



International Journal of Biodiversity and Conservation

Volume 6 Number 12, December 2014

ISSN 2141-243X



*Academic
Journals*

ABOUT IJBC

The **International Journal of Biodiversity and Conservation (IJBC)** (ISSN 2141-243X) is published Monthly (one volume per year) by Academic Journals.

International Journal of Biodiversity and Conservation (IJBC) provides rapid publication (monthly) of articles in all areas of the subject such as Information Technology and its Applications in Environmental Management and Planning, Environmental Management and Technologies, Green Technology and Environmental Conservation, Health: Environment and Sustainable Development etc.

The Journal welcomes the submission of manuscripts that meet the general criteria of significance and scientific excellence. Papers will be published shortly after acceptance. All articles published in IJBC are peer reviewed.

Submission of Manuscript

Please read the **Instructions for Authors** before submitting your manuscript. The manuscript files should be given the last name of the first author

[Click here to Submit manuscripts online](#)

If you have any difficulty using the online submission system, kindly submit via this email ijbc@academicjournals.org.

With questions or concerns, please contact the Editorial Office at ijbc@academicjournals.org.

Editor-In-Chief

Prof. Samir I. Ghabbour

*Department of Natural Resources,
Institute of African Research & Studies, Cairo
University, Egypt*

Editors

Dr. Edilegnaw Wale, PhD

*Department of Agricultural Economics
School of Agricultural Sciences and Agribusiness
University of Kwazulu-Natal
P bag X 01 Scoffsville 3209
Pietermaritzburg
South Africa.*

Dr. Beqiraj Sajmir

*Department of Biology
Faculty of Natural Sciences,
University of Tirana
Bulevardi Zog I, Tirana,
Albania*

Dr. Grizelle González

*Research Ecologist
Int. Inst. of Tropical Forestry / USDA Forest Service
Jardín Botánico Sur
1201 Calle Ceiba
San Juan, PR 00926-1119*

Dr. Korous Khoshbakht

*Shahid Beheshti University
Environmental Science Research Institute
Vice President of Research & Post Graduation
Evin, Tehran, Iran*

Dr. Al. Kucheryavyy

*Ichthyology Dep. of Biological Sci Faculty
Moscow State University.
Ecology and Evolution Lab, IPEE (www.sevin.ru)
Russia*

Dr. Marko Sabovljevic

*Institute of Botany and Garden
Faculty of Biology, University of Belgrade
Takovska 43, 11000 Belgrade
Serbia.*

Associate Editors

Dr. Shannon Barber-Meyer

*World Wildlife Fund
1250 24th St. NW, Washington, DC 20037
USA*

Dr. Shyam Singh Yadav

*National Agricultural Research Institute, Papua
New Guinea*

Dr. Michael G. Andreu

*School of Forest Resources and Conservation
University of Florida - GCREC
1200 N. Park Road
Plant City, FL
USA*

Dr. S.S. Samant

*Biodiversity Conservation and Management
G>B. Pant Institute of Himalayan
Environment and Development,
Himachal Unit, Mohal-Kullu- 175 126,
Himachal Pradesh,
India*

Prof. M. A. Said

*National Institute of Oceanography & Fisheries, Kayet
Bey, Alexandria, Egypt*

Prof. Reda Helmy Sammour

*Botany Department
Faculty of Science,
Tanta University
Tanta,
Egypt*

Editorial Board

Shreekar Pant

*Centre for Biodiversity Studies
School of Biosciences and Biotechnology,
Baba Ghulam Shah Badshah University,
India*

Prof. Philomena George

*Karunanagar, coimbatore ,tamil nadu,
India.*

Feng XU

*Xinjiang Institute of Ecology and Geography,
Chinese Academy of Sciences, China*

Naseem Ahmad

*Aligarh Muslim University, Aligarh- 202002
(UP)India*

Eman A Alam

*National Research Centre, El-behoos street,
Dokki, Giza,
Egypt*

Hemant K Badola

*GB Pant Institute of Himalayan Environment
& Development, Sikkim Unit, India*

Ashwinikumar Bhagwant Kshirsagar

*MGM Campus, N6 CIDCO, Aurangabad.
India*

Wagner de Souza Tavares

*Universidade Federal de Viçosa - Campus
Universitário,
Brasil*

Suphla Gupta

*Indian Institute of Integrative Medicine- Council
for Scientific and Industrial Research
(CSIR-IIIM),
India*

Prof. Dharma Raj Dangol

*Department of Environmental Science
Institute of Agriculture and Animal Science
Tribhuvan University Rampur, Chitwan,
Nepal.*

Audil Rashid

*Assistant Professor
Department of Environmental Sciences
PMAS Arid Agriculture University, Rawalpindi
Pakistan*

Krishnendu Mondal

*Wildlife Institute of India. P.O. Box 18.
Chandrabani. Dehradun 248001. Uttarakhand,
India*

Anna Maria Mercuri

*Department of Biology,
University of Modena and Reggio Emilia
Viale Caduti in Guerra 127, 41123 Modena - Italy*

Ozge Zencir

*Erzincan University
Kemah Vocational Training School,
Erzincan University, Kemah, Erzincan, Turkey*

Ashwinikumar bhagwant kshirsagar

*Mgm, College of Agricultural Biotechnology
Mgm campus, n6 Cidco, Aurangabad*

Prof emer. Edmond de Langhe

*Katholieke Universiteit Leuven,
Belgium Leeuwerikenstraat 52/0801*

Elsayed Elsayed Hafez

*City for Scientific Research and
Technology Applications
New Borg el Arab City, Alexandria,
Egypt*

Gary M. Barker

*Landcare Research, Private Bag
3127,Hamilton, New Zealand*

Mahmudul Hasan

*China Agricultural University
Department of Plant Nutrition, China Agricultural
University, Beijing-100093, pr China*

Hemant K Badola

*Gb Pant Institute of Himalayan Environment &
Development, Sikkim Unit
Po box-40, Gangtok, Sikkim 737 101, India*

Prof. Hu

China West Normal University, Institute of Rare Wildlife, Shida rd. Nanchong, Sichuan, 637009. P.R.China

Laghetti Gaetano

*Institute of Plant Genetics (National Research Council)
Via g. Amendola, 165/a - 70126 – bari.
Italy*

Osei Yeboah

*North Carolina Agricultural Technical State University
1601 east market street, greensboro, nc 27441*

Roberto Cazzolla Gatti

*University of Tuscia (viterbo)
Via San Camillo de Lellis, Snc 01100 Viterbo, Italy*

Seyed Kazem Sabbagh

*Department of Plant Pathology, Faculty of Agriculture,
University of Zabol, Iran, siastan –balochistan,
Zabol, 4km Bonjar ddv.*

Uzoma Darlington Chima

*University of Port Harcourt, Nigeria
Dept. of Forestry and Wildlife Management, Faculty of Agriculture,
University of Port Harcourt, P.M.B. 5323 Port Harcourt,
Rivers State, Nigeria.*

Dr. Vu Dinh Thong

*Institute of Ecology and Biological Resources,
Vietnam Academy of Science and Technology
18 Hoang Quoc Viet road, cau giay district, Hanoi,
Vietnam*

Yusuf Garba

*Bayero University, Kano P.M.B 3011 Kano - Nigeria
Department of Animal Science,
Faculty of Agriculture,
Bayero University, Kano*

K. Sankar

*Wildlife Institute of India
P. O. Box 18. Chandrabani
Dehradun- 248001. Uttarakhand*

Dr. Mulugeta Taye

*Production Ecology and Resource
Conservation/Horticulture/
Rural Development
Institute of Agriculture and Development Studies
Ethiopia*

Dr. Murugan Sankaran

*Breeding and Biotechnology of Horticultural Crops
Division of Horticulture and Forestry
Central Agricultural Research Institute,
Port Blair-744101, A&N Islands
India*

Instructions for Author

Electronic submission of manuscripts is strongly encouraged, provided that the text, tables, and figures are included in a single Microsoft Word file (preferably in Arial font).

The **cover letter** should include the corresponding author's full address and telephone/fax numbers and should be in an e-mail message sent to the Editor, with the file, whose name should begin with the first author's surname, as an attachment.

Article Types

Three types of manuscripts may be submitted:

Regular articles: These should describe new and carefully confirmed findings, and experimental procedures should be given in sufficient detail for others to verify the work. The length of a full paper should be the minimum required to describe and interpret the work clearly.

Short Communications: A Short Communication is suitable for recording the results of complete small investigations or giving details of new models or hypotheses, innovative methods, techniques or apparatus. The style of main sections need not conform to that of full-length papers. Short communications are 2 to 4 printed pages (about 6 to 12 manuscript pages) in length.

Reviews: Submissions of reviews and perspectives covering topics of current interest are welcome and encouraged. Reviews should be concise and no longer than 4-6 printed pages (about 12 to 18 manuscript pages). Reviews are also peer-reviewed.

Review Process

All manuscripts are reviewed by an editor and members of the Editorial Board or qualified outside reviewers. Authors cannot nominate reviewers. Only reviewers randomly selected from our database with specialization in the subject area will be contacted to evaluate the manuscripts. The process will be blind review.

Decisions will be made as rapidly as possible, and the journal strives to return reviewers' comments to authors as fast as possible. The editorial board will re-review manuscripts that are accepted pending revision. It is the goal of the AJFS to publish manuscripts within weeks after submission.

Regular articles

All portions of the manuscript must be typed double-spaced and all pages numbered starting from the title page.

The Title should be a brief phrase describing the contents of the paper. The Title Page should include the authors' full names and affiliations, the name of the corresponding author along with phone, fax and E-mail information. Present addresses of authors should appear as a footnote.

The Abstract should be informative and completely self-explanatory, briefly present the topic, state the scope of the experiments, indicate significant data, and point out major findings and conclusions. The Abstract should be 100 to 200 words in length. Complete sentences, active verbs, and the third person should be used, and the abstract should be written in the past tense. Standard nomenclature should be used and abbreviations should be avoided. No literature should be cited.

Following the abstract, about 3 to 10 key words that will provide indexing references should be listed.

A list of non-standard **Abbreviations** should be added. In general, non-standard abbreviations should be used only when the full term is very long and used often. Each abbreviation should be spelled out and introduced in parentheses the first time it is used in the text. Only recommended SI units should be used. Authors should use the solidus presentation (mg/ml). Standard abbreviations (such as ATP and DNA) need not be defined.

The Introduction should provide a clear statement of the problem, the relevant literature on the subject, and the proposed approach or solution. It should be understandable to colleagues from a broad range of scientific disciplines.

Materials and methods should be complete enough to allow experiments to be reproduced. However, only truly new procedures should be described in detail; previously published procedures should be cited, and important modifications of published procedures should be mentioned briefly. Capitalize trade names and include the manufacturer's name and address. Subheadings should be used. Methods in general use need not be described in detail.

Results should be presented with clarity and precision. The results should be written in the past tense when describing findings in the authors' experiments. Previously published findings should be written in the present tense. Results should be explained, but largely without referring to the literature. Discussion, speculation and detailed interpretation of data should not be included in the Results but should be put into the Discussion section.

The Discussion should interpret the findings in view of the results obtained in this and in past studies on this topic. State the conclusions in a few sentences at the end of the paper. The Results and Discussion sections can include subheadings, and when appropriate, both sections can be combined.

The Acknowledgments of people, grants, funds, etc should be brief.

Tables should be kept to a minimum and be designed to be as simple as possible. Tables are to be typed double-spaced throughout, including headings and footnotes. Each table should be on a separate page, numbered consecutively in Arabic numerals and supplied with a heading and a legend. Tables should be self-explanatory without reference to the text. The details of the methods used in the experiments should preferably be described in the legend instead of in the text. The same data should not be presented in both table and graph form or repeated in the text.

Figure legends should be typed in numerical order on a separate sheet. Graphics should be prepared using applications capable of generating high resolution GIF, TIFF, JPEG or Powerpoint before pasting in the Microsoft Word manuscript file. Tables should be prepared in Microsoft Word. Use Arabic numerals to designate figures and upper case letters for their parts (Figure 1). Begin each legend with a title and include sufficient description so that the figure is understandable without reading the text of the manuscript. Information given in legends should not be repeated in the text.

References: In the text, a reference identified by means of an author's name should be followed by the date of the reference in parentheses. When there are more than two authors, only the first author's name should be mentioned, followed by 'et al'. In the event that an author cited has had two or more works published during the same year, the reference, both in the text and in the reference list, should be identified by a lower case letter like 'a' and 'b' after the date to distinguish the works.

Examples:

Abayomi (2000), Agindotan et al. (2003), (Kelebeni, 1983), (Usman and Smith, 1992), (Chege, 1998;

1987a,b; Tijani, 1993,1995), (Kumasi et al., 2001)
References should be listed at the end of the paper in alphabetical order. Articles in preparation or articles submitted for publication, unpublished observations, personal communications, etc. should not be included in the reference list but should only be mentioned in the article text (e.g., A. Kingori, University of Nairobi, Kenya, personal communication). Journal names are abbreviated according to Chemical Abstracts. Authors are fully responsible for the accuracy of the references.

Examples:

Chikere CB, Omoni VT and Chikere BO (2008). Distribution of potential nosocomial pathogens in a hospital environment. *Afr. J. Biotechnol.* 7: 3535-3539.

Moran GJ, Amii RN, Abrahamian FM, Talan DA (2005). Methicillinresistant *Staphylococcus aureus* in community-acquired skin infections. *Emerg. Infect. Dis.* 11: 928-930.

Pitout JDD, Church DL, Gregson DB, Chow BL, McCracken M, Mulvey M, Laupland KB (2007). Molecular epidemiology of CTXM-producing *Escherichia coli* in the Calgary Health Region: emergence of CTX-M-15-producing isolates. *Antimicrob. Agents Chemother.* 51: 1281-1286.

Pelczar JR, Harley JP, Klein DA (1993). *Microbiology: Concepts and Applications.* McGraw-Hill Inc., New York, pp. 591-603.

Short Communications

Short Communications are limited to a maximum of two figures and one table. They should present a complete study that is more limited in scope than is found in full-length papers. The items of manuscript preparation listed above apply to Short Communications with the following differences: (1) Abstracts are limited to 100 words; (2) instead of a separate Materials and Methods section, experimental procedures may be incorporated into Figure Legends and Table footnotes; (3) Results and Discussion should be combined into a single section.

Proofs and Reprints: Electronic proofs will be sent (e-mail attachment) to the corresponding author as a PDF file. Page proofs are considered to be the final version of the manuscript. With the exception of typographical or minor clerical errors, no changes will be made in the manuscript at the proof stage.

Fees and Charges: Authors are required to pay a \$550 handling fee. Publication of an article in the International Journal of Biodiversity and Conservation is not contingent upon the author's ability to pay the charges. Neither is acceptance to pay the handling fee a guarantee that the paper will be accepted for publication. Authors may still request (in advance) that the editorial office waive some of the handling fee under special circumstances

Copyright: © 2014, Academic Journals.

All rights Reserved. In accessing this journal, you agree that you will access the contents for your own personal use but not for any commercial use. Any use and or copies of this Journal in whole or in part must include the customary bibliographic citation, including author attribution, date and article title.

Submission of a manuscript implies: that the work described has not been published before (except in the form of an abstract or as part of a published lecture, or thesis) that it is not under consideration for publication elsewhere; that if and when the manuscript is accepted for publication, the authors agree to automatic transfer of the copyright to the publisher.

Disclaimer of Warranties

In no event shall Academic Journals be liable for any special, incidental, indirect, or consequential damages of any kind arising out of or in connection with the use of the articles or other material derived from the IJBC, whether or not advised of the possibility of damage, and on any theory of liability.

This publication is provided "as is" without warranty of any kind, either expressed or implied, including, but not limited to, the implied warranties of merchantability, fitness for a particular purpose, or non-infringement. Descriptions of, or references to, products or publications does not imply endorsement of that product or publication. While every effort is made by Academic Journals to see that no inaccurate or misleading data, opinion or statements appear in this publication, they wish to make it clear that the data and opinions appearing in the articles and advertisements herein are the responsibility of the contributor or advertiser concerned. Academic Journals makes no warranty of any kind, either express or implied, regarding the quality, accuracy, availability, or validity of the data or information in this publication or of any other publication to which it may be linked.

International Journal of Biodiversity and Conservation

Table of Contents: Volume 6 Number 12 December, 2014

ARTICLES

Screening Of Onion Genotypes Against *Thrips Tabaci* Lind. In Central India

Pushpendra Engla, A. S. Thakur, Moni Thomas, A. K. Bhowmick and H. L. Sharma

Natural Resource Use Conflict In Bale Mountains National Park, Southeast Ethiopia

Anteneh Gezahegn Kebede, Melaku Bekele and Teshale Woldeamanuel

Assessment Of The Trees Diversity At The Edge Of Stream And Forest Road In Shast Kalateh District

Aidin Parsakhoo and Benyamin Matinnia

Vegetation Diversity And Soil Nutrient Status Of Submergence Zone Of Hydroelectric Project In Srinagar Of Garhwal Himalayas, India

Sajed Saleem and Munesh Kumar

Comparative Study Of Shrub Diversity In Lower Dachigam Kashmir Himalaya

Arif Yaqoob, Mohammad Yunus and G. A. Bhat

Assessment Of Genetic Diversity Of A Critically Endangered Important Medicinal Plant *Chlorophytum Borivianum* In Different Agro-Climatic Regions Of India Revealed By Random Amplified Polymorphic Primer (DNA Marker)

Baby Kumari, M. A. Mallick and Govind K. Vyas

Physico-Chemical Parameters And Ichthyofauna Diversity Of Arasalar Estuary In Southeast Coast Of India

C. Raju, G. Sridharan, P. Mariappan and G. Chelladurai

Population Structure And Regeneration Status Of *Prunus Africana* (Hook.F.) Kalkm. After Selective And Clear Felling In Kibale National Park, Uganda

Arthur A. Owiny and Geoffrey M. Malinga

Full Length Research Paper

Screening of onion genotypes against *Thrips tabaci* Lind. in Central India

Pushpendra Engla, A. S. Thakur, Moni Thomas*, A. K. Bhowmick and H. L. Sharma

Department of Entomology, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur-482004, India.

Received 9 July, 2014; Accepted 25 September, 2014

Twenty-two (22) genotypes of onion (*Allium cepa* Lin.) was screened against *Thrips tabaci* Lind. in the experimental field of Department of Horticulture Maharajpur, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh, India during late wet season in the year 2010-11. The incidence of *T. tabaci* was observed from 45th standard metrological week (SMW) to 3rd SMW, that is, from transplanting till harvesting, in all the 22 genotypes. The mean *T. tabaci* population varied from 0.45-6.64 per plant during this period among the genotypes. Out of 22 genotypes of onion screened against *T. tabaci*, BKHO 1018 had highest yield and was the most tolerant followed by BKHO 1006. Genotype BKHO 1005 was most susceptible and had the lowest yield. *T. tabaci* appeared in the second week of November, 2010, that is, 12th November (45th SMW) and active up to 3rd week of January. The peak activity of the pest was observed during 1st SMW (last week of December to first week of January). *T. tabaci* population had significantly positively correlation with the maximum and minimum temperature and sunshine hours; but, it was significantly negative correlated with morning relative humidity.

Key words: Genotypes, onion, *Thrips tabaci*, tolerant.

