*Indigofera heterantha*
Fuel wood	Bhitaru	*Juniperus indica*
	Chamla	*Desmodium elegans*
	Devdar	*Cedrus deodara*
	Ghenu	*Viburnum cotinifolium*
	Jaamun	*Prunus comuta*
	Kail/Chir	*Pinus wallichiana*
	Khains	*Salix* sp.
	Paangar	*Esculus indica*
	Raaga	*Abies pindrove*
	Sakina	*Indigofera heterantha*
	Surai	*Cupress torulosa*
	Wild walnut	*Juglans regia*
Medicinal	Atis	*Aconitum heterophylum*
	Ban kakri	*Podophullum hexandrum*
	Chhipi	*Pleurospermum angelicoides*
	Choru	*Pleurospermum angelicoides*
	Dolu	*Rheum emoli*
	Hatthajadi	*Dactylorrhiza hatagirea*
	Keedajadi	*Ophiocordyceps sinensis*
	Kutki/ Kaduwi	*Picorrhiza kurrooa*
	Laljadi (Baljadi, Ratanjot)	*Arnebia benthamii*
Decoction	Thuner	*Taxux baccata*
	Silpodi	*Bergenia ciliata*
Fruits	Bedu	*Ficus palmata*
	Bhyula	*Gaultheria trichophylla*
	Ghenu	*Viburnum cotinifolium*
	Ghingaru	*Crategus cranilata*
	Hisalu	*Rubus ellipticus*
	Hivol	*Rubus*
	Themuku	*Prunus cornuta*
	Wild peach	*Prunus persica*
Vegetables	Bermau	*Megacarpaea polyandra*
	Bhathua	*Chenopodium foliolosum*
	Chandra	*Paeonia emodi*
	Dholkanali/ pachu	*Girardinia diversifolia*
	Doom	*Allium semnovii*
	Garhamilu/ Payoom	*Rumex nepalensis*
	Jagra	*Phtolacca acinosa*
	Kandali	*Urtica hyperborea*
	Linguda	*Diplazium esculentum*
	Puyonu	*Smilacina purpurea*
	Tatri	*Rheum moorcroftianum*
	Wild Chaulai	*Amaranthus bilatum*
	Wild Palak	*Silone vulgaris*

Spices	Choru	*Angelica glauca*
	Faran	*Allium stracheyi*
	Thawe/ Kala jeera	*Carum carvi*
	Timur	*Zanthoxylum armatum*
Plants for religious ceremonies	Bhitaru	*Juniperus indica*
	Bhojpatra	*Betula utilis*
	Brahmkamal	*Saussurea obvallata*
	Devdar	*Cedrus deodara*
	Dhoop	*Juniperus dolomiaea*
	Dhoop	*Juniperus recurva*
	Jatamansi	*Nardostachys jatamansi*
	Nair	*Skimmia anquetilia*
	Purchu	*Artemisia maritime*
	Tagar	*Valeriana wallichi*
	Takkar	*Pleurospermum brunonis*

From ethno-biological point of view, 173 plant species were observed to be used by these people of which, 82% plant species are used for medicine, spices and condiments, vegetables and fruits etc. and 18% are used for house construction material, fuel, fodder, agricultural implements and fencing etc. Temporary bridges are prepared using woodlogs when the water is very less in the river in order to access the much needed pastures across Dhauli Ganga during winters. The quantification and documentation of the indigenous knowledge related to the usage of these wild resources which is restricted only with a few people locally known as vaidya (local medical practitioner) is extremely important. It is also important is to assess their contribution in the village ecosystem function otherwise it will be lost forever in the process of acculturation which is taking place in this community at an alarming rate. Strategy of domesticating high value low volume minor forest produce will be helpful for achieving both conservation objectives and economic upliftment of local people (Nautiyal 1999).

Cultural Heritage and Rituals

The community perform all kind of traditional rituals during summers in their period of stay from April to October in the valley. The entire population in the Niti Valley is Hindu and the Hindu festivals are celebrated with great joy and ceremony. The main festivals are Basant Panchami, Baisakhi (Bikhoti), Nag Panchami (Fela Panchnag), Nanda Astami, and Dussehra (Durga Astami). The community has a strong belief in the importance of forefathers or ancestors ('pitra'). One important ritual is 'dharma', a welfare work which involves the construction of resting places along the village route as a remembrance to departed souls. The main deity of devotion is the goddess Nanda Devi, with the Nanda Devi peak revered as a goddess by the entire region. She is looked upon as Gaura, the wife of Lord Shiva, and is the chief patron of the local communities. The temple of Nanda Devi at Lata is revered highly among people, which is believed to have been constructed during the Katyuri period. Due to the presence of this temple at Lata, the village has a reputation in the valley. *Saussurea obvallata* (Brahmakamal) are collected as religious offerings to goddesses Nanda Devi. However, the annual offerings to the goddess Dubri are discontinued as the place of worship now falls within the core zone of the Nanda Devi National Park.