INTRODUCTION

Onion (*Allium cepa*) is widely cultivated in India for domestic consumption as well as for export (Brewster, 1994). The productivity of onion in India is 13.05 metric ton/ha in comparison with world productivity, 17.91 metric ton/ha.

Maharashtra State is the largest onion producer in India with a market share of 29%. Karnataka, Gujarat, Bihar and Madhya Pradesh are onion producing states in India. Madhya Pradesh produces 8.1 m ton onion from 0.053 mha. The major onion producing districts in Madhya Pradesh are Khandwa, Burhanpur and Indore. The productivity of onion varies widely in India due to biotic

and abiotic stress. Damping off, Stemphylium blight, Purple blotch and Rot (diseases) as well as Thrips, Army worm and Gram cutworm (insects) induce biotic stress that lower the yield of onion (Lorbeer et al., 2002).

Among the insect pests of onion, *Thrips tabaci* Lind. (Thysanoptera: Thripidae) is a potential pest of onion in tropical areas (Rechter et al., 1999; Murai, 2000; Liu and Sparks, 2003). *T. tabaci* attack onion at all the stages of crop growth, but their number increase from bulb initiation (Ibrahim and Adesiyun, 2009). This sap feeder cause direct damage (Koschier et al., 2002), causing curling and twisting of leaves which turn to white blotches and

*Corresponding author. E-mail: moni_thomas@rediffmail.com.

Table 1. Details of the onion genotypes.

Code of genotype	Source
NRCRO-1	DOGR
NRCRO-2	DOGR
NRCRO-3	DOGR
NRCRO-4	DOGR
NRCWO-1	DOGR
NRCWO-2	DOGR
NRCWO-3	DOGR
NRCWO-4	DOGR
Sel-397	IARI
Sel-157	Nirmal seeds
NOL-103	Nirmal seeds
NOL-115	IIHR
VG-18	IIHR
VG-19	IIHR
Soyal-2009	IIHR
COL-652	Hisar
Bhima Super	DOGR
RO-252	Durgapur
RO-282	Durgapur
Line-355	NHRDF
Pusa White Round	IARI
PKV White	PDKV Akola

DOGR- Directorate of Onion and Garlic Research; IARI- Indian Agricultural Research Institute; IIHR- Indian Institute of Horticultural Research; NHRDF- National Horticulture Research and development Foundation; PDKV- Panjabrao Deshmukh krishi Vidyapeeth.

silvery patches (Andaloro and Shelton, 1983; Childers, 1997; Jenser et al., 2003) reducing yield up to 50% (Gupta, 1994; Fournier et al., 1995, Kumar et al., 2001).

Chemical pest management has become uneconomical and environmentally hazardous. *T. tabaci* resistance to pyrethroids and organophosphate insecticides in New York is reported. Screening of onion genotypes against *T. tabaci* therefore is an economical and environmental friendly approach.

MATERIALS AND METHODS

Screening of 22 genotypes (Table 1) of *A. cepa* against *T. tabaci* was carried out in randomized block design (Figure 1 and Table 2), in the experimental field of Department of Horticulture, Maharajpur, Jawaharlal Nehru Krishi Vishwa Vidyalyaya, Jabalpur, Madhya Pradesh during the year 2010-11.

Geographically, Jabalpur is situated between 22° 49' and 24° 8' North latitude and 78° 21' and 80° 58' East longitude, 411.78 m above mean sea level. Agro-climatically, it is in the Zone-IV Kymore Plateau and Satpura Hills Zone and in rice-wheat crop zone of the Central India. Jabalpur has a typical sub-tropical climate experiencing hot dry summer and cool dry winter. Temperature extremes vary between minimum temperatures of 20°C (in December and January months) to maximum temperature of 45°C (in May and June months). The mean annual rainfall ranges between 1000 to 1500 mm which is mostly received between mid

June to first week of October, with occasional winter showers. The relative humidity remains minimum 20 to 35% during summer and medium (50 to 60%) during winter season, while it attains maximum values of 80 to 95% during rainy season. The meteorological data during the course of the study, that is, from August 2010 to January 2011 is mentioned in Table 3.

Method of observation

T. tabaci and its natural enemies were recorded from the lower side of leaves of ten randomly selected plants in a plot, once in a standard metrological week (SMW) from transplanting to the maturity of the crop. The data on pest population and the percentage data were transformed to square root (\sqrt{x}) and arc sine transformed values, respectively. Transformed data was statistical analyzed for the significance of different treatments, following the techniques of analysis of variance (Panse and Sukhatme, 1967).

RESULTS AND DISCUSSION

The five growth stages of all the 22 onion genotypes were categorized against the SMW during the crop stages.

- i. Vegetative stage: 45-47 SMW
- ii. Bulb initiation stage: 48-50 SMW
- iii. Early bulb development stage: 51-52 SMW

Table 2. Details of the experiment.

Particulars	Details
No. of genotypes	22
Design	RBD
Replication	3
Plot size	3 x 2 m
No. of rows/ plot	20
Row length	3.0 m
Spacing	
Row to row	15 cm
Plant to plant	10 cm
Fertilizer dose	100:50:75:50 kg NPK/ ha
Date of sowing	11-08-2010
Date of transplanting	29-09-2010
Schedule of irrigation	15 days interval
Date of harvesting	29-01-2011

Table 3. Weekly meteorological observation (August 2010 - January 2011).

SMW*	Temperature (°C)		Sunshine (h)	Rainfall (mm)	Relative humidity (%)		Rainy days
	Max	Min			Max	Min	
45	31.5	16.3			91	48	0
46	29.7	19.4	4.7	1.4	92	48	0
47	29.2	14.5	7.5	0	86	38	0
48	23.7	16.3	6.3	0	91	55	0
49	24.8	11.5	7.1	7.6	89	47	1
50	24.2	8.9	7.6	0	91	32	0
51	24	4.9	9.1	0	89	24	0
52	27	8.7	8.8	0	81	36	0
1	21	3.1	8.5	0	95	35	0
2	23.8	3.5	9.2	0	87	25	0
3	24.6	6.1	9.4	0	87	25	0

*Standard meteorological week.

iv. Late bulb development stage: 1-2 SMW

v. Maturity stage: 3 SMW

The incidence of *T. tabaci* was observed from 45th SMW to 3rd SMW, that is, from transplanting till harvesting, in all the 22 genotypes, but its population varied during this period among the genotypes. During the five growth stages of onion, there were four population peaks of *T. tabaci*: 1st Peak- 47th SMW; 2nd Peak- 49th SMW; 3rd Peak- 52nd SMW; 4th Peak- 1st SMW.

Among the 4 peaks, the highest was during 1st SMW, followed by that in 52th, 47th and 49th SMW. During each peaks, four genotypes with high *T. tabaci* population and 2 genotypes with lowest population were noted (Table 4).

During the 1st peak, BKHO 1016 had the highest mean of *T. tabaci* population (12.26) followed by BKHO 1015 (8.76), BKHO 1014 (8.2) and BKHO 1005 (7.8) while BKHO 1006 had the lowest mean *T. tabaci* population (2.73) followed by BKHO 1013 (3.33).

During the 2nd peak, again BKHO 1016 had highest mean *T. tabaci* population (7.13) followed by BKHO 1024 (6.66), BKHO 1008 (5.1) and BKHO 1014 (4.63) while the BKHO 1006 and BKHO 1013 had the least mean population (0.9 and 1.73 respectively).

During the 3rd peak, BKHO 1004 had the highest *T. tabaci* population (13.3) followed by BKHO 1005 (11.36), BKHO 1001 (9.96) and BKHO 1003 (8.56) while BKHO 1006 had the least mean *T. tabaci* population (3.87)

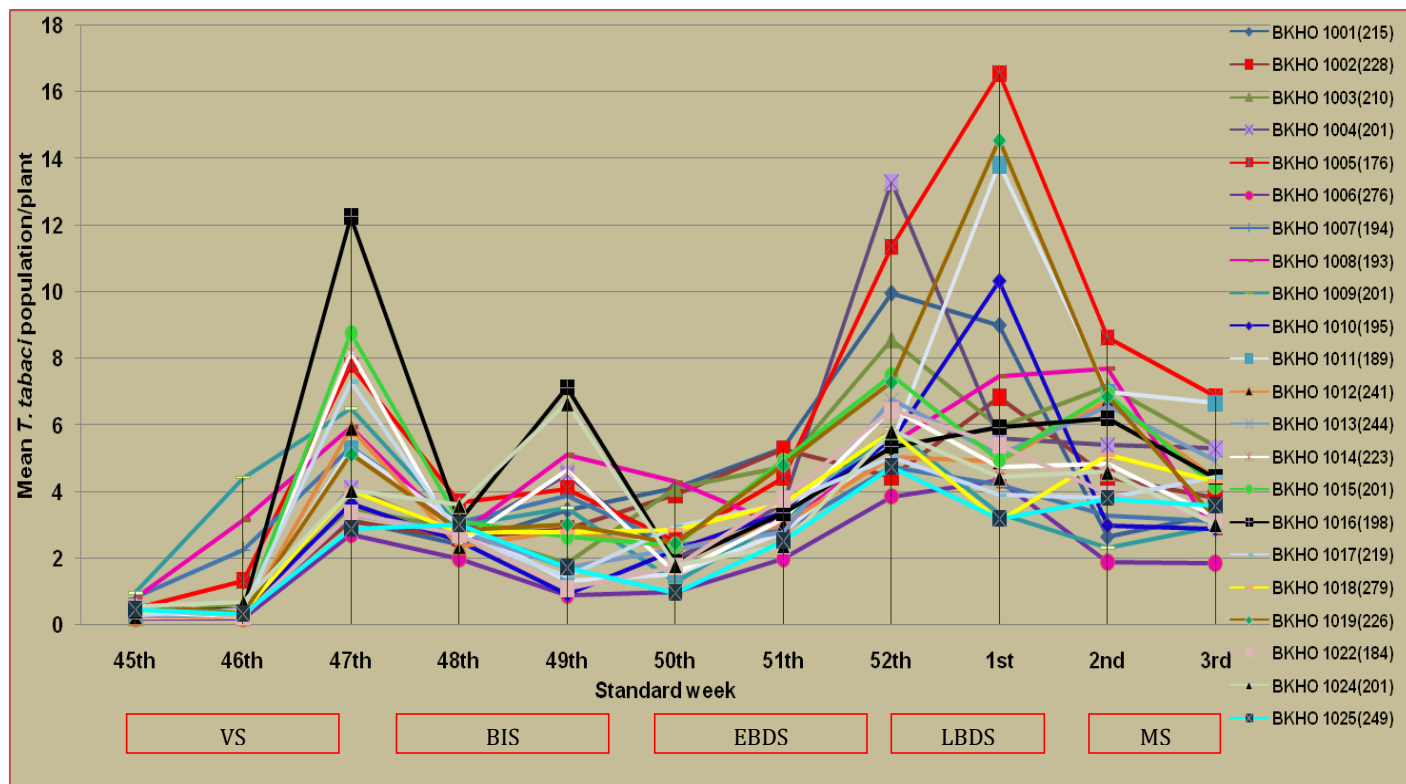


Figure 1. Screening of different genotypes of onion against *T. tabaci*. V- Vegetative, BI- bulb initiation, EBI- early bulb initiation, LBI- late bulb initiation, H- harvesting.

Table 4. Different peaks of *T. tabaci* on onion genotypes.

Peak	SMW	Growth stage	<i>T. tabaci</i> population in genotypes	
			High	Low
1	47 th (58 DAT)	Vegetative	BKHO 1016, BKHO 1015, BKHO 1014, BKHO 1005	BKHO 1006, BKHO 1013
2	49 th (72 DAT)	Bulb initiation	BKHO 1016, BKHO 1024, BKHO 1008, BKHO 1014	BKHO 1006, BKHO 1010
3	52 nd (93 DAT)	Bulb development (early)	BKHO 1004, BKHO 1005, BKHO 1001, BKHO 1003	BKHO 1006, BKHO 1010
4	1 st (100 DAT)	Bulb development (late)	BKHO 1005, BKHO 1019, BKHO 1011, BKHO 1010	BKHO 1018, BKHO 1025

*DAT- Days after transplantation.

followed by BKHO 1002 (4.43).

During the 4th peak, BKHO 1005 had the highest mean *T. tabaci* population (16.56) followed by BKHO 1019 (14.56), BKHO 1011 (13.83) and BKHO 1010 (10.33) where BKHO 1018 had the least mean *T. tabaci*

population (3.13) followed by BKHO 1022 (3.2). BKHO 1006 continuously has least population (2.73, 0.9 and 3.87 respectively) of *T. tabaci* in the first 3 peaks (Table 5).

In the process of screening, six genotypes (Table 6)

Table 5. Mean population of *T. tabaci* on different genotypes of *A cepa*

Genotype	Population of <i>T. tabaci</i> per plant in a Standard meteorological weeks											Mean	Mkt. yield (q/ha)
	45 th	46 th	47 th	48 th	49 th	50 th	51 th	52 th	1 st	2 nd	3 rd		
BKHO1001	0.43(0.96)	0.4(0.95)	3.16(1.90)	2.43(1.71)	3.46(1.96)	4.13(2.15)	5.3(2.38)	9.96(3.22)	9(3.08)	2.66(1.77)	3.33(1.96)	4.02(2.13)	215.55
BKHO1002	0.3 (0.89)	0.47(0.98)	3.13(1.90)	2.63(1.77)	2.9(1.77)	3.9(2.08)	5.26(2.39)	4.43(2.22)	6.83(2.55)	4.43(2.21)	3.83(2.06)	3.46(1.99)	228.71
BKHO1003	0.23(0.85)	0.67(1.08)	3.5(1.99)	2.86(1.83)	1.86(1.51)	4.1(2.14)	4.73(2.27)	8.56(2.99)	5.93(2.51)	7.16(2.77)	5.36(2.42)	4.08(2.14)	210.77
BKHO1004	0.37(0.93)	0.27(0.88)	4.1(2.14)	2.73(1.80)	4.53(2.18)	2(1.57)	3.63(2.03)	13.3(3.70)	5.6(2.42)	5.4(2.41)	5.3(2.38)	4.29(2.19)	201.1
BKHO1005	0.5(1.0)	1.33(1.34)	7.8(2.86)	3.7(2.03)	4.1(2.14)	2.53(1.72)	4.43(2.21)	11.36(3.40)	16.56(3.81)	8.63(3.02)	6.86(2.71)	6.16(2.58)	176.95
BKHO1006	0.27(0.84)	0.2(0.84)	2.73(1.79)	2(1.58)	0.9 (1.18)	1(1.22)	2.0(1.58)	3.87(2.09)	4.36(2.18)	1.9(1.46)	1.86(1.54)	2.03(1.59)	276.1
BKHO1007	0.83(1.15)	2.26(1.66)	5.36(2.40)	3.1(1.90)	3.9(2.07)	2.4(1.69)	2.86(1.83)	4.76(2.29)	4.23(2.16)	3.3(1.94)	3.13(1.90)	3.28(1.94)	194.33
BKHO1008	0.8(1.14)	3.16(1.91)	5.93(2.52)	2.73(1.80)	5.1(2.36)	4.3(2.14)	2.96(1.86)	5.46(2.44)	7.46(2.81)	7.7(2.78)	2.76(1.79)	4.39(2.21)	193.88
BKHO1009	0.97(1.19)	4.43(2.22)	6.5(2.62)	3(1.87)	3.53(1.99)	1.3(1.33)	3.16(1.91)	5.86(2.51)	3.36(1.97)	2.33(1.68)	2.96(1.85)	3.4(1.97)	201.77
BKHO1010	0.5(0.99)	0.4(0.95)	3.66(2.04)	2.53(1.74)	0.93(1.15)	2.26(1.66)	3.4(1.97)	5.5(2.45)	10.33(3.29)	3(1.86)	2.9(1.84)	3.21(1.93)	195.66
BKHO1011	0.23(0.85)	0.23(0.85)	5.3(2.38)	3.03(1.88)	1.33(1.32)	1.53(1.41)	2.8(1.82)	5.43(2.43)	13.83(3.78)	7(2.73)	6.66(2.66)	4.30(2.19)	189.44
BKHO1012	0.26(0.88)	0.23(0.85)	5.9(2.51)	2.36(1.69)	2.86(1.72)	2.26(1.65)	3.03(1.88)	5.03(2.35)	4.9(2.32)	6.73(2.67)	4.4(2.17)	3.45(1.99)	241.55
BKHO 1013	0.3(0.89)	0.3(0.89)	3.33(1.96)	2.83(1.82)	1.73(1.49)	2.3(1.67)	2.8(1.82)	6.76(2.69)	5.1(2.36)	6.56(2.60)	4.93(2.29)	3.35(1.96)	244.22
BKHO 1014	0.4(0.95)	0.26(0.87)	8.2(2.93)	2.46(1.72)	4.63(2.22)	1.56(1.41)	3.2(1.91)	6.5(2.64)	4.73(2.27)	4.86(2.31)	3.26(1.93)	3.64(2.03)	223.19
BKHO 1015	0.43(0.96)	0.3(0.89)	8.76(3.03)	3.13(1.90)	2.66(1.47)	2.4(1.69)	4.93(2.32)	7.5(2.80)	4.96(2.32)	6.93(2.71)	4.16(2.15)	4.19(2.17)	201.48
BKHO 1016	0.43(0.96)	0.46(0.98)	12.2(3.56)	3.13(1.90)	7.13(2.75)	1.86(1.52)	3.36(1.96)	5.36(2.41)	5.93(2.53)	6.2(2.56)	4.43(2.19)	4.59(2.26)	198.45
BKHO 1017	0.3(0.89)	0.46(0.98)	7.3(2.78)	2.7(1.79)	1.46(1.39)	2.96(1.82)	3.66(2.04)	5.06(2.35)	3.9(2.08)	3.83(2.04)	4.46(2.22)	3.28(1.94)	219.22
BKHO 1018	0.43(0.96)	0.4(0.94)	4.06(2.13)	2.8(1.81)	2.8(1.77)	2.86(1.82)	3.66(2.04)	5.8(2.51)	3.13(1.91)	5.1(2.35)	4.3(2.18)	3.21(1.93)	279.44
BKHO 1019	0.6(1.05)	0.36(0.93)	5.13(2.37)	2.86(1.83)	3.03(1.85)	2.46(1.69)	4.8(2.29)	7.3(2.79)	14.56(3.87)	6.86(2.64)	3.2(1.92)	4.65(2.27)	183.44
BKHO 1022	0.5(0.99)	0.26(0.87)	3.36(1.96)	2.73(1.80)	1.1(1.21)	1.76(1.50)	3.8(2.06)	6.46(2.64)	5.4(2.42)	3.93(2.07)	3.16(1.91)	2.95(1.86)	184.93
BKHO 1024	0.57(1.03)	0.7(1.09)	4.06(2.13)	3.6(2.02)	6.66(2.65)	1.8(1.44)	2.4(1.70)	5.83(2.51)	4.43(2.19)	4.6(2.22)	3.03(1.87)	3.42(1.98)	201.96
BKHO 1025	0.47(0.98)	0.33(0.91)	2.9(1.84)	3.03(1.88)	1.73(1.47)	0.96(1.21)	2.53(1.74)	4.76(2.29)	3.2(1.89)	3.8(2.05)	3.6(2.02)	2.48(1.73)	249.6
Mean	0.45	0.812	5.39	2.83	3.1	2.39	3.57	6.64	6.71	5.13	3.99		
CD 5%	0.179	0.16	0.469	0.206	0.608	0.499	0.327	0.459	0.898	0.678	0.465		
SEm±	0.063	0.056	0.164	0.072	0.213	0.175	0.115	0.161	0.315	0.238	0.163		

Figures in parenthesis are square root ($\sqrt{x+0.5}$) transformed values.

were identified which had lowest mean population of *T. tabaci* during the 4 different peaks. Incidentally, these six genotypes also had the highest yield. Similarly, there was variation in the colour of leaf and bulbs of their genotypes. BKHO 1006 had light green leaves and white bulb, while BKHO 1025 had yellow green leaves and white bulb.