A special celebration, Lapsu or Lapsa, takes place at the beginning of the winter migration when the communities prepare to leave their dwellings in the higher areas. Idols, of village deities are taken in a procession from the village temple and settled in a house in the village. The headman and other senior members of the community host at least three baris or feasts for the entire village. The community bids adieu to the deity and promises to perform their rituals on their return to the land. The festival takes place at Malari, witnessed by the deity Dharma Danu (a 'pitradevta'), who makes a voyage from Jelum to Malari and back to Jelum. Other important festivals include the Pandava dance, a 15-day festival in August and occasional performances of the hero of the land, Jitu Bagdwal. The village of Lata performs a ritualistic mask dance at the onset of summer season. Folklore, song, drama, and dance are an integral part of the festivals and lifestyle of the Bhotiya society, which are also marked by the consumption of traditional drink, known as Jaan which is prepared by fermenting the flour of *Eleusine coracana* preferably in an earthen pot for few months.

In every village the selection of a family for the bari is done before the summer harvest during the occasion of Bhumyal Pujan, a ceremony to offer prayers and offerings to Bhumyal Devta, the God of Earth. Harvesting starts after the Bhumyal Puja. Basant Panchami (spring) used to be the start of the community movement towards the summer villages. There is a strong relationship between the location of villages and rights over the use of adjoining forests and rangelands. The settlement history of the villages and the rights of later immigrants also play an important role in defining their status. The grazing areas have been categorised into accessible areas and areas forbidden to animals. The inaccessible areas are distributed equally among families for a period of five years for guarding or stewardship. The accessible areas are open for grazing.

Conflict with the Biosphere management

After the notification of Nanda Devi National Park in 1982 (No. 3921/14-3-35-80, Uttar Pradesh Government Order, 1982), grazing, trekking, quarrying, extraction and entry rights were curtailed. These restrictions had a severe impact on the villages of Reni, Lata and Tolma which lie in the buffer zone of the National Park as they lost their seasonal grazing grounds, access to NTFPs and income from tourism (Naithani *et al.,* 2015). However, these sanctions proved crucial for the Forest Department while expressing their interest for inclusion as Biosphere Reserve under the Man and Biosphere (MAB) programme of UNESCO in 1988 and further inclusion under UNESCO's world network of Biosphere Reservesin 2004. The restrictions imposed on the locals consequently resulted into an agitation among them leading to Chhino Jhapto Andolan (swoop and grab movement) in 1998 when hundreds of villagers with their cattle marched inside the core zone of the Nanda Devi National Park. As a result of this, they could reclaim their traditional forest rights upto some distance inside the Park. The local people again initiated a movement against the hydropower project on Rishi Ganga near Lata village which had been taken up by Larsen & Toubro Limited. The people gave the logic how could any hydropower project start inside the Nanda Devi National Park when their activities and rights were being denied. Denial of the rights to use forest resources which had been enjoyed by them for centuries before the notification of the Park, absence of alternative livelihood means after curtailment of usufruct rights, loss of employment opportunities due to abandonment of tourism activities in the core zone and damage to life and crop caused by wildlife have resulted into conflict between NDBR and the local residents in the buffer zone.

Economic Losses

Before creation of national park in 1982 and reserve in 1988, people in the area were fully dependent on the reserve for the collection of resources like medicinal and aromatic plants, fuel, fodder, leaf litter, timber, livestock grazing, working as a tour guides and porters with the expedition team, etc. However, now there is growing unrest among the local communities, who are being denied access to resources after the creation of the Biosphere Reserve, on which they have traditional rights to utilize since time immemorial. After the imposition of conservation policies in the region, the damage caused by wildlife to the crops increased ranging from 4% in Malari village to as high as 60% in Tolma village (Nautiyal 1999). (Rao *et al.,* 2000) has calculated the loss of economic activities to the local people residing in the buffer zone of NDBR under heads viz. loss of grazing resources (40%), loss of access to NTFPs (23%), loss of income due to restrictions on tourism activities (24%) and loss of property and produce due to wildlife depredation (13%).