BKHO 1010, BKHO 1019, BKHO 1013 and BKHO 1005 though had blue green leaves but the bulbs were dark red, red, white and light red coloured, respectively.

Ten (10) genotypes (Table 7) which had highest mean population of *T. tabaci* population during 4 peaks were the lowest yielder. These had varia-

tion in the colour of leaves and bulb. BKHO 1011 and BKHO 1014 had yellow coloured leaves and light red colour of bulb. Genotypes BKHO 1005, BKHO 1019, BKHO 1016, BKHO 1008, BKHO 1015, BKHO 1003, BKHO 1001 and BKHO 1014 though had blue green coloured leaves but the bulbs were dark red, light red, white, bronze,

Table 6. *A cepa* genotypes with lowest *T. tabaci* population.

Genotype	Mean <i>T. tabaci</i> population/plant in SMW											Yield q/ha	Colour	
	45 th	46 th	47 th	48 th	49 th	50 th	51 st	52 nd	1 st	2 nd	3 rd		Leaf	Bulb
BKHO 1006	0.27 (0.84)	0.2 (0.84)	2.73 (1.79)	2 (1.58)	0.9 (1.18)	1 (1.22)	2 (1.58)	3.87 (2.09)	4.36 (2.18)	1.9 (1.46)	1.86 (1.54)	276.1	Light green	White
BKHO 1025	0.47 (0.98)	0.33 (0.91)	2.9 (1.84)	3.03 (1.88)	1.73 (1.47)	0.96 (1.21)	2.53 (1.74)	4.76 (2.29)	3.2 (1.89)	3.8 (2.05)	3.6 (2.02)	249.6	Yellow green	White
BKHO 1010	0.5 (0.99)	0.4 (0.95)	3.66 (2.04)	2.53 (1.74)	0.93 (1.15)	2.26 (1.66)	3.4 (1.97)	5.5 (2.45)	10.33 (3.29)	3 (1.86)	2.9 (1.84)	195.66	Blue green	Dark red
BKHO 1018	0.43 (0.96)	0.4 (0.94)	4.06 (2.13)	2.8 (1.81)	2.8 (1.77)	2.86 (1.82)	3.66 (2.04)	5.8 (2.51)	3.13 (1.91)	5.1 (2.35)	4.3 (2.18)	279.44	Blue green	Red
BKHO 1013	0.3 (0.89)	0.3 (0.89)	3.33 (1.96)	2.83 (1.82)	1.73 (1.49)	2.3 (1.67)	2.8 (1.82)	6.76 (2.69)	5.1 (2.36)	6.56 (2.60)	4.93 (2.29)	244.22	Blue green	White
BKHO 1002	0.3 (0.89)	0.47 (0.98)	3.13 (1.90)	2.63 (1.77)	2.9 (1.77)	3.9 (2.08)	5.26 (2.39)	4.43 (2.22)	6.83 (2.55)	4.43 (2.21)	3.83 (2.06)	228.71	Blue green	Light red

Figures in parenthesis are square root ($\sqrt{x+0.5}$) transformed values.

Table 7. *A cepa* genotypes with highest *T. tabaci* population.

Genotype	Mean <i>T. tabaci</i> population per plant in SMW											Yield q/ha	Colour	
	45 th	46 th	47 th	48 th	49 th	50 th	51 st	52 nd	1 st	2 nd	3 rd		Leaf	Bulb
BKHO 1005	0.5 (1.0)	1.33 (1.34)	7.8 (2.86)	3.7 (2.03)	4.1 (2.14)	2.53 (1.72)	4.43 (2.21)	11.36 (3.40)	16.56 (3.81)	8.63 (3.02)	6.86 (2.71)	176.95	Blue green	Dark red
BKHO 1019	0.6 (1.05)	0.36 (0.93)	5.13 (2.37)	2.86 (1.83)	3.03 (1.85)	2.46 (1.69)	4.8 (2.29)	7.3 (2.79)	14.56 (3.87)	6.86 (2.64)	3.2 (1.92)	183.44	Blue green	Light red
BKHO 1016	0.43 (0.96)	0.46 (0.98)	12.26 (3.56)	3.13 (1.90)	7.13 (2.75)	1.86 (1.52)	3.36 (1.96)	5.36 (2.41)	5.93 (2.53)	6.2 (2.56)	4.43 (2.19)	198.45	Blue green	White
BKHO 1011	0.23 (0.85)	0.23 (0.85)	5.3 (2.38)	3.03 (1.88)	1.33 (1.32)	1.53 (1.41)	2.8 (1.82)	5.43 (2.43)	13.83 (3.78)	7 (2.73)	6.66 (2.66)	189.44	Yellow green	Light red

Table 7. Contd.

Genotype	Mean <i>T. tabaci</i> population per plant in SMW											Yield q/ha	Colour	
	45 th	46 th	47 th	48 th	49 th	50 th	51 st	52 nd	1 st	2 nd	3 rd		Leaf	Bulb
BKHO 1008	0.8 (1.14)	3.16 (1.91)	5.93 (2.52)	2.73 (1.80)	5.1 (2.36)	4.3 (2.14)	2.96 (1.86)	5.46 (2.44)	7.46 (2.81)	7.7 (2.78)	2.76 (1.79)	193.88	Blue green	Bronze
BKHO 1004	0.37 (0.93)	0.27 (0.88)	4.1 (2.14)	2.73 (1.80)	4.53 (2.18)	2 (1.57)	3.63 (2.03)	13.3 (3.70)	5.6 (2.42)	5.4 (2.41)	5.3 (2.38)	201.1	Yellow green	Light red
BKHO 1015	0.43 (0.96)	0.3 (0.89)	8.76 (3.03)	3.13 (1.90)	2.66 (1.47)	2.4 (1.69)	4.93 (2.32)	7.5 (2.80)	4.96 (2.32)	6.93 (2.71)	4.16 (2.15)	201.48	Blue green	White
BKHO 1003	0.23 (0.85)	0.67 (1.08)	3.5 (1.99)	2.86 (1.83)	1.86 (1.51)	4.1 (2.14)	4.73 (2.27)	8.56 (2.99)	5.93 (2.51)	7.16 (2.77)	5.36 (2.42)	210.77	Blue green	Light red
BKHO 1001	0.43 (0.96)	0.4 (0.95)	3.16 (1.90)	2.43 (1.71)	3.46 (1.96)	4.13 (2.15)	5.3 (2.38)	9.96 (3.22)	9 (3.08)	2.66 (1.77)	3.33 (1.96)	215.55	Blue green	Light red
BKHO 1014	0.4 (0.95)	0.26 (0.87)	8.2 (2.93)	2.46 (1.72)	4.63 (2.22)	1.56 (1.41)	3.2 (1.91)	6.5 (2.64)	4.73 (2.27)	4.86 (2.31)	3.26 (1.93)	223.19	Blue green	Light red
BKHO 1024	0.57 (1.03)	0.7 (1.09)	4.06 (2.13)	3.6 (2.02)	6.66 (2.65)	1.8 (1.44)	2.4 (1.70)	5.83 (2.51)	4.43 (2.19)	4.6 (2.22)	3.03 (1.87)	201.96	Blue green	Dark red

Figures in parenthesis are square root ($\sqrt{x+0.5}$) transformed values.

white, light red and dark red, respectively. *T. tabaci* is the serious pest of onion (Mound, 1977; Rechter et al., 1999; Murai, 2000; Schmutterer et al., 1969) and it causes yield loss varying from 10-50% (Gupta, 1994; Fournier et al., 1995; Kumar et al., 2001; Montano, 2010). Thus, worldwide screening of onion genotypes against *T. tabaci* have been carried out by various workers (Brar et al., 1993; Duchovskiene, 2006; Shakeel et al., 2006; Alimousavi et al., 2007; Martin et al., 2010). Peak population of *T. tabaci* in onion has been reported during September (Liu, 2004),

November (Lorini et al., 1986), November to March (Ibrahim, 2010), December (Ibrahim and Adesiyun, 2009), February to May (Ibrahim and Adesiyun, 2009). Thus, population peak of *T. tabaci* varied depending on the location and genotype.

In the present finding, it was observed that incidence of *T. tabaci* at critical crop stages determined the yield of the crop. Incidence at vegetative stage and bulb initiation stages do not influence the yield, while high incidence at early bulb development stage and late bulb development stage is detrimental to the yield of

crop. On the basis of susceptible in our case, BKHO 1005 had highest population peak during early and late bulb development stages. This genotype had lowest yield. Genotype BKHO 1006 had lowest population during the first three consecutive population peaks. BKHO 1006 was second highest yield. The genotype BKHO 1018 never had lowest population during any growth stages, except in the late bulb development stage where it had lowest population. The highest yield was recorded in BKHO 1018. It thus proves that incidence of *T. tabaci* at growth stages decides the susceptibility

and tolerance level of onion. Colour of leaves and bulb also has influence on the incidence of *T. tabaci* in onion. The earlier findings are in accordance with our findings. The light green coloured leaves and white colour of bulb had lowest *T. tabaci* population, while blue green leaves and dark red colour of bulb had highest *T. tabaci* population. Earlier workers reported resistance and susceptible on the basis of mean population/plant (Lewis, 1997), leaf colour (Harvey, 1924), bulb colour (Verma, 1996; Lall and Singh, 1968), leaf surface and canopy of plant (Jones et al., 1934), wax percentage (Alimousavi et al., 2007). Thus onion plant architecture too plays an important role in the level of tolerance to *T. tabaci*.

Conflict of Interests

The author(s) have not declared any conflict of interests.

REFERENCES

- Alimousavi SA, Hassandokht MR, Moharramipour S (2007). Evaluation of Iranian onion germplasm for resistance to thrips. *Int. J. Agric. Biol.* 3:455-458.
- Andaloro JT, Shelton AM (1983). Insects of onion and cabbage; onion thrips. *Proc. 10th Int. Congress Plant Prot.* 2:750-775.
- Brar KS, Sidhu AS, Chadha ML (1993). Screening onion varieties for resistance to *T. tabaci* Lind. and *Helicoverpa armigera* (Hubner). *Insect Sci.* 6:123-124.
- Brewster JL (1994). Onion and other vegetable alliums. *CABI Int. Publ.*, pp:236.
- Childers CC (1997). Feeding and oviposition injuries to plants. *T. tabaci* a crop pest *CAB International*, pp:505-537.
- Duchovskiene (2006). The abundance and population dynamics of onion *T. tabaci* in leek under field conditions. *Agron. Res.* 4:163-166.
- Fournier F, Boivin G, Stewart RK (1995). Effect of *T. tabaci* (Thysanoptera: Thripidae) on yellow onion yields and economic thresholds for its management. *J. Econ. Entomol.* 88:1401-1407.
- Gupta RP, Srivastava KJ, Pandey UB (1994). Diseases and insect pests of onion in India. *Acta Hortic.* 358:265-269.
- Harvey RB (1924). Sunscalds of tomatoes. *Minnesota Studies Plant Science. St. Biol. Sci.* 5:229-234.
- Ibrahim ND (2010). Seasonal abundance of onion thrips. *T. tabaci* L. *J. Agric. Sci.* 2(1):2-10.
- Ibrahim ND, Adesiyun AA (2009). Effects of age and height of onion (*Allium cepa* L.) plants on infestation thrips, *T. tabaci* Lind. (Thysanoptera: Thripidae) in Sokoto, Nigeria *African J. Agric. Res.* 4(2):76-84.
- Ibrahim ND, Adesiyun AA (2009). Effects of staggered planting dates on the control of *T. tabaci* Lind. and yield of onion in Nigeria *African J. Agric. Res.* 4(1):33-39.
- Jenser G, Ga'borja'nyi R, Sze'nasi A, Alma'asi A, Grasselli M (2003). Significance of hibernated *T. tabaci* (Thysanoptera: Thripidae) adults in the epidemic of tomato spotted wilt virus. *J. Appl. Entomol.* 127:7-11.
- Jones HA, Bailey SF, EmSMWeller SL (1934). *T. tabaci* resistance in the onion. *Hilgardia* 8:215-232.
- Koschier EH, Sedy KA, Novak J (2002). Influence of plant volatiles on feeding damage caused by onion *T. tabaci* Lind. *Crop. Prot.* 21:419-425.
- Kumar NK, Gowda RV, Rao SE, Moorthy PNK (2001). Response of onion genotypes for *T. tabaci* Lind. resistance. *Proceedings of the Second National Symposium on IPM in Horticultural Crops New Molecule Pesticides.* 2:17-19.
- Lall BS, Singh LM (1968). Biology and control of the onion *T. tabaci* India. *Indian J. Econ. Entomol.* 61:676-679.
- Lewis T (1997). Flight and dispersal. In T. Lewis (ed.), *T. tabaci* crop pests. CAB, Oxon, United Kingdom, pp: 175-196.
- Liu TX (2004). Seasonal population dynamics, life stage, composition of *T. tabaci* (Thysanoptera: Thripidae) and predacious natural enemies on onions in south Texas. *Southwest. Entomol.* 29:127-135.
- Liu TX, Sparks AN (2003). Injury and distribution of onion *T. tabaci* (Thysanoptera: Thripidae) in red cabbage heads. *Southwestern Entomol.* 28:77-79.
- Lorbeer JW, Kuhar TP, Hoffmann MP (2002). Monitoring and forecasting for disease and insect attack in onions and Allium crops within IPM strategies. *Allium Crop Science: Recent Advances.* 2:293-309.
- Lorini I, Torres L, Guimaraes DR (1986). Study about Population fluctuations of *T. tabaci* in an onion crop. *International J. Entomol.* 62:1-9.
- Martin NA, Workman PJ, Hedderley D, Fagan LL (2010). Monitoring onion (*Allium cepa*) crops for onion *T. tabaci* (*T. tabaci*) (Thysanoptera: Thripidae). *New Zealand J. Crop Hortic. Sci.* 36:145-152.
- Montano JD, Brian A, Nault JO, Shelton AM (2011). Onion *T. tabaci* (Thysanoptera: Thripidae): A Global Pest of Increasing Concern in Onion *J. Econ. Entomol.* 104(1):1-13.
- Mound LA (1997). Biological diversity, *T. tabaci* crop pests. *CAB International.* pp: 197-215.
- Murai T (2000). Effect of temperature on development and reproduction of the onion thrips, *T. tabaci* Lind. (Thysanoptera: Thripidae) on pollen and honey solution. *Appl. Entomol. Zool.* 35:499-504.
- Richter E, Hommes M, Krauthausen JH (1999) Investigations on the supervised control of *T. tabaci* in leek and onion crops. *IOBC/WPRS Bulletin* 22(5):61-72.
- Schmutterer H, Evans DE, Hassan HM, Schultz LR (1969). Pests of Crops in Northeast and Central Africa with particular Reference to the Sudan. *Gustav Fisher Verlag, U.S.A.* 2:296-298.
- Shakeel M, Mehmood T, Khokhar KM (2006). Host plant resistant of promising onion varieties against onion *T. tabaci* Lind. *Sarhad J. Agric.* 22(3):477-480
- Verma SK (1996). Studies on the host preference of the onion *T. tabaci* (*T. tabaci* Lind.) to the varieties of onion. *Indian J. Entomol.* 28:396-398.

Full Length Research Paper

Natural resource use conflict in Bale Mountains National Park, Southeast Ethiopia

Anteneh Gezahegn Kebede^{1*}, Melaku Bekele² and Teshale Woldeamanuel³

¹Forestry Course Team, School of Biodiversity and Natural Resources, Madawalabu University, Ethiopia.

²School of Natural Resource and Environmental Studies, Wondogenet College of Forestry and Natural Resources, Hawassa University, Ethiopia.

³Wondogenet Department of Natural Resource Economics and Policy, School of Natural Resource and Environmental Studies, College of Forestry and Natural Resources, Hawassa University, Ethiopia.

Received 10 September, 2014; Accepted 7 November, 2014

Conflict over natural resources including wildlife, forest, land and water is common particularly in developing countries. It is extremely difficult to sustainably manage a resource if it is under conflict. This study aimed to assess the causes of resource use conflict in Bale Mountains National Park and attitudes of local community towards the Park. Finally, to find measures to reduce resource use conflict. This study was conducted in Dinsho Woreda of Bale Zone, southeast Ethiopia from December 11, 2012 to May 10, 2013. Both primary and secondary sources of data gathering tools such as key informant and stakeholder's interview, focus group discussion (FGD) and household survey techniques were used. The result revealed that conflict of interest between Bale Mountains National Park (BMNP) and the surrounding community could be traced back to the 1970s, the time of the park establishment. The establishment of the park gradually restricted free movement of herds of those living particularly by rearing animals. Gradual expansion of agriculture and the need for more land became additional cause of conflict. Based on the household survey, causes of resource conflict were exclusion of resources access from the park and illegal activity made either individually or in a group to access resources from the park by residents living in and around the park. There was no significant difference among kebeles and wealth classes, except lack of income ($\chi^2 = 8.083$, DF = 2, P = 0.018). However, majority (63.5%) of the respondents had a positive attitude and the remaining (36.5%) had a negative attitude towards the park conservation. To reduce this conflict, different options were suggested by stakeholders: local community should be involved in the management of the park, compensation scheme should be made for crop raiding and livestock predation by wild fauna, government and NGOs should take initiatives in bringing developmental projects for local communities, and awareness creation of local community should also be made.

Key words: Attitude, illegal activity, management options, protected areas, punishment and stakeholder.

INTRODUCTION

Protected areas (PAs) are the cornerstone of national and international conservation strategies (Dudley, 2008). To date, more than 100,000 protected areas cover 12% of the Earth's land area, of which 28% (by area) are found

in the tropics (Lele et al., 2010). Protected areas fall into one of the six conservation categories ranging from areas that strictly limit human activity to those that allow for sustainable human use (Hayes, 2006). Meanwhile, protected

area management is challenged by conflict of interest between stakeholders; economic or livelihood interest of local people on one side and conservation needs by park management on the other side (Andrew-Essien and Bisong, 2009). Lack of support and conflict between people residing in and around PAs and conservation agencies are other challenges of PA management (Schweithelm et al., 2006).

In Ethiopia, PAs cover approximately 16.4% of the country's land area including 20 national parks, 2 wildlife reserves, 3 wildlife sanctuaries and 17 controlled and 7 open hunting areas and 3 community conserved areas (EWCA, 2014). These PAs are facing many challenges due to growing populations, border conflicts and recurring drought and livelihood dependency of people living in and around PAs (Tessema et al., 2010).

Bale Mountains National Park is one of the PAs found in Ethiopia. It was established by the Ethiopian Wildlife Conservation Organization in 1971 with the primary objective of conserving Afro-alpine habitat and population of rare and endemic species of Mountain Nyala (*Tragelaphus buxtoni*) and Ethiopian Wolf (*Canis simensis*) (Hillman, 1986; Alers et al., 2007; GMP, 2007). It is the largest and most important protected area in Afromontane habitat in Africa. Nevertheless, BMNP had been facing a threat due to local people vested interest (Tessema et al., 2010, 2011). Historically, Bale Oromo known as a pastoralist, locally called *Godantu*¹ was a key feature of people in Bale Mountains. They move their livestock seasonally in order to exploit areas away from their permanent settlement site and moves from place to place in search for grazing land and spring water for their livestock (Barbre, 2013). However, the establishment of BMNP restricted free movements of livestock from place to place. Consequently, in the past two-three decades, this practice had been declined. During this time, barley cultivation became more prominent. Gradually, competition between local community for cultivation and grazing lands was intensified. For those yet primarily pastoralists, it is becoming more difficult to access sufficient grazing lands without pushing into someone else's grazing area or the national park.

The pressure posed on the park via local community was increasing with population growth. Yet, the majority of local community sees no benefits from the park rather incurs costs from the damage of crops by wild animals and restrictions on the use of natural resources from the park (Mamo, 2007; Soromessa, 2007). On the other hand, most community viewed protected areas and wildlife favorably, lack of benefits limited local willingness to aid conservation work (Tessema et al., 2007).

Various studies conducted in BMNP shows the biodiversity richness, endemism of the park and threat the park has been facing (Alers et al., 2007; Soromessa, 2007; Tessema et al., 2010; Vial, 2010). However, the causes of conflict between local community and park

management and attitude of local community towards the park were seldom studied (Mamo, 2007; Tessema et al., 2010). For this reason, this study was conducted to assess causes of resource use conflict in BMNP, to assess attitude of local community towards the conservation existence of the park and finally, to find options which will help to reduce conflict and help sustainable management of the park.

MATERIALS AND METHODS

Description of the study area

BMNP lies within five Woredas² of the Bale Zone: Dinsho in the north, Adaba to the west, Goba to the northeast, Mena-Angetu to the south and Barbare to the east (GMP, 2007; Mamo, 2007). For this study, Dinshoworeda was selected. The administrative town of the woreda is Dinsho, which is located 400 km far from Addis Ababa; the capital city of Ethiopia. The Woreda is located in the coordinates of 7°10' - 7°10'02" N Latitude and 39°55' - 39° 55' 02"E Longitude. The rainfall distribution pattern of the woreda is characterized by eight month rainy season from late March to October (Solomon et al., 2008). In general, the area receives annually 600-1000 mm rainfall in lower altitude areas and 1000-1400 mm in the higher altitude areas (Williams, 2002). It has a mild sub-tropical highland climate with annual mean minimum and maximum temperature of 2 and 20°C, respectively (Solomon et al., 2008).

Historically, people living in Bale Mountain areas were pastoralists (Barbre, 2013). The contemporary livelihood means of the residents are mixed farming (Debele, 2007; Tadesse et al., 2011; Barbre, 2013). The 2007 national census report shows the total population of the woreda was 39,124 (CSA, 2008). For this study, Dinshoworeda was selected purposively based on their proximity to researchers and where BMNP head quarter is found. The woreda has 9 kebeles, of these, 3 kebeles (Gojera, Dinsho 02 and Hora soba kebele) were selected based on their proximity to the park and accessibility for research. Gojerakebele is found inside the park while Dinsho- 02 and Horasobakebele are located outside the park boundary (Figure 1). To accomplish the intended objectives, mixed research (qualitative and quantitative) methods were used.

Data collection methods and analysis

To achieve the intended objective of the study, both primary and secondary data collection methods were used. Firstly, following Pilot survey, nine (9) key informants were selected through Snowball sampling methods. Secondly, in three purposively selected kebeles, Households were selected randomly based on the size of Household population in the three kebeles using formula developed by Yamane (1967) as cited in Israel (2012).

$$n = \frac{1}{(1+N(e)^2)}$$

n = the intended sample size, e = level of precision (8% level of precision), N = population size. Following random selection, respondents

¹Godantu is name given to the pastoralist in the area and it implies moving from place to place (Barbre, 2013).

²In Ethiopia the highest level of governmental organization is Federal. There are 9 regions and 2 satellite cities, which make up Ethiopia. The regions are divided into zones. The zones are divided into woredas. The woreda is an important administrative level structure for bicultural diversity as they are semi-autonomous in deciding on how the natural resources of their area should be managed. The next level is kebele. Kebeles are a cluster of villages called gots (Barbre, 2013).

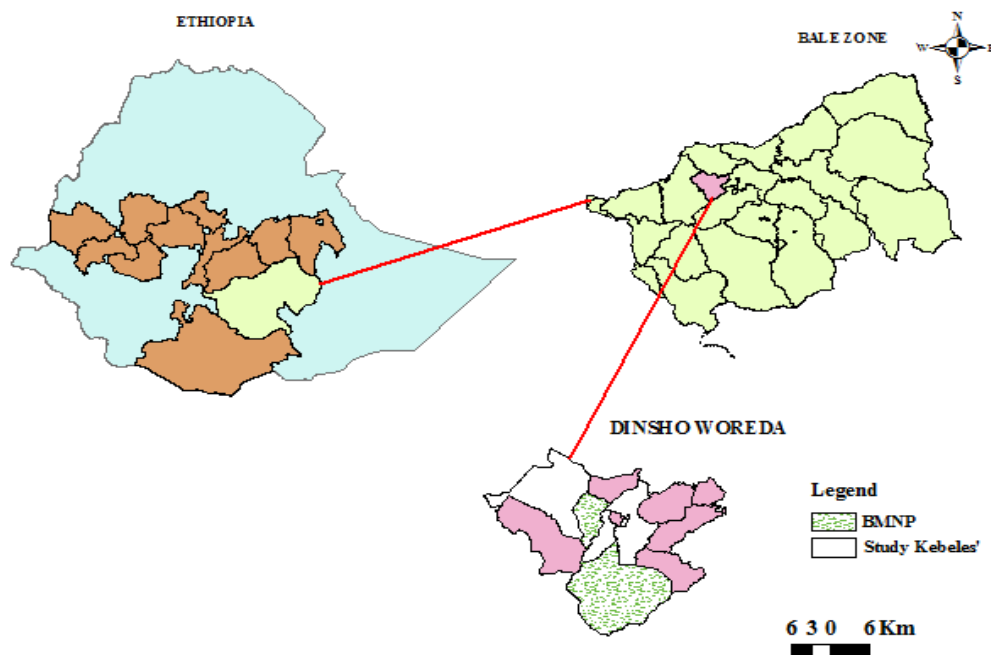


Figure 1. Location map of the study area.

were grouped into three wealth classes. Accordingly, 148 HHs were selected for interview. Thirdly, semi-structured interview were conducted to get detailed understanding of the major issues of the study and to triangulate data obtained through questionnaire. This helps to identify the stakeholders their vested interest (Thorsen et al., 2009). Lastly, a focus group discussion (FGD) was conducted to collect in-depth information from a group of people which represent the population of interest. Totally, Five FGD was held with local communities from three kebeles. FGD were held with the household heads (two individuals from each wealth classes) and youth who do not have a job (from the three kebeles). Three FGD were carried out with household head in each kebele separately and one with young member of the society, those found in the age of 18-28, totally 8 individuals participated in the discussion (2 from Gojera and 6 from the other kebeles). Finally, selected female household head from all kebeles were grouped under one group.

The collected data were analyzed using SPSS version 16.0. To understand underlying motives of conflict in relation socio-economic condition, their home and the attitude of people towards BMNP Pearson Chi-square test (two tailed) was used.

RESULTS AND DISCUSSION

Socio-economic characteristics of respondents

From the total of 148 respondents, the average ages of household heads are 38 years, the minimum and maximum ages of household head were 24 and 57, respectively. This shows that all the respondents were in the productive age group. The average landholding size of the

household is 2.3 ha. The maximum land holding size was 5 ha while, the minimum was 1 ha. Though, they had large tracts of land, unpleasant cold climate condition made the area known unproductive unlike other highland area of Ethiopia by crop production. As result, their priority livelihood means are livestock rearing than crop productions which corroborate with Asmamawu and Verma, (2013) and Barbre (2013). However, the land holding of households is not statistically different between kebeles ($\chi^2 = 20.35$, DF = 2, P = 0.62). Livestock mainly raised in the area were cattle and sheep. The average size of livestock owned by respondents was 13. Majority of the respondents livestock size ranges in 1-15 (65.5%), followed by 16-25 (27%) and lastly, greater than 26 (7.4%). Concerning their occupations, all respondents have been engaged in livestock rearing as their livelihood means while, 95% of them were engaged in crop cultivation. In addition, 7.4% of them were employed in the park and 5 respondents were employed in other government offices.

Based on information gathered from key informants, households were grouped into three wealth classes for this study which takes into consideration the landholding and livestock size. Accordingly, rich household should have greater than 4 ha of land and more than 15 livestock (more of cattles), while the medium had more than 2 ha of land but less than 4 ha and less than 15 livestock and the poor classes had less size of livestock

*Corresponding author. E-mail: antegez@gmail.com.

Table 1. Resource types, functions and /or uses and stakeholders of Bale Mountains National Park.

Resources in the park	Function and/ or uses	Who uses, involved and Interested from the Park	Who affected
(i) Land	(i) In direct : Ecosystem Maintenance, Climate regulation	(i) Park management	(i) Local community
(ii) Forest (trees)		(ii) Local community	
(iii) Grasses (Grazing land)		(iii) Cooperatives (iv) NGOs: FZS, EWCP	
(iv) Water	(ii) Direct: Income Biodiversity, conservation, Education, Fodder	(v) Local government: Woreda administration, ARDO, CTO	(ii) The Park (Wild life)
(v) Wild animals			
(vi) Birds and other organisms			

Frankfurt Zoological Society (FZS), Ethiopian Wolf Conservation Project (EWCP), Agriculture and Rural Development office (ARDO) and Culture and Tourism office (CTO). Source: Field observation and interview of park management (2012).

and land than the medium classes. Accordingly, majority (55.4%) of the household were grouped into poor class and followed by medium class which represent 33.16% and the least part, which only takes 11 of them or 7.43% of the respondents were considered as a rich.

Stakeholder identification and conflict of interest

Stakeholders of BMNP identified based on their level of involvement, interest and impact or impacted. Stakeholders are those who are affected either negatively or positively, or those who can affect the outcomes of a proposed intervention (Karl, 2000). Identified local stakeholders of BMNP were; local community, Park management, NGOs such as Frankfurt Zoological Society (FZS) and Ethiopian Wolf Conservation Project (EWCP), local government administration, and sectors that is, Agriculture and Rural Development office (ARDO) and Culture and Tourism office (CTO), cooperatives and higher education (College or University) (Table 1).

Accordingly, primary stakeholders are local community and Park management. They have direct interest in the resource; either because they depend on it for their livelihoods or they are directly involved in its exploitation (FAO, 1998; Karl, 2000). While, identified Secondary stakeholders were local Government, cooperatives and Higher Education Institution; they involved in the Park management through financial, technical and logistic support and interested in the protection of endemic and biodiversity of the park. Local government administration and sectors (ARDO and CTO) have been less involvement but interested to conserve resources sustainably and enhance livelihood of community, cooperatives engaged in tour guide and provision of cultural handicraft and finally, universities or higher institution interest for education and research and participated in Fire breaking considered as a Secondary stakeholders. Generally, secondary stakeholders have indirect interest in management and conservation of natural resources and/or depend at least partially on wealth or business generated

by the resource and intermediaries in the process of delivering aid to primary stakeholders (FAO, 1998; Karl, 2000).

Local community living in and around BMNP had historical interest of resource use from the park due to livelihood dependency. Thus, BMNP have been facing major threat because of growing strain of two contradicting interest of stakeholders (local community and the park management). Biodiversity conservation on one side and economic needs on the other side. According to elder's, interest clash started earlier when the park established and local community denied resource access from the park. The community depends on livestock rearing and moves from place to place in search of fodder for their cattles. Local community had more agricultural land for cultivation as compared to other places in Ethiopia. Unsuitable weather condition limited crop cultivation except Barley, as a result, local community still practice livestock rearing as first priority.

As clearly described above, the primary interest of local community was restricted via the establishment of the park. Though it is illegal and punished by the park, local community does not stopped resources access from the park yet. Consequently, revenue collected through punishment from 2006/07-2012/13 shows increasing trend (Figure 2).

The main resources which local community need to access are land, grass, forest product and water from the park while, the park planned to conserve endemic and other biodiversity of the park by excluding local community. This interest clash of stakeholders is the manifestation of conflict. Illegal activity (livestock grazing and cutting trees) and higher punishment, crop raiding and domestic animal damage and lack of compensation for losses, lack of benefit from the park and low participation of local community in the park affairs created claims and lack of sense of ownership were factors that exacerbated conflict.

Local community directly affected by the establishment of park than any other group. As it stands now, they could not consider the park as a source of benefit rather incurs

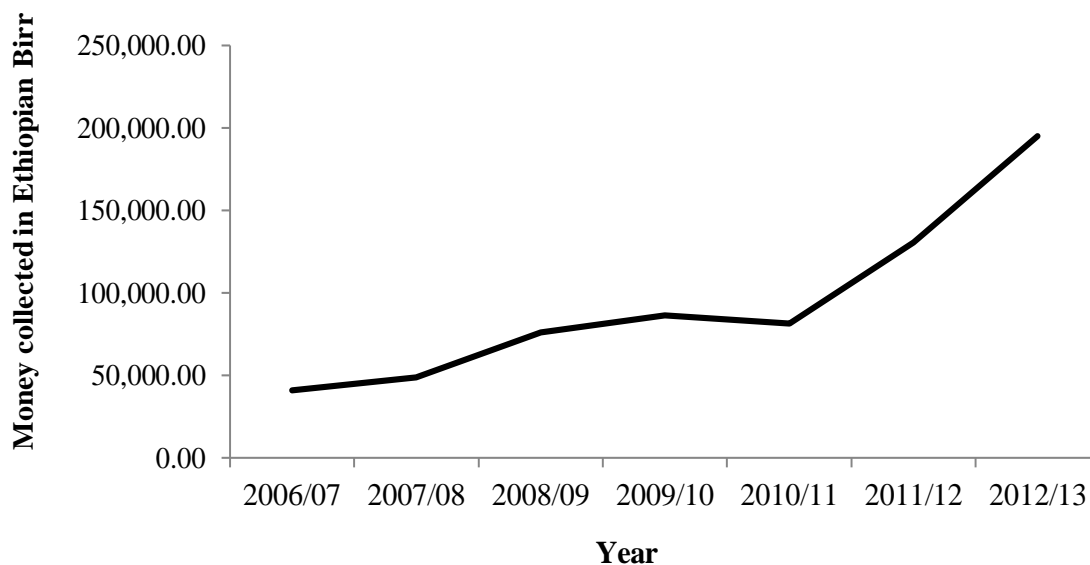


Figure 1. Money collected from local community fines (Source: BMNP, 2012).

cost. As a result, they are considered to be a primary stakeholder. Park management who stands to guard the wild life and have an authority to protect and manage the park is a primary stakeholder, because they are the ones who made decision concerning the park and took responsibility to handle issues pertinent to them (Table 2).

The livelihood dependency and vested interest of local community coupled with park management approach³ underlying causes of conflict. BMNP had been following the so-called 'Yellowstone Model' of parks as wilderness areas, which is conventional and exclusionary. This management approach does not give due consideration to the interest of local community living in and around the park. Such an outcome can undermine protection policies through conflicts between park managers and local communities (Andrade and Rhode, 2012).

Conflicts in PAs can be seen to be the result of competing and diverse interests, goals and aspirations that individuals or groups within legally established and secluded environments have (FAO, 2000; Andrew-Essien and Bisong, 2009). The same is true in the cases of BMNP on which local community depends historically on the resources for their livelihood and conservation interest of the park management on the other side. This is similar to study conducted in Senkele Sanctuary (Tewodros Kumssa and Afework Bekele, 2013).

According to 88.6% of the respondents, causes of park-people conflict were resource use exclusion by the park. This corroborates study made by Asmamawu and Verma (2013) in BMNP. Though, most of the respondents do not heavily dependent on the resources of the park, about 31.1% of them need to access resources from the park to

sustain their lives. As a result, local community illegally accessed resources in the park. Such illegal acts of local community inevitable result in disharmonies relation between local community and the park. Money collected via punishment from 2005/07-2012/12 from local community was a good indicator of increasing illegally activity. Increasing population and illegal activity to access resources from the park were the main factor that instigated conflict. Population living in the park was minimal when the park was established but, currently the size of population increased by 20 folds (GMP, 2007). Thus, put heavy pressure on the management of the park. Studies conducted in Digya National Park in Ghana and Royal Chitwan National Park in Nepal's shows resources use exclusion approach, the PA following and illegal activity made individually and in group in PAs are the main causes of park-people conflict (Nepal and Weber, 1995; Ayivor et al., 2013).

The need of local community to access resources from the park depends on their wealth and Kebele. The poor household head and Kebele found in the park need to have more land for agriculture than medium and rich classes and kebeles outside the park boundary. Household having less size of agricultural land are less likely to be positive regarding conservation of the park (Ngabonziza, 2010). In addition, lack of benefit from the park was underlying causes of park and people conflict. Study conducted by Mamo (2007) in BMNP shows that "local community currently does not see the park, as it stands now, as source of substantial benefit".

The other causes of conflict between the park and local community in BMNP were crop raiding by wild fauna, that is common with Warhog and Mountain Nyala (92.1%) and associated lack of compensation for the damage was the major claims local community raised (Asmamawu and

³Strategies adopted by park management in integrating local residents in the overall management framework (Ayivor et al., 2013)

Table 2. Interest, role and claims of BMNP stakeholders.

Stakeholders	Interest	Involvement/role	Claims/ challenges
Local community	Resources use and access. Income (job and other off-farm activity).	Fire breaking Exposing illegal activities Protection of wild animals.	Resource use exclusion Crop and domestic animal damage Participation and benefit Punishment
Park management	Sustainable management of the park	In all affairs of the park Responsible and accountable	Pressure via Grazing, forest harvesting and settlement.
FZS	Conservation of indigenous and other biodiversity of the park.	Providing technical , logistic and financial support	Lack of financial and technical support by government Population pressure Less support of local government
EWCP (Ethiopian wolf Conservation Project)	Protection of rare Ethiopian wolf from extinction.	Creating awareness about the impact of domestic dog on Ethiopian wolf	Anthropogenic activity(settlement, grazing, fire, agricultural land expansion, Deforestation Disease transmission)
Local government	Sustainable management and livelihood improvement	Less involvement	Illegal activities Local community Claims
ARDO	Natural resource management	Increasing community awareness and cooperation	Conflict
CTO	Enhancing ecotourism activity and income generation		
Cooperatives	Income	Tour guide (horse rent and provision of cultural artifacts)	Decreasing trend in tourist

FZS (Frankfurt Zoological Society). Source: Data obtained from stakeholder's interview (December, 2012 and May, 2013).

Verma, 2013). This phenomenon is common in most protected areas in the world, where communities live in and around protected areas. Crop raiding is the common causes of conflict between local community and wildlife, that is, Koshi Tappu Wildlife Reserve in Nepal and Akegera National Park in Rwanda (Limbu and Kariki, 2003;

Ngabonziza, 2010). Study conducted in Uganda also revealed that wild animals near protected area destroyed 85% of the crop grown (Kagoro-Rugunda, 2004). Likewise, a survey conducted in Nepal showed that wild animals were responsible for 32% of the crop loss (Limbu and Kariki, 2003). Generally, resources access (park-people) conflict,

benefit sharing and human-wildlife conflict are the conflict type between local community and the park (Crawford, 2012).