There is a need to address the grievances of the communities through Forest Rights Act (2006) which makes provision for granting forest rights to the communities living in and around forest areas. There is also an urgent need to regularize collection and sale of Keeda jadi (*Ophiocordyceps sinensis*), an expensive medicinal fungi collected from alpine meadows by majority of the inhabitants of Niti valley, who would then be able to get its appropriate price at par with that of the international market. As has been done in the Kumaon, border between India and Tibet Autonomous Region should be opened here also for cross-border trade and tourism, which would be of immense help to rejuvenate the economy of this region. Promotion of medicinal plant cultivation and sustainable harvesting of non-timber forest products, establishment of cottage industries for manufacturing indigenous medicines/ drugs and essential oilsin remote and far flung areas having easy access to the resources, establishing efficient marketing channels, eco-tourism and extension programmesare some other feasible options to be implemented to generate employment opportunities, improve the local economy and resolve the conflictsin the Buffer zone of NDBR.

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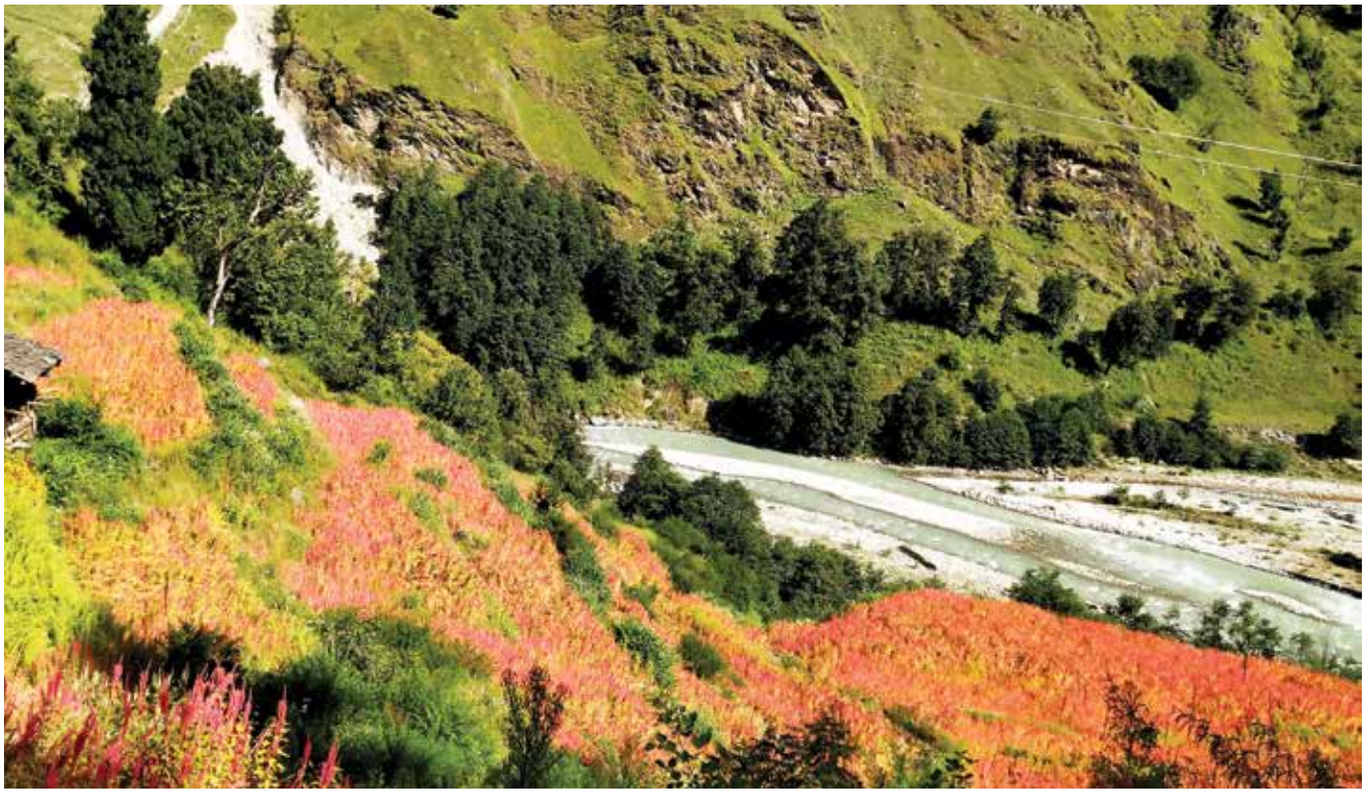

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