Attitudes of local community towards BMNP

Majority (63.5%) of the respondents had a favorable

or positive attitude towards BMNP existence and conservation while, 36.5% of respondents had a negative attitude. This is contrary to community living surrounding Ajai Wildlife Reserve in Uganda (Richard, 2006). Positive attitude of respondents linked with benefit is received via involvement in the park and awareness of the role and values of the park. The benefits were expressed in terms of money gained from different temporary employment of local people in the park. This is similar to study conducted in Nepal and Myanmar (Allendorf, 2007; Macura et al., 2011). Participation in the park and associated economic benefit, awareness of the role and values of the park were the underlying factors for positive attitude of respondents, which is similar to study conducted in Marsabit National Reserve in Kenya (Shiba, 2010). Communities surrounding protected areas in most cases could not support biodiversity conservation, because the establishment of these protected areas leads to loss of their traditional economic and subsistence opportunities (Richard, 2006; Bosak, 2008; Andrade and Rhodes, 2012). Though local community currently does not see the park as a source of substantial benefit, most of the respondents living in and around BMNP had positive attitude towards the park.

On the other hand, negative attitude of respondents associated with resource use exclusion, crop raiding and domestic animal damage and lack of compensation for, and higher punishment is posed on local community while doing illegal action. This is similar to study conducted in three upper Myanmar protected areas (Allendorf et al., 2006). Statistically, no significant difference prevailed over attitudes of local community via wealth status of household, respondents living in the park showed their negative attitude than respondents living outside the park which is related to fear of eviction for that matter, they support the removal of the park and unlikely to support the conservation. This result corroborate with study of Ngabonziza (2010). In addition, the proximity of household to the conservation area also brought an impact on the attitude, because communities living closer or with the boundaries of the park suffered from crop raiding and animal damage by wild animals. Furthermore, communities settling in nearby areas to the park had fear of eviction for that matter, they support the removal of the park and unlikely to support the conservation (Ngabonziza, 2010).

Institutional or policy options available to overcome the problem

In order to reduce resource use conflict and improve the relationship between local community and the park, different options were forwarded by stakeholders. According to respondents, 124 (83.8%) of the respondents supported local community should be involved in different activities of the park. Ashley (1995) stated that the success and sustainability of a rural development project depends on

local people's participation in different phases of the project. About 120(81%) respondents raised, more job opportunity should be created and they should receive benefit from the park. Active participation of local communities in developmental projects plays a significant role in providing them with financial benefits for enhancing their livelihoods (Mehta and Kellert, 1998; King, 2007; Andrew-Essien and Bisong, 2009).

The impact of participation clearly observed on the attitudes of local community, where the protected are managed by the state with little local community involvement and community based conservation in which local community took the lion share. Under the some risk, local community supported community based conservation than state based conservation (Andrew-Essien and Bisong, 2009; Lepp and Holland, 2011). Though, local community living in and around BMNP was involved in different conservation activities of the park, their participation was not genuine, only involved during emergencies rather than actively participating in planning and management decisions (Asmamawu and Verma, 2013). Furthermore, household respondents need the park managers to follow their deeds and damage they encounter via wild animals and resource access during the long dry season. To overcome the claims of local community, the park should take measures in paying compensation for crop raiding and domestic animal damage made by park fauna which is supported by 117 (79%) of the respondents. Crop raiding is a real problem faced by farmers around PAs (Fungo, 2011). Study conducted in southern Kenya, regarding predator-damage compensation, Maasai community bears positive attitudes towards the conservation of wild life, though they claim unfair and inequitable compensation scheme (Rodriguez, 2007).

According to key informants and informal interview made with different stakes, punishment rate were decided by community but, they had been complaining the increased punishment per cattle. Local community, NGOs and park management agreed that the current park-people relation is poor and to reverse the current trend, supported idea of awareness should be created for local community. Likewise, to create good relationship between local community and conservation agencies, creating awareness of community was recommended as an essential measure (Allendorf et al., 2006). In addition, focus group discussants affirmed that the presence of the park should bring development of infrastructural activity for the benefit of the local community. The provision of institutional and infrastructure development is the basic options to reduce conflict between park and local people (Andrew-Essien and Bisong, 2009). While strict enforcement of rules and regulation, enhancing local community awareness about values of the conservation and management of the park, encouraging and allowing local community participation and finally, government should pay attention and support the park technically and financially was some of management solution forwarded by park managers (EWCA, FZS

and EWCP).

Conclusion and recommendation

Historically, people living in BMNP area depends on rearing livestock as their priority livelihood means and moves from place to place in search of grazing lands. However, park establishment restricted free movement of livestock by endorsing strict rule enforcement and preventing resources access. Concurrently, local people do not stop access resource from the park though it is considered illegal and liable for punishment. That was the underlying cause of resources use conflict between local community and park management. The identified causes of conflict were: Resources use exclusion approach the park have been following and illegal activity made by local people either individually or in a group to access resources from the park, crop raiding and domestic animal damage by common warthog and hyena, lack of income from the park and dispute with park scouts. In addition to the fore mentioned factors, absence of local community involvement in park affairs, unfulfilled promises of the park in integrating local community in different affairs of the park, higher punishment posed for illegal activity were the main claims raised by local community. Consequently, the park obliged to reduce the park area by 50 km² with the aim of reducing pressure and better management.

REFERENCES

- Alers M, Bovarnick A, Boyle A, Sobrevila C (2007). Reducing threats to protected areas: Lessons from the field. The International Bank for Reconstruction and Development / THE WORLD BANK. Washington, D.C. 20433, U.S.A
- Allendorf T (2007). Residents' attitudes toward three protected areas in southwestern Nepal. *Biodiv. Conserv.* 16:2087-2102.
- Allendorf T, Swe K, Oo T, Htut Y, Aung M, Allendorf K, Ayek L, Leimgruber L, Wemmer K (2006). Community attitudes toward three protected areas in Upper Myanmar (Burma). *Environ. Conserv.* 33(4):344-352.
- Allendorf T (2010). A framework for the Park–people relationship: insights from protected areas in Nepal and Myanmar. *Int. J. Sust. Dev. World Ecol.* 17(5):417-422.
- Andrade G, Rhodes J (2012). Protected Areas and Local Communities: an Inevitable Partnership toward Successful Conservation Strategies? *Ecol. Soc.* 17(4):14.
- Andrew-Essien E, Bisong E (2009). Conflicts, Conservation and Natural Resource use in Protected Area Systems: An Analysis of Recurrent Issues. *Eur. J. Sci. Res.* 25(1):118-129.
- Andrew-Essien E, Elizabeth E, Bisong E (2012). Conflicts as Indices to Evaluating the Effectiveness of Natural Resources Conservation in the Cross River National Park, Nigeria. *Global J. Human Social Sci.* 12(6). ISSN:2249-460
- Ashley C (1995). Tourism, Communities, and the Potential Impacts on Local Incomes and Conservation. Res. Discussion Paper No. 10. Windhoek, Namibia.
- Asmamaw D, Verma A (2013). Ecotourism as a tool for environmental conservation and its implication to community livelihoods, the case of the bale mountains national park, Ethiopia. *J. Environ. Sci, Water Res.* 2(8):250-259.
- Ayivor J, Gordon C, Ntiamao-Baidu Y (2013). Protected area management and livelihood conflicts in Ghana: a case study of Digya National Park. *Parks.* 19(1):37-50.
- Barbre B (2013). Biomass Fuel-briquettes and improved stoves in Dinsho, Ethiopia. A report Submitted in partial fulfillment of the requirements for the degree of Master of Science in Forest Ecology and Management, Michigan Technological University.
- BMNP (2013). History of Bale Mountains National Park. Bale Mountains Conservation Project available at: http://balemountains.org/the_park/history/ [Accessed on 8/12/13].
- Bogale S, Melaku S, Yami Y (2008). Potential use of crop residues as livestock feed resources under smallholder farmer's conditions in Bale highlands of Ethiopia. *Tropical and Subtropical Agro ecosystems,* 8 (2008):107-114.
- Bosak K (2008). Nature, Conflict and Biodiversity Conservation in the Nanda Devi Biosphere Reserve. *Conserv. Soc.* 6 (3):211-224.
- Crawford A (2012). Conflict-Sensitive Conservation in Nyungwe National Park: Conflict analysis. *Int. Ins. Sust. Dev. Report.*
- Debele M (2007). Conservation and Ecotourism in Bale Mountains National Park, Southern Oromia, Ethiopia: Analysis of Collaboration Discourses and Practices among Stakeholders. M.Sc. Thesis, Wageningen University,
- Dudley N (Editor) (2008). Guidelines for Applying Protected Area Management Categories. Gland, Switzerland: IUCN. x + 86pp.
- Dudley N, Stolton S (editors). (2008). Defining protected areas: an international conference in Almeria, Spain. Gland, Switzerland: IUCN. 220 pp.
- EWCA (Ethiopian wildlife conservation Authority). (2014). Available at: <http://www.ewca.gov.et/en/node> [Accessed on 27/10/2014].
- FAO (1998). Fisheries Technical Paper. No. 375. Rome, Italy. P 93.

Concurrently, majority of local community could not receive benefit from the park rather they incur costs from wild animal's damage on their crop and domestics animals. Nevertheless, majority had favorable attitude towards BMNP existence and conservation. Participation and benefit received from the park, awareness of the values and roles of the park in for the country is the underlying factors for prevalence of positive attitude.

To reduce the resource use conflict between local community and the park, different options were forwarded by different stakeholders. Accordingly, benefit scheme should be developed for residents, encouraging and supporting participation, and awareness creation of local community and following up their deeds and strict rule enforcement for sustainable park management was some of the essential measure forwarded by the stakes.

Conflict of Interests

The author(s) have not declared any conflict of interests.

ACKNOWLEDGEMENTS

I would like to thank Madawalabu University for giving me the opportunity to conduct this research. In addition, the authors give great thanks to Bale Mountains National Park (BMNP) office workers for making life easier during the stay of one of them.

Kebede et al. 821

FAO (1998). Integrated Coastal Area Management and Agriculture, Forestry and Fisheries. Rome, Italy.

FAO. (2000). Conflict and Natural Resource Management. Rome, Italy.

Fungo B (2011). A Review Crop Raiding Around Protected Areas: Nature. Control and Res. Gaps Environ. Res. J. 5 (2):87-92.

General Management Plan. (2007). Bale Mountains National Park General Management Plan. Compiled and Edited by Frankfurt Zoological Society. Institute of Biodiversity Conservation, Ethiopia.

Hayes T (2006). Parks, People, and Forest Protection: An Institutional Assessment of the Effectiveness of Protected Areas. World Dev. J. 34(12):2064-2075.

Hillman J (1986). Conservation in Ethiopia's Bale Mountains. Technical Bulletin Reprint. Endangered species.3(4).

Hillman J (1993). Ethiopia: Compendium of Wildlife Conservation Information. Wildlife Conservation in Ethiopia. Volume. II. Ethiopia Wildlife Conservation Organization. Addis Ababa, Ethiopia.

Israel G (2012). Determining Sample Size. University of Florida IFAS Extension. PEOD6.

IUCN (1994). United Nations List of National Parks and Protected Areas. IUCN Gland, Switzerland, (1990) "Living with Wildlife. Wildlife Resources Management with Local Participation in Africa. World Bank Technical Paper, No 130 African. Technical Department serves Washington: World Bank.

Karl M (2000). Monitoring and evaluating stakeholder participation in agriculture and rural development projects: a literature review. Sustainable Development Department, Food and Agricultural Organization of United Nations. Available from: <http://www.fao.org/sd/ppdirect/ppre0074.htm> [Accessed on 8/22/13].

King B (2009). Conservation Geographies in Sub-Saharan Africa: The Politics of National Parks, Community Conservation and Peace Parks. Geography Compass. 3 (2009):1-14.

Lepp A, Holland S (2006). A Comparison of Attitudes toward State-Led Conservation and Community-Based Conservation in the Village of Bigodi, Uganda. Soc. Nat. Res. 19:609-623.

Lele S, Wilshusen P, Brockington D, Seidler R, Bawa K. (2010). Beyond exclusion: Alternative approaches to biodiversity conservation in the developing tropics. Current Opinion in Environ. Sust. 2010(2):1-7.

Lepp A, Holland S (2006). A Comparison of Attitudes toward State-Led Conservation and Community-Based Conservation in the Village of Bigodi, Uganda. Society & Natural Resources: An Int. J. 19(7):609-623.

Limbu K, Karki T (2003). Park-people Conflict in Koshi-Tappu Wildlife Reserve. Our Nature: 2003(1):15-18

Macura B, Zorondo-Rodríguez F, Grau-Satorras M, Demps K, Laval M, Garcia A, eyes-Garcia A (2011). Local community attitudes toward forests outside protected areas in India. Impact of legal awareness, trust, and participation. Ecology and Society, 16(3):10.

Mamo Y (2007). Ecology and Conservation of Mountain Nyala (*Tragelaphus buxtoni*: Lydekker 1910) in Bale Mountains National Park, Ethiopia. Ph.D. Thesis, University of Aberdeen School of Biological Science.

Nepal S, Weber K (1995). The quandary of local people- Park relations in Nepal's Royal Chitwan National Park. 19: 853-866.

Ngabonziza G (2010). A critical investigation of conservation attitudes of the local community living adjacent to Akagera National Park, Rwanda. MSc. thesis. Cape Peninsula University of Technology.

Richard R (2011). Conflicts Between local communities and Uganda wildlife Authority in Ajai wildlife reserve. Ph.D., Dissertation, Makerere University.

Mehta N, ellert R (1998). Local Attitudes toward Community-Based Conservation Policy and Programmes in Nepal: A Case Study in the Makalu-Barun Conservation Area. Environmental Conservation, 25(4):320-333.

Rodriguez S (2007). Perceptions and attitudes of a Maasai community in southern Kenya regarding predator-damage compensation, wildlife conservation and the predators that prey on their livestock. Master of Sustainable Development at the School for International Training in Brattleboro, VT, USA

Schweithelm J, Kanaan R, Yonzon P (2006). Conflict over natural Resources at the community level in Nepal including its relation to armed conflict. U. S. Agency for International Development 1300 Pennsylvania Avenue, NW Washington, DC.

Shibia M (2010). Determinants of Attitudes and Perceptions on Resource Use and Management of Marsabit National Reserve, Kenya. J. Human Ecol, 30(1): 55-62.

Tadesse D, Williams T, Irwin B (2011). People in National Parks – Joint Natural Resource Management in Bale Mountains National Park - Why it makes Sense to Work with Local People. Journal of the Ethiopian Wildlife and Natural History Society. Walia-Special Edition on the Bale Mountains: 257-268.

Tessema T, Robert L, Zelealem A, Nigel L. (2010). Community Attitudes toward Wildlife and Protected Areas in Ethiopia. 23(6):489-506

Soromessa T (2007). Mountain resources and conflict instigating issues, Ethiopia. Department of Biology Education, Addis Ababa University, Ethiopia.

TewodrosKumssa and AfeworkBekele.(2013). Human-wildlife conflict in Senkele Swayne's Hartebeest Sanctuary, Ethiopia. Journal of Experimental Biology and Agricultural Sciences: 1(1). ISSN No. 2320-8694.

The Health communication unit (HCU). Using Focus Groups Version 2.0 June 30, 2002. University of Toronto.

Thompson R (2012). Stakeholder Analysis. Winning Support for Your Projects. Available at: http://www.mindtools.com/pages/article/newPPM_07.htm [Accessed on 11/27/13]

Thorsen A, Teklemeriam D, Reta F, Vodouhe M, Asefa M, Garcia N (2009). Conflict over Forest Resource Use in Ban Pang Eka, Mae Ram Watershed, Chiang Mai Province, Northern Thailand. SLUSE report 6th of April 2009. Interdisciplinary Land Use and Natural Resource Management (ILUNRM). University of Copenhagen and Roskilde University.

Vial F (2010). Conservation science for common ground: developing the necessary tools to manage livestock grazing pressure in Bale Mountains National Park, Ethiopia. Ph.D Dissertation, University of Glasgow.

Williams S (2002). Bale Mountains a Guide Book. United Press, Addis Ababa, Ethiopia.

Full Length Research Paper

Assessment of the trees diversity at the edge of stream and forest road in Shast Kalateh district

Aidin Parsakhoo* and Benyamin Matinnia

Department of Forestry, Faculty of Forest Sciences, Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Iran.

Received 14 July, 2014; Accepted 17 October, 2014

This study was conducted in an uneven aged deciduous natural forest of Hyrcanian zone to evaluate the status of trees diversity at the edge of streams and forest road. Transects were established parallel to road and perpendicular to stream and then all regenerations and trees were counted in circular plots on each transect. Past software was used to apply Shannon biodiversity index, Margalef richness index and Camargo evenness index. Results show that biodiversity index decreased with increasing distance from road edge and stream. Shannon heterogeneity index at the edge of stream (2.06) was more than that of road edge (2.03). Indeed trees species diversity tended to increase at the edge of forest roads and streams of study area.

Key words: Trees diversity, forest road, stream, past software, Shast Kalateh.

INTRODUCTION

Forest roads affects plant composition and diversity by creating gaps and altering environmental conditions such as light, soil moisture and bulk density (Ferris et al., 2000; Watkins et al., 2003; Hansen and Clevenger, 2005). Zhou et al. (2010) showed that plant diversity and soil moisture tended to increase in wide roads.

Moreover, streams are also efficient corridors for plant species in forest (Calçada et al., 2013). Scalley et al. (2009) in a study in Puerto Rico found that there is greater variation in species composition closer to streams, and less variation in species composition farther from streams. Feng et al. (2011) reported that the were significantly lower than those of the control, but the species

composition had no significant difference.

Li et al. (2010) showed that in Huzhong forest of China, the effect distance reached up to 20-34 m. The plant species diversity of shrub stratum and herb stratum within the effect zone was greater than that in adjacent habitat, and the Shannon-Weiner index increased by 21 and 60%, respectively. The construction and maintenance of roads could increase the plant species diversities of communities (Li et al., 2014). Species richness is defined as the observed number of species in a mixed stand. In coverage and density of shrubs at the edge of highway contrast, species diversity considers the number and frequency of the species present (Pretzsch, 2009).

*Corresponding author. E-mail: parsakhoo@gau.ac.ir or Aidinparsakhoo@yahoo.com. Tel: +98 171 4427050. Fax: +98 171 4427176.

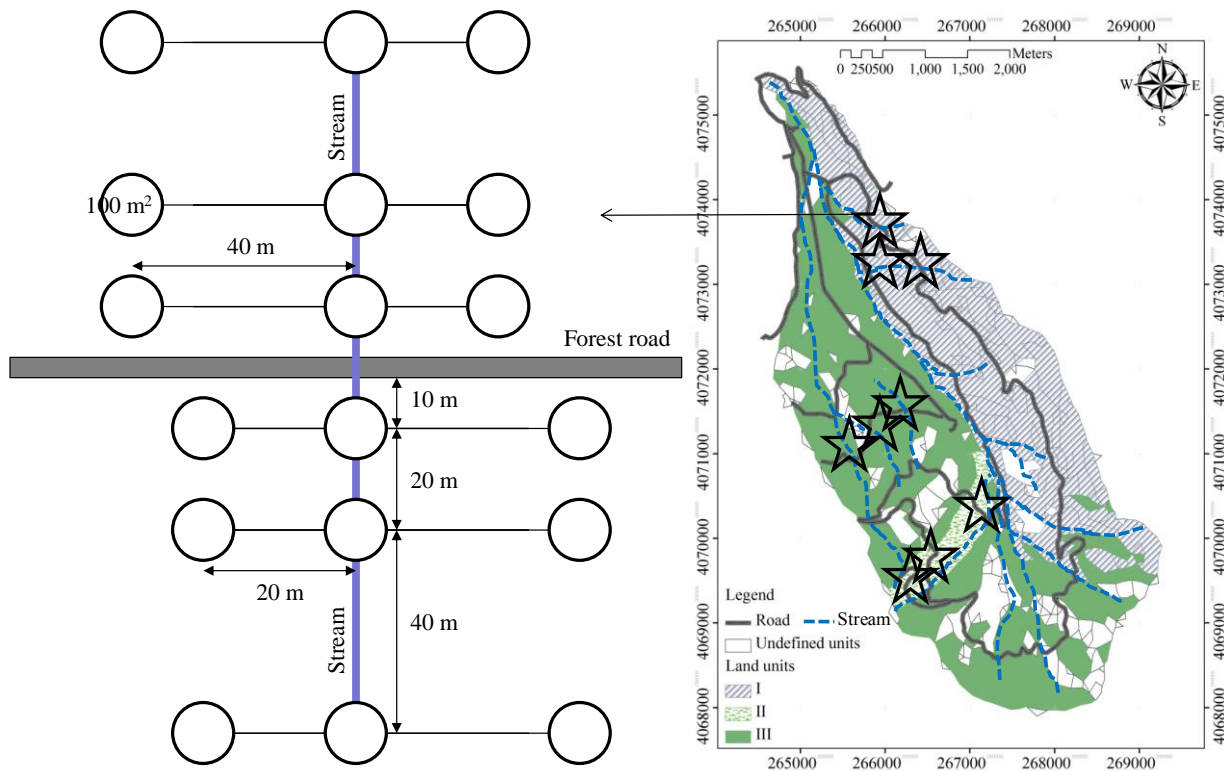


Figure 1. Sampling design in land units of study area.

Species evenness is defined as the number of individual in each of the species (Yue-hui et al., 2010).

Forest roads and streams has important effects on plant species composition and diversity across different scales, and the estimation of its effect distance is a key factor to integrate the road, stream and ecological processes in forest region (Li et al., 2010). The main objectives of this research were: (i) to evaluate the status of trees regeneration biodiversity at the edge of streams and forest road and (ii) to assess the effects of land units on tree regeneration in mentioned areas.

MATERIALS AND METHODS

Study site

District one in Shast Kalateh forests with an area of 1713 hectares is located in Golestan province and in watershed number of 85 (36°43'27" to 36°48'6" N and 54°21'26" to 54°24'57" E). The bedrock of this forest is lime and sand stone with altitude ranging from 100 to 1000 m above sea level. The forest is mixed deciduous which has been established on brown forest soil with mostly sandstone as bedrock Clay-loam-silty texture and worn stones are spread around the region. The mean forest stock growth in the study area was 247 m³ ha⁻¹. The climate of the region is Mediterranean warm and moist. The mean annual precipitation is 562 mm with the lowest in July and August (Figure 1).

Sampling design and field survey

In this study the hydrograph map of Shast kalateh forest was extracted from topographic map. Then, a natural stream was randomly selected in each land units. Map of land units was previously prepared by the researchers in Department of Forestry in Faculty of Forest Sciences (Table 1). It attempted the stream dimension, longitudinal slope of streams, roughness of the stream's bed and hillside gradient to be same. In the next stage, at each side three transect were established parallel to road and perpendicular to stream. Three circular plots with an area of 100 m² and distances of 20 and 40 m were taken on each transect. All regenerations and trees were counted in plots according to the scientific name of species.

Biodiversity and statistical analysis

Vegetation diversity (Equation 1), richness (Equation 2) and evenness (Equation 3) were calculated in Past software.

$$H' = - \sum_{i=1}^s [P_i \ln(P_i)] \tag{1}$$

$$M = \frac{s-1}{\ln D} \tag{2}$$

Table 1. Features of land units in study area.

Land units	Geology	Slope direction	Hillside slope (%)	Stock growth (m ³ ha ⁻¹)
I	Conglomerate sand stone	West	10-25	>300
II	Conglomerate sand stone, current age stream deposits	East	25-50	>300
III	current age stream deposits	North	0-10	100-200

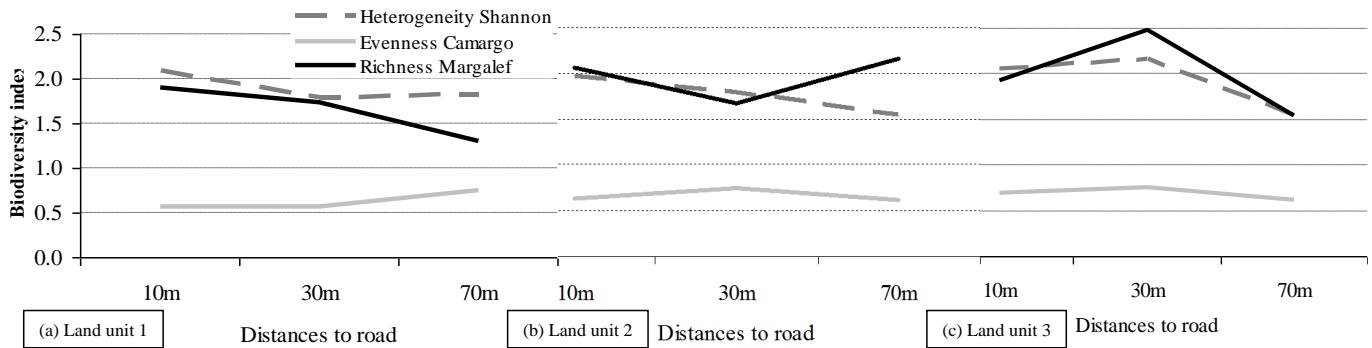


Figure 2. Variations of biodiversity indices at different distances from road.

$$E' = 1 - \left(\sum_{i=1}^S \sum_{j=i+1}^S \left| \frac{P_i - P_j}{S} \right| \right) \quad (3)$$

H' is Shannon biodiversity index, P_i is each of specimen's frequency percentage ratios to total species in each of community, M is Margalef richness index, s is number of species, D is number of individuals, E' is Camargo evenness index, P_i is proportion of species i in total sample, P_j is proportion of species j in total sample, and S is number of species in total sample. Data were statistically analyzed using the GLM procedure in SAS software. Student Newman Kolus test (SNK) at probability level of 0.05 was used to compare means of biodiversity indices.

RESULTS AND DISCUSSION

Plant diversity at the edge of forest road

Results of this research showed that the Shannon biodiversity index decreased with increasing distance from road in all land units (Figure 2). This case was in agreement with the findings of Zhou et al. (2010). They proved that plant diversity and soil moisture tended to increase at the road edge.

The frequency of *Parrotia persica* C.A.M. was more than that of other species in all land units (Figure 3). The mean of Shannon biodiversity index at distance of 10 m from road was 2.03 and at distances of 30 and 70 m were 1.91 and 1.64, respectively (Table 2). Road provide an

corridor which can be affected by climatic, soil and human disturbances, so the seed of exotic plant species is distributed by wind and tourism. Therefore plant diversity is increased.

Plant diversity at the edge of forest stream

Shannon biodiversity index at the edge of stream was more than that of other distances from stream in different land units except for land unit 3 (Figure 4). Scalley et al. (2009) recorded the greater variation in species composition closer to streams. The reason of inverse trend of heterogeneity index in land unit 3 was unknown and need more researches especially on soil. The Margalef richness index in land unit 1 decreased with increasing distance from stream.

In land unit 2 the trend of richness index was stationary and in land unit 3 it increased by increasing distances from stream. The reason of this issue is the appearance of some species such as *Crataegus* spp. and *Fagus orientalis* L. at the distances of 40 m. *Laurocerasus officinalis* Roemex cannot be observed in land unit 1 because of the unit features (Figure 5). The mean of Shannon biodiversity index at distance of 0 m from stream was 2.06 and at distances of 20 and 40 m were 1.75 and 1.86, respectively (Table 3). It seems that depositing different materials and nutrient due sedimentation along stream lead to establishing different vegetation

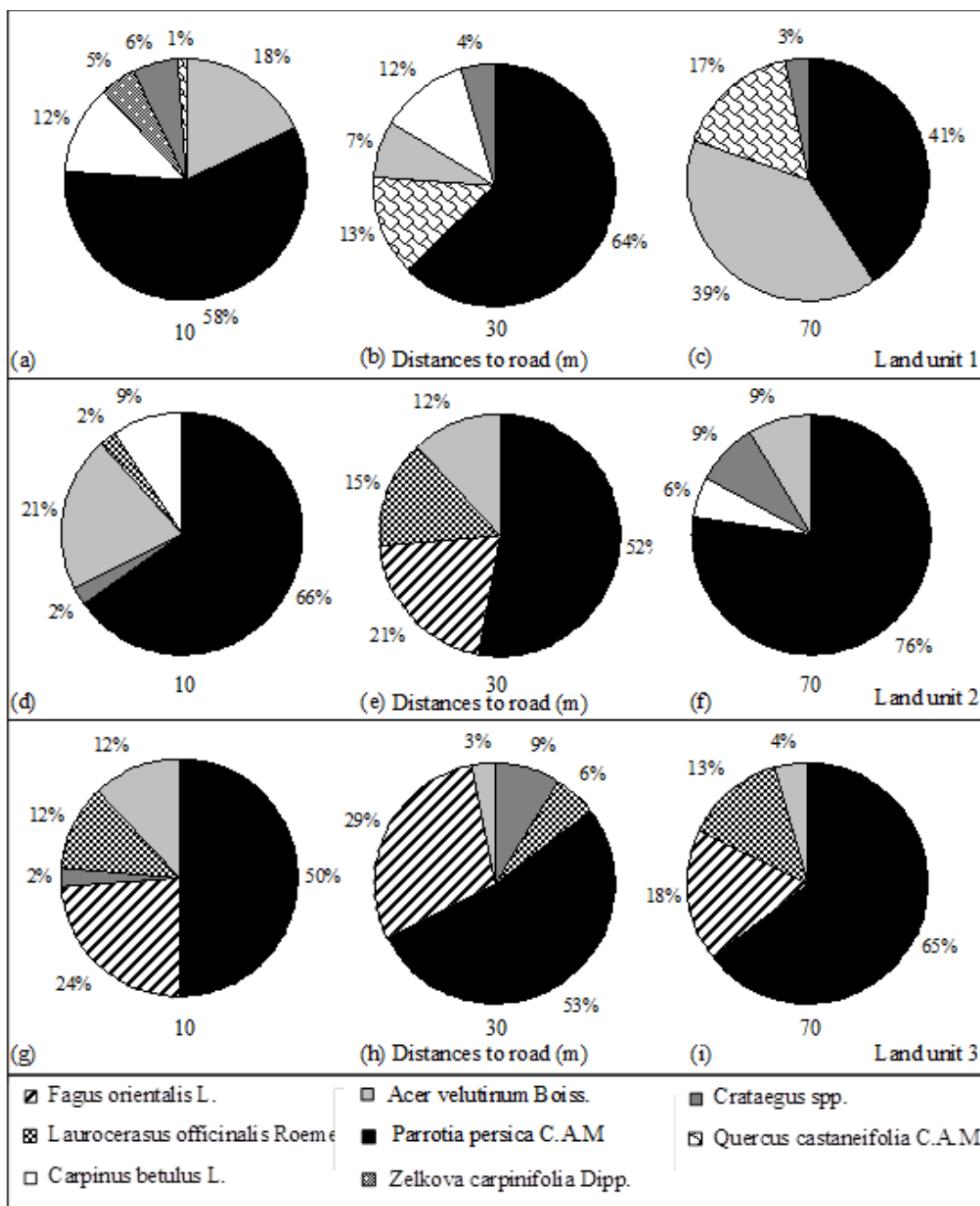


Figure 3. Frequency percentage of tree species at different distances from road.

Table 2. Mean of biodiversity indices at different distances from road.

Index Distance	Heterogeneity Shannon	Evenness Camargo	Richness Margalef
10	2.03 ^a	0.63 ^a	1.96 ^a
30	1.91 ^a	0.69 ^a	1.97 ^a
70	1.64 ^b	0.67 ^a	1.67 ^b

Columns with different superscripts show significant difference at $p < 0.05$ in SNK test.

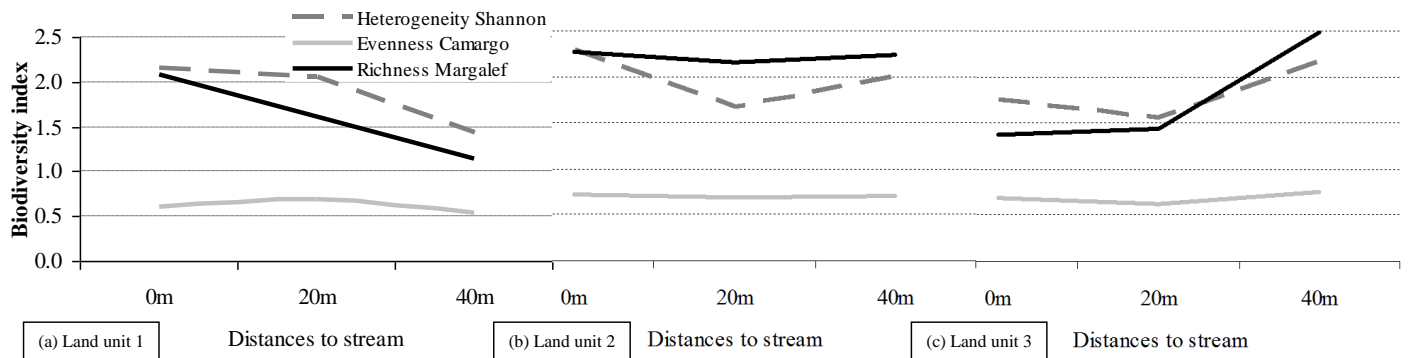


Figure 4. Variations of biodiversity indices at different distances from stream.

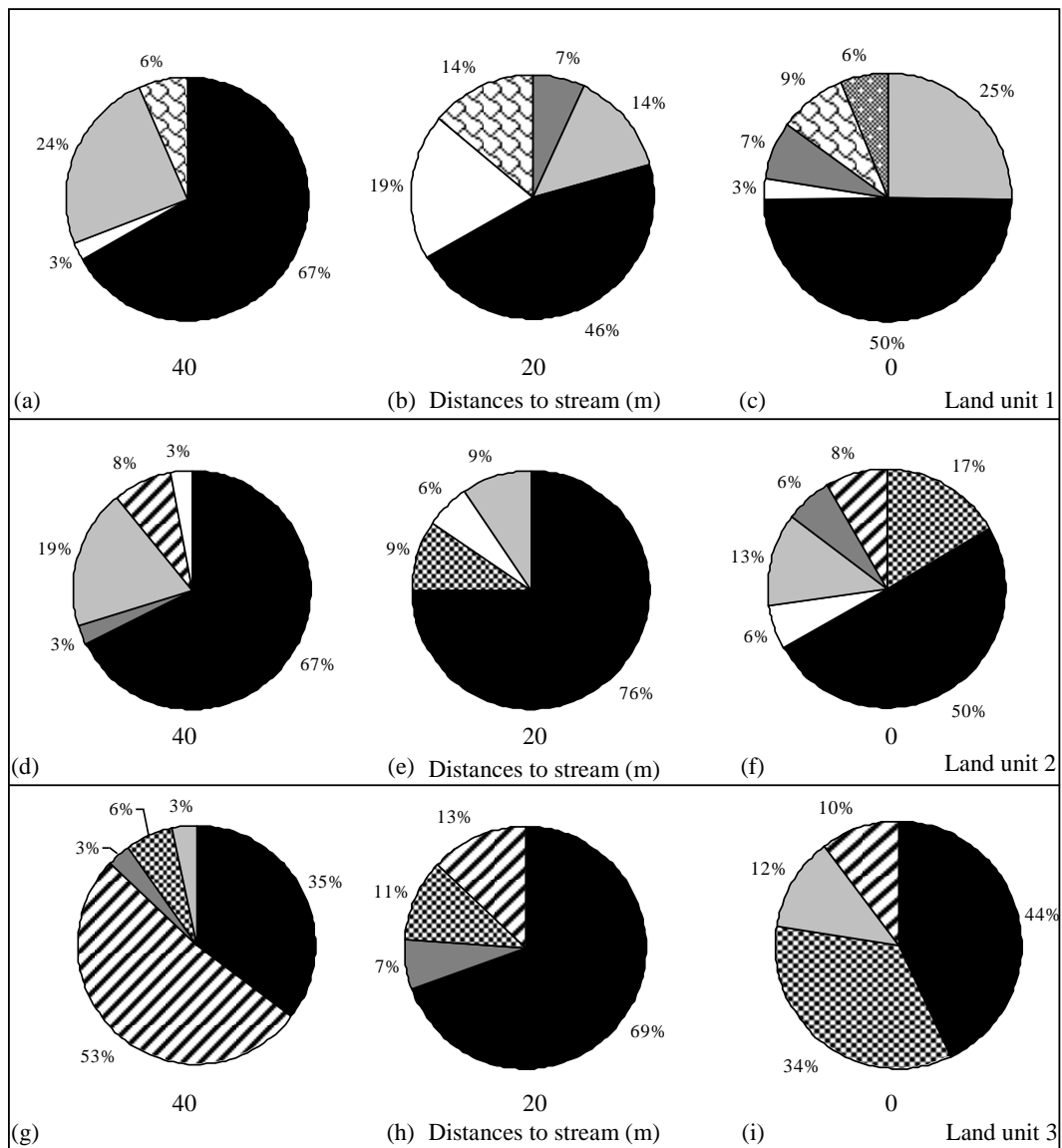


Figure 5. Frequency percentage of tree species at different distances from stream.

Table 3. Mean of biodiversity indices at different distances from stream.

Index distance	Heterogeneity Shannon	Evenness Camargo	Richness Margalef
0	2.06 ^a	0.67 ^a	1.91 ^a
20	1.75 ^c	0.67 ^a	1.74 ^b
40	1.86 ^b	0.66 ^a	1.95 ^a

Columns with different superscripts show significant difference at $p < 0.05$ in SNK test.

species on these soil.

Several authors have observed that soil moisture, organic matter content, bulk density, pH and light regime change significantly within the narrow width of the road and stream corridor, affecting plant community composition and the pattern of roadside plant communities (Lausi and Nimis, 1985; Ullman et al., 1995; Olander et al., 1998; Cilliers and Bredenkamp, 2000; Delgado et al., 2007; Karim and Mallik, 2008).

Conclusions

It was concluded that biodiversity index decreases with increasing distance from road edge and stream. Shannon heterogeneity index at the edge of stream was more than that of road edge. Indeed trees species diversity tended to increase at the edge of forest roads and streams in our study area. The frequency of *P. persica* C.A.M. was more than that of other species in all land units. These results provide important information for forest managers for managing plant species composition and maintaining the integrity of biological communities.

Conflict of Interests

The author(s) have not declared any conflict of interests.

REFERENCES

- Calçada EA, Closset-Kopp D, Gallet-Moron E, Lenoir J, Rêve M, Hermy M, Decocq G (2013). Streams are efficient corridors for plant species in forest metacommunities. *J. Appl. Ecol.* 50(5):1152-1160.
- Cilliers SS, Bredenkamp GJ (2000). Vegetation of road verges on an urbanization gradient in Potchefstroom, South Africa. *Land. Urb. Plan.* 46:217-239.
- Delgado JD, Arroyo NL, Arévalo JR, Fernández-Palacios JM (2007). Edge effects of roads on temperature, light, canopy cover, and canopy height in laurel and pine forests (Tenerife, Canary Islands). *Land. Urb. Plan.* 81:328-340.
- Feng L, Li XR, Guo Q, Zhang JG, Zhang ZS (2011). Effects of highway on the vegetation species composition along a distance gradient from road edge in southeastern margin of Tengger Desert. *Ying Yong Sheng Tai Xue Bao.* 22(5):1114-1120.
- Ferris R, Peace AJ, Humphrey JW, Broome AC (2000). Relationships between vegetation, site type and stand structure in coniferous plantations in Britain. *For. Ecol. Manage.* 136:35-51.
- Hansen MJ, Clevenger AP (2005). The influence of disturbance and habitat on the presence of non-native plant species along transport corridors. *Biol. Conserv.* 125:249-259.
- Karim MN, Mallik AU (2008). Roadside revegetation by native plants I. Roadside microhabitats, floristic zonation and species traits. *Ecol Eng.* 32:222-237.
- Lausi D, Nimis T (1985). Roadside vegetation in boreal South Yukon and adjacent Alaska. *Phytocoenologia.* 13:103-138.
- Li Y, Yu J, Ning K, Du S, Han G, Qu F, Wang G, Fu Y, Zhan C (2014). Ecological Effects of Roads on the Plant Diversity of Coastal Wetland in the Yellow River Delta. *The Scientific World Journal.* Article ID 952051, 8 pages.
- Li YH, Hu YM, Chang Y, Li XZ, Bu RC, Hu CH, Wang CL (2010). Effect zone of forest road on plant species diversity in Great Hing'an Mountains. *Ying Yong Sheng Tai Xue Bao.* 21(5):1112-1119.
- Olander LP, Scatena FN, Silver LW (1998). Impacts of disturbance initiated by road construction in a subtropical clouds forest in the Luquillo Experimental Forest, Puerto Rico. *For. Ecol. Manage.* 109:33-49.
- Pretzsch H (2009). *Forest dynamics, growth and yield.* ISBN: 978-3-540-88306-7. Springer publications, 664 pp.
- Scalley TH, Crowl TA, Thompson J (2009). Tree species distributions in relation to stream distance in a mid-montane wet forest, Puerto Rico. *Caribbean J. Sci.* 45(1):52-63.
- Ullman L, Bannister P, Wilson JB (1995). The vegetation of roadside verges with respect to environmental gradients in southern New Zealand. *J. Veg. Sci.* 6:131-142.
- Watkins RZ, Chen J, Pickens J (2003). Effects of forest roads on understory plants in a managed hardwood landscape. *Conserv. Biol.* 17:411-419.
- Yue-hui L, Yuan-man H, Yu C, Xiu-zhen L, Ren-cang B, Chang-he H, Chun-lin W (2010). Effect zone of forest road on plant species diversity in Great Hing'an Mountains. *Chinese J. Appl. Ecol.* 21(5):1112-1119.
- Zhou T, Peng S, Wu J, Liu J, Wu K (2010). Edge effects of roads on forest plant diversity and ecosystem properties: A case study from Southern China", *The Preliminary Program for 95th ESA Annual Meeting, Pennsylvania* (August 1-6), 10 pp.

Full Length Research Paper

Vegetation diversity and soil nutrient status of submergence zone of hydroelectric project in Srinagar of Garhwal Himalayas, India

Sajed Saleem and Munesh Kumar*

Department of Forestry and Natural Resources, HNB Garhwal University, Srinagar Garhwal, Uttarakhand, India.

Received 14 July, 2014; Accepted 5 November, 2014

The aim of the present study was to assess vegetation diversity and soil nutrients status in submergence zone of hydroelectric project in Srinagar Garhwal Himalaya. The information on submergence zone was taken from hydroelectric project (HEP), the height of the dam is 93 m and subsequently submergence zone area will be developed. The submergence zone is presently under open condition and soon after completion of project work, the area will be submerged. The analysis of vegetation was done using quadrats method, and soil physico-chemical analysis was done using standard methods. The results indicate that average moisture percent of the study area was 7.78 %, water holding capacity 30.56% and bulk density 1.28 g m^{-3} . The soil pH was slightly basic (7.33). The soil organic carbon (SOC) was 0.23%. The amount of phosphorus (P) and potassium (K) were reported to be 12.25 and 103.07 kg ha^{-1} , respectively. The species diversity (H) ranged from H = 0.39-3.26 (trees) H = 1.84-3.01 (shrubs), H = 0.08-0.23 (herbs) and concentration of dominance (CD) ranged from CD=0.12-0.86 (trees), CD = 0.14 to 0.31 (shrubs), CD = 0.08-0.23 (herbs) however beta-diversity (β) ranged from β -2.72-4.0 (trees), β -3.10-4.0 (shrubs), β -4.93-9.77 (herbs). In the submergence zone, villagers are directly dependent on the resources traditionally for fuel, fodder, timber and many other things and have cultural and emotional attachment. Soon after submergence, the resources pressure of villager will be shifted to the adjacent forest (influenced zone). Therefore, special attention is needed through awareness of the villagers to restore the vegetation of adjacent forest from further degradation.

Key words: Submergence, plant and soil resources, hydroelectric project, Garhwal Himalaya.

INTRODUCTION

Biodiversity is essential for human survival, economic well-being and for the ecosystem function and stability (Singh, 2002). Biodiversity is essential to humankind,

brings innumerable benefits, and has other importance values although humans have had strong negative impacts on biodiversity. Various ecosystem functions and

*Corresponding author. E-mail: muneshmzu@yahoo.com. Tel/Fax: +911370267483.

services may be negatively affected by the loss of biodiversity (Schulze and Mooney, 1994). Habitat destruction, over exploitation, pollution and species introduction are the major causes of biodiversity loss (UNEP, 2001). Depletion of biodiversity is today's alarming problem all over the world. Extinction rate has been enhanced by human intervention resulting into habitat loss and climate change. Human have extensively altered the global environment, changing global bio-geological cycles, transforming land and enhancing the mobility of biota. Many species have been eliminated from areas dominated by human influences (Chapin III et al., 2000). The human influences on biodiversity and ecosystem are rapid and large, leading to frequent changes in land and resource use, increased frequency of biotic invasions, reduction in species number, creation of stresses and the potential for changes in the climate system (Kumar and Ram, 2005). The loss of biodiversity actually hampers and contrasts economic development (Kim and Weaver, 1994). The depletion of biodiversity is an alarming problem of the world. The rate of extinction has been enhanced by human-related habitat loss and climate change (Singh and Kushwaha, 2008).

Major causes of habitat destruction in the river valleys is construction of large hydroelectric projects, which have several benefits such as power, irrigation, tourism and industrial development, etc. But from biodiversity point of view, such projects are unethical as they impede the biological web of the environment, as a large hydro project leads to a complete alteration of a terrestrial habitat into an aquatic ecosystem (Gaur, 2007). Modifications in normal flow of river systems result in several complexities to people, forests, fauna, flora, microorganisms and land use pattern (Sharma, 2006). Gauthier et al. (2000) described that the vegetation dynamics of forest systems are controlled by numerous factors such as the available pool of species, the physical characteristics of the land, soil fertility, climate and disturbance regime characteristics.

Human and biological resources relations are closely linked. Human beings are taking several resources from the forests, but when the resources are exploited ruthlessly, it degrades the resources and hamper its further survival.

Keeping in view the importance of biodiversity and the consequent losses caused due to human activities, like road constructions, urbanization, dam constructions, etc., the present study was taken to assess the vegetation diversity and soil nutrient status in submergence zone of hydroelectric project in Srinagar valley, which may lost after submergence and affect the need of local inhabitants. Thus, the study was designed with the objectives: i) Assessment of vegetation diversity of proposed submergence zone of hydroelectric project on Alaknanda river, ii) soil nutrient status of the submergence zone, iii) Documentation of uses value of plants and iv) Possible recommendations for the conser-

vation measures of vegetation diversity and soil nutrient status of the submergence zone.

METHODS

Study area

The study was conducted in the proposed submergence zone of hydroelectric project (HEP) of River Alkananda in Srinagar Garhwal Himalayas between the villages of Supana and Dhari Devi, covering a distance of 12 km approximately (Figure 1). A total of five sites, that is, site-I, II, III, IV and V were selected in the entire zone of 12 km. Each site was selected at 2 km interval to cover the complete zone with suitable representative samples of the study area. The River Alaknanda originates in the glacial region (Alkapuri glacier) of Himalaya in Chamoli district of Uttarakhand and enters district Pauri and Tehri Garhwal in Srinagar. The study was carried out in the right side of river flow from east to west direction which is proposed submergence zone of HEP, the area is located between 30° 14.472' N latitude and 78° 49.953' E longitude at an elevation ranging between 535-630 m from initial river flow. The identification marks of the study area for the soil and vegetation analysis in submergence zone was categorized with the help of GPS. The total height of dam is expected to be 93 m which is marked from the initial river flow at an elevation of 535 m above sea level marked in winter season.

Climate and vegetation

The climate of the study area is of monsoon type and has three different marked seasons in a year, viz., rainy, winter and summer. The mean annual temperature ranges between 17 to 23°C and the mean annual rainfall 960 mm. The forest was dominated by *Anogeissus latifolia* in tree layer and associated with *Acacia catechu* and *Lannea coromandelica* and in shrub species, *Carissa opaca* was observed dominant. The surrounding peaks are covered by *Pinus roxburghii* trees associated with *A. latifolia* in lower transitional boundaries.

Soil sampling and analysis

The soil sampling in submergence zone was done by categorizing total area into five sub-sites. The soil characteristic of each sub-site was done by collecting three samples randomly from two different depths, that is, 0-30, 30-60 cm. From each site, six samples were collected (two depths and 3 replicates each). Thus, from entire zone, 30 samples were collected for analysis. The collected soil samples were placed in a clean dried polythene bags with suitable description and identification marks. The collected soil samples were screened for coarse concentrations, stones, pieces of roots, leaves and other undecomposed or organic residues which were later removed. The samples were mixed well individually before use and were air dried at 20 to 25°C and 20 to 60% relative humidity (Jackson, 1958).

The moisture (%) was calculated by samples placed in oven at 100±2°C till their successive weights were constant. Water holding capacity (WHC) and texture of soil was determined as the methods described by Misra (1968). Soil bulk density (BD) was determined by the known volume of soil without disturbing the natural soil structure dried to remove moisture content. Soil pH was calculated with the help of dynamic digital pH meter by making (1:2.5, soil: water) solution. Soil organic carbon (SOC) was determined by Walkley and Black's rapid titration method (Walkley and Black, 1934). Exchangeable phosphorus (P) and available potassium



Figure 1. Location map of the study area.

(K) was determined as methods described by Jackson (1958).

Vegetation sampling and analysis

The vegetation sampling and analysis was carried out by placing 10

quadrats in each site and the total number of quadrats for entire submergence zone was fifty (50). The size of quadrat for trees was 100 m² and 10 quadrats which were randomly placed, 25 m² for shrubs and 1 m² for herbs was used in each site. The size and number of quadrats were determined based on species area curve (Misra, 1968) and the running means methods (Kershaw, 1973). In

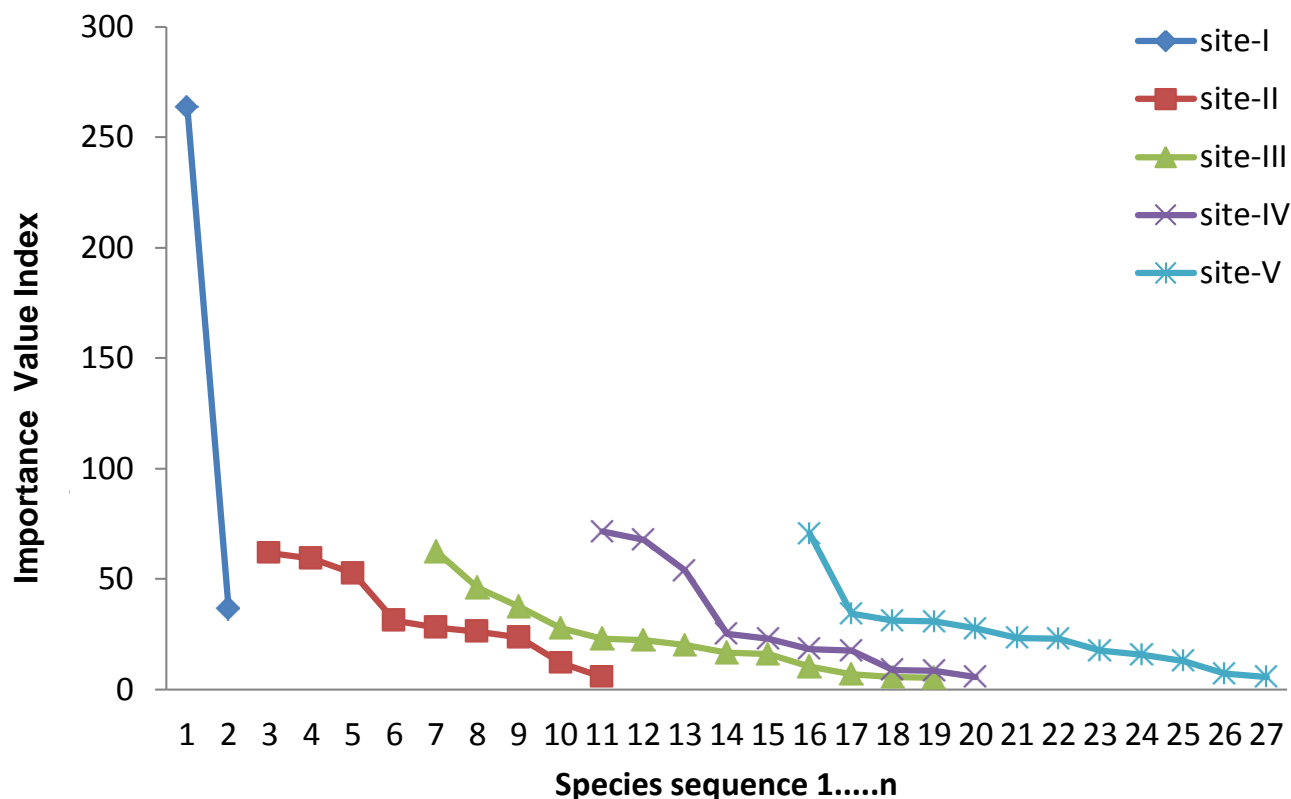


Figure 2. Dominance-diversity curve of trees on different sites.

each quadrat, the tree was considered having girth ≥ 30 cm (at 1.37 m from the ground). The quantitative analysis of vegetation was done according to Curtis and McIntosh (1950). Importance value index (IVI) was calculated as sum of the relative frequency + relative density + relative dominance (Curtis, 1959) for trees and shrubs while for herbs importance value (IV) was calculated as sum of relative frequency + relative density. Abundance to frequency ratio (A/F ratio) was determined for different species as regular (<0.025), random ($0.025-0.05$) and contagious (>0.05) following Curtis and Cottam (1956). Diversity index (H) was calculated using as the method described by Shannon and Wiener (1963), as: $H' = -\sum (N_i/N) \log_2 (N_i/N)$, where 'N_i' is total number of species 'i' and 'N' is the number of individuals of all species in that site. Concentration of dominance (CD) was also calculated as per Simpson (1949), as: $CD = \sum (N_i/N)^2$, where 'N_i' and 'N' is the same as Shannon and Wiener information index. The beta-diversity (β -diversity) was calculated using following formula as: $B\text{-diversity} = S_c/S$, where $S_c = \alpha$ -diversity (species richness, S = total number of species that occurred in all sampling unit/total number of sampling unit. Dominance-diversity (D-D) curve was plotted between importance value index and species rank of trees (Figure 2) and shrubs (Figure 3). The curves indicate relationship among different species which shows the importance value of the site. The flora of Chamoli (Naithani, 1984) and Flora of western Himalayas (Gaur, 1999) were consulted for the identification of species. The details of species, their uses, parts used for different purposes by local inhabitant are based on secondary data (Table 6).

Similarity index

The similarity index was calculated using method given by Sorenson

(1948) as followed: $IS = 2C/A+B$, where A = total number of species in forest A, B = total number of species in forest B and C = number of species common in A and B forests.

Social status of the inhabitants

The living standards of the people close to HEP were of all categories but most of them are poor. Although through dam compensation, for various purposes the living standard of people is improved. The cropping pattern of the area is of both types, rain fed and irrigated but most of the agriculture land is rain fed and has been affected under dam developmental activities. Some of the lands become unproductive due to dam construction work. Now the land holding of surrounding villagers have changed into small land holding and the agriculture productivity also affected, therefore agriculture based dependency of animals is also affected and utilizing forest resources for generating their income.

RESULTS

Soil properties

In the entire study area, the moisture content of the soils was highest on site-I followed by sites of II, III, V and lowest on IV, however, the water holding capacity was highest on site-III and lowest on site-IV (Table 1). The bulk density was reported highest on site IV followed by site-II, V and lowest was on site-I. In texture (%), the

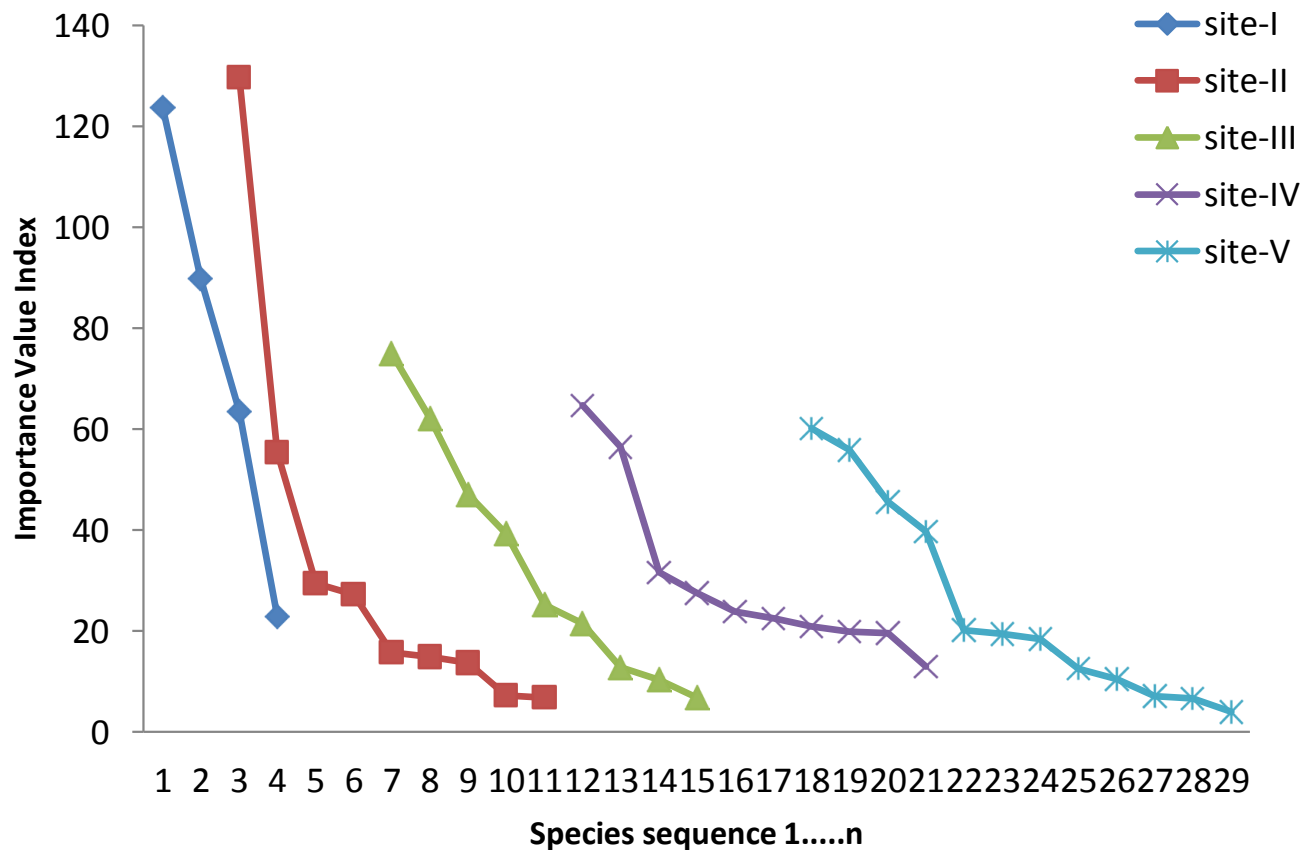


Figure 3. Dominance-diversity curve of shrubs on different sites.

maximum proportion of soil particles was contributed by sand particles on all the sites. The soil pH on all sites was slightly basic in nature. The minimum and maximum percentage of soil organic carbon was 0.16% and 0.28% on site-I and site-V. The soil organic carbon on each site reduced with increasing depth. Phosphorus (P) on each site reduced with depth except on site-II where, the amount of phosphorus was higher on lower depth. Among the site, the highest value of phosphorus was on site-II and lowest on site-I. Minimum and maximum amount of potassium was reported on site-I and site-III respectively (Table 1).

Dominance and species composition

Trees

On site-I, only two species, that is, *A. latifolia* and *Leucena leucocephala* were recorded of which the highest density and total basal cover was recorded for *A. latifolia* followed by *L. leucocephala* (Table 2). On site-II, a total of nine tree species were recorded where, *Holoptelia integrifolia* was the most dominant and *Cassia fistula* least dominant. The density was highest for *H.*

integrifolia and lowest for *C. fistula*. While total basal cover was highest for *Mangifera indica* and lowest for *C. fistula*. Other associated species on the site were *A. latifolia*, *Adina cordifolia*, *Mallotus philippensis*, *Aegle marmelos* and *Phoenix humilis*. On site-III, total thirteen species were recorded. The most and least dominant trees were *A. latifolia* and *Emblica officinalis* respectively. The density and total basal cover reported highest for *A. latifolia* and least total basal cover for *E. officinalis* and *Lannea coromandelica* however, least density for *H. integrifolia*, *Ficus bengalensis* and *E. officinalis*. Other associated species were *Acacia catechu*, *Mangifera indica*, *Aegle marmelos*, *Toona ciliata*, *Grewia oppositifolia*, *Ficus religiosa* and *Leucena leucocephala*. On site-IV, ten species were recorded. The highest values of importance value index, density and total basal cover were recorded for *A. latifolia*. The least total basal cover and importance value index was for *Toona ciliata*. The other species were *Acacia catechu*, *Mallotus philippensis*, *Aegle marmelos*, *Toona ciliata*, *Bauhinia variegata*, *F. religiosa*, *Lannea coromandelica* and *Leucena leucocephala*. On site-V, a total of twelve species were recorded where, the most and least dominant trees reported *A. latifolia* and *Bauhinia variegata*. The total basal cover, frequency and density

Table 1. Soil characteristics in different sites of submergence zone of hydroelectric project.

Site	Depth (cm)	Moisture (%)	WHC (%)	BD (g cm ³)	Sand (%)	Silt (%)	Clay (%)	pH (1:2.5 ratio)	SOC (%)	Phosphorus (kg/ha)	Potassium (kg/ha)
Site-I	0-30	10.57±1.39	34.40±3.65	1.11 ±0.08	61.51 ±9.07	17.3 ±5.84	21.22±4.15	7.2±0.36	0.2±0.05	11.05±2.08	128.05±21.84
	30-60	9.24±2.06	34.24±4.32	1.09±0.13	63.73±11.01	16.75±6.70	19.62±4.89	7.5±0.2	0.12±0.04	5.52±0.62	60.89±17.56
Site-II	0-30	9.76±2.15	34.16±1.03	1.28±0.25	59.88±16.93	23.02±12.12	17.1±4.98	7.1±0.06	0.3±0.02	13.62±1.94	145.97±19.15
	30-60	6.86±1.30	34.15±1.80	1.31±0.07	56.80±17.70	23.72±13.34	19.47±4.52	7.6±0.17	0.15±0.04	21.90±0.74	65.57±10.64
Site-III	0-30	9.76±4.13	28.78±1.84	1.08±0.02	65.69±6.13	14.47±2.19	19.84±3.98	7.2±0.17	0.30±0.04	15.29±2.48	158.29±23.23
	30-60	6.53±2.05	26.34±0.96	1.34±0.05	62.97±5.40	14.45±2.58	22.59±2.81	7.6±0.12	0.13±0.03	5.92±1.78	75.04±7.84
Site-IV	0-30	4.47±1.41	23.11±1.03	1.64±0.08	49.85±6.92	25.15±7.90	25.01±1.86	7.1±0.2	0.34±0.04	15.89±4.28	141.87±5.17
	30-60	5.94±0.84	26.44±1.12	1.51±0.06	50.53±6.89	25.60±8.27	23.87±4.13	7.7±0.17	0.15±0.03	6.71±4.20	60.48±2.96
Site-V	0-30	6.27±1.05	30.66±2.44	1.24±0.22	67.37±12.82	16.45±4.28	16.18±8.57	6.8±0.21	0.4±0.06	18.75±0.90	142.24±13.44
	30-60	8.41±4.83	33.34±1.88	1.24±0.19	62.78±12.87	17.72±8.68	19.50±4.36	7.5±0.25	0.16±0.06	7.89±3.33	52.27±9.53

values were also highest for *A. latifolia*. The associated species on the site were *Acacia catechu*, *Mallotus philippensis*, *Aegle marmelos*, *Toona ciliata*, *F. religiosa*, *F. bengalensis*, *Cassia fistula*, *Ficus carica*, *Lannea coromandelica* and *L. leucocephala* (Table 2).

Shrubs

On site-I, four species of shrub were reported of which *Mimosa himalayana* was the most dominant and *Eupatorium adenophorum* least dominant. The highest total basal cover was for *M. himalayana* and least for *E. adenophorum*. The highest density was for *Carissa opaca*.

On site-II, a total of 9 species were reported. The highest total basal cover, density and importance value index was for *Adhatoda vasica*, however lowest total basal cover of *Lantana*

camara and density and importance value index for *Randia tetrasperma*. Other associated species were *Mimosa himalayana*, *Murraya koenigii*, *Carissa opaca*, *Abrus precatorius*, *Sida cordifolia*, *Euphorbia royleana* (Table 3).

On site-III, dominant shrub was *Adhatoda vasica* while highest total basal cover and density were reported for *E. royleana* and *Adhatoda vasica* respectively. The other associated species reported on this site were *Woodfordia fruticosa*, *Ricinus communis*, *Plumbago zeylanica*, *Carissa opaca*, *Mimosa himalayana* and *Abrus precatorius*.

On site-IV, a total 10 species were reported where the most dominant and the least dominant species were *A. vasica* and *E. adenophorum* respectively. The highest total basal cover and density on the site was for *A. vasica*. The associated species were *W. fruticosa*, *R. communis*, *C. opaca*, *M. himalayana*, *Euphorbia*

royleana, *Murraya koenigii*, *Lantana camara*.

On site-V, Twelve species were reported with dominant species *Euphorbia royleana* and least dominant *R. communis*. The highest total basal cover and density was of *E. royleana* and *A. vasica* respectively. However, least total basal cover and density was for *R. communis*. The highest frequency was recorded for *C. opaca* and *M. koenigii*. The associated species on the site were *Ziziphus mauritiana*, *Rhus parviflora*, *Lantana camara*, *Colebrookia oppositifolia* and *Sida cordifolia* (Table 3).

Herbs

On site-I, ten species were reported with the highest importance value of *Peristrophe bicalyculata* and lowest for *Achyranthes aspera*. The highest and lowest values of density were

Table 2. Density (Ind. ha⁻¹), total basal cover (m² ha⁻¹), A/F ratio of trees on different sites in submergence zone of hydroelectric project.

Species	Site-I			Site-II			Site-III			Site-IV			Site-V		
	Density	TBC	A/F ratio	Density	TBC	A/F Ratio	Density	TBC	A/F ratio	Density	TBC	A/F Ratio	Density	TBC	A/F ratio
<i>Anogeissus latifolia</i>	120	1.7	0.075	50	2.65	0.056	210	4.25	0.058	150	2.96	0.031	130	5.17	0.052
<i>Leucena leucocephala</i>	10	0.2	1.250	-	-	-	20	0.55	0.050	30	0.44	0.033	30	0.25	0.033
<i>Acacia catechu</i>	-	-	-	180	4.69	0.037	120	1.54	0.033	50	0.91	0.056	70	1.12	0.044
<i>Mengifera indica</i>	-	-	-	60	11.73	0.067	30	2.34	0.017	-	-	-	-	-	-
<i>Adina cordifolia</i>	-	-	-	80	1.76	0.050	160	2.24	0.044	130	2.58	0.020	60	1.42	0.038
<i>Mallotus philippensis</i>	-	-	-	90	1.71	0.100	-	-	-	40	0.88	0.044	110	1.20	0.123
<i>Holoptelia integrifolia</i>	-	-	-	190	6.08	0.053	10	0.36	0.100	-	-	-	-	-	-
<i>Aegle marmelos</i>	-	-	-	80	2.83	0.050	50	0.97	0.125	20	0.24	0.200	30	0.31	0.075
<i>Phonex humilis</i>	-	-	-	20	1.02	0.050	-	-	-	-	-	-	-	-	-
<i>Cassia fistula</i>	-	-	-	10	0.45	0.100	-	-	-	-	-	-	60	0.64	0.067
<i>T oona ciliata</i>	-	-	-	-	-	-	40	2.44	0.100	10	0.11	0.100	-	-	-
<i>Ficus bengalensis</i>	-	-	-	-	-	-	10	0.64	0.100	-	-	-	10	0.37	0.100
<i>Grewia oppositifolia</i>	-	-	-	-	-	-	90	1.84	0.100	-	-	-	-	-	-
<i>Ficus religiosa</i>	-	-	-	-	-	-	20	1.84	0.050	10	0.51	0.100	20	2.07	0.050
<i>Embllica officinalis</i>	-	-	-	-	-	-	10	0.32	0.100	-	-	-	-	-	-
<i>Lannea comandelica</i>	-	-	-	-	--	-	50	0.32	0.020	100	2.93	0.063	60	1.82	0.150
<i>Bauhinia variegata</i>	-	-	-	-	-	-	-	-	-	20	0.38	0.050	10	0.13	0.100
<i>Ficus carica</i>	-	-	-	-	-	-	-	-	-	-	-	-	60	0.32	0.150

reported for *Solanum nigrum* and *Oxalis corniculata*. The other associated species on the site were *Parthenium hysterophorus*, *Tridax procumbens*, *Euphorbia hirta*, *Bidens pilosa*, *Gnaphalium luteo-album* and *Leptadenia reticulata*.

On site-II, a total of 22 species were recorded. The highest importance value was for *Poa annua* and lowest for *Sida acuta*. The associated species on the site observed were *Achyranthes aspera*, *Barleria strigosa*, *Nepeta hindostana*, *Sida cordifolia*, *Borreria articularis*, *Abrus precatoricus*, *Debregeasia longifolia*, *Solanum nigrum*, *Bidens pilosa*, *Blepharis maderaspatensis*, *Lamium*

amplexicaule, *Chenopodium album*, *Gnaphalium luteo-album*, *Adiantum incisum*, *Cynodon dactylon*, *Euphorbia hirta*, *Brassica rugosa*, *Parthenium hysterophorus*, *Cymbopogon martinii* and *Thysanolaena maxima*.

On site-III, sixteen species were reported. The highest and lowest values of importance value and density were reported for *Andropogon munroi* and *Asparagus racemosus* (Table 4). The associated species were *Phymbeyo zeylanica*, *Cryptolapis buehananii*, *Parthenium hysterophorus*, *Cissampelos pareira*, *Chenopodium album*, *Cynodon dactylon*, *Solanum nigrum*, *Poa annua*, *Gnaphalium luteo-album*,

Achyranthes aspera, *Peristrophe bicalyculata*, *Barleria cristata* and *Lamium amplexicaule*.

On site IV, Out of eighteen species, the highest importance value was reported for *Parthenium hysterophorus* and lowest for *Asclepias curassavica*. The highest density was of *Andropogon munroi* and lowest for *Asclepias curassavica*. The other associated species were *Adiantum incisum*, *Reinwardtia indica*, *Coccinia grandis*, *Ipomoea nil*, *Peristrophe bicalyculata*, *Barleria cristata*, *Cynodon dactylon*, *Asclepias curassavica*, *Boehreria diffusa*, *Achyranthes aspera*, *Evolvulus alsinoides*, *Oxalis corniculata*, *Debregeasia longifolia*, *Poa corniculata*, *Euphor-*

Table 3. Density (ind. 25m²), total basal cover (cm² 25 m²) of shrubs on different sites in submergence zone of hydroelectric project.

Species	Site-I			Site-II			Site-III			Site-IV			Site-V		
	Density	TBC	A/F ratio	Density	TBC	A/F ratio	Density	TBC	A/F ratio	Density	TBC	A/F ratio	Density	TBC	A/F ratio
<i>Adhatoda vasica</i>	1.9	0.06	0.211	9	0.115	0.090	5.4	0.016	0.084	2.9	0.04	0.080	4.1	0.036	0.164
<i>Mimosa himalayana</i>	1.3	0.94	0.325	1.5	0.031	0.375	2.1	0.010	0.084	2.6	0.03	0.067	0.3	0.009	0.300
<i>Murraya koenigii</i>	-	-	-	3.3	0.040	0.092	4.2	0.013	0.086	1.4	0.02	0.157	4.0	0.070	0.112
<i>Carissa opaca</i>	2.8	0.09	0.175	0.9	0.006	0.225	1.2	0.012	0.300	1.1	0.01	0.123	2.9	0.025	0.081
<i>Abrus precatorius</i>	-	-	-	0.9	0.009	0.225	0.4	0.005	0.400	-	-	-	-	-	-
<i>Lantana camara</i>	-	-	-	0.4	0.003	0.400	-	-	-	1.9	0.01	0.475	0.5	0.021	0.500
<i>Sida cordifolia</i>	-	-	-	0.8	0.005	0.200	-	-	-	-	-	-	-	-	-
<i>Randia tetrasperma</i>	-	-	-	0.3	0.004	0.300	-	-	-	-	-	-	-	-	-
<i>Euphorbia royleana</i>	-	-	-	0.8	0.057	0.800	1.0	0.039	0.250	0.4	0.02	0.100	1.8	0.170	0.113
<i>Eupatorium adenophorum</i>	0.7	0.03	0.700	-	-	-	-	-	-	0.4	0.01	0.400	-	-	-
<i>Woodfordia fruticosa</i>	-	-	-	-	-	-	0.4	0.008	0.400	0.4	0.03	0.400	-	-	-
<i>Ricinus communis</i>	-	-	-	-	-	-	0.6	0.009	0.067	0.9	0.01	0.058	0.1	0.002	0.100
<i>Plumbago zeylanica</i>	-	-	-	-	-	-	0.2	0.003	0.200	-	-	-	-	-	-
<i>Rhus parviflora</i>	-	-	-	-	-	-	-	-	-	0.6	0.01	0.150	0.3	0.069	0.300
<i>Ziziphus mauritiana</i>	-	-	-	-	-	-	-	-	-	-	-	-	0.4	0.008	0.400
<i>Colebrookia oppositifolia</i>	-	-	-	-	-	-	-	-	-	-	-	-	1.8	0.016	0.450
<i>Sida cordifolia</i>	-	-	-	-	-	-	-	-	-	-	-	-	1.1	0.015	0.123
<i>Aerva sanguinolenta</i>	-	-	-	-	-	-	-	-	-	-	-	-	0.9	0.007	0.225

Bia hirta and *Tridax procumbens*.

On site-V, a total of 17 species were reported, where the highest importance value among species was for *Andropogon munroi* and lowest of *A. racemosus*. The highest density again was reported for *Andropogon munroi* and lowest for *A. racemosus*. The other associated species were *Ipomoea nil*, *Chenopodium album*, *Adiantum incisum*, *Barleria strigosa*, *Boehreria diffusa*, *Parthenium hysterophorus*, *Cynodon dactylon*, *Cissampelos pareira*, *Achyranthes aspera*, *Poa annua*, *Oxalis corniculata*, *Euphorbia hirta*, *Rubia manjitha*, *Anisochilus carnosus* and *Tridax procumbens* (Table 4).

Species richness

In tree layer, among the sites, the maximum species richness (13 species) was on site-III and minimum richness (2 species) on site-I. Among the shrub, the richness was highest on site-V and lowest on site-I. In herb layer, the maximum species were on site-II (22 species) and minimum (10 species) on site-I (Table 5).

Distribution pattern (%)

In tree layer (Table 2), on site-I, the distribution pattern of both species was contagious. On site-II,

the distribution pattern of all species was contagious, and some of the species were distributed randomly and none of the species were reported regularly in distribution. On site-III, maximum species were distributed contagiously. *M. indica* and *L. coromandelica* were distributed regular and rests of the species were distributed randomly. On site-IV, the distribution pattern of most species was contagious except of *Mallotus philippensis*, *Anogeissus latifolia* and *L. leucocephala* which were distributed random and *Adina cordifolia* regularly (site-IV). On site V, among the species, majority of species were distributed contagiously, few random and none of

Table 4. Density (ind. m²), IV (importance Value) and A/F ratio of herbs on different sites in submergence zone of hydroelectric project.

Species	Site-I			Site-II			Site-III			Site-IV			Site-V		
	Density	IV	A/F ratio	Density	IV	A/F ratio	Density	IV	A/F ratio	Density	IV	A/F ratio	Density	IV	A/F ratio
<i>Solanum nigrum</i>	1.85	43.6	0.074	0.35	11.0	0.152	0.25	5.3	0.250	-	-	-	-	-	-
<i>Achyranthes aspera</i>	0.2	4.5	0.8	0.25	5.1	0.250	0.15	2.8	0.600	0.15	3.4	0.150	0.35	8.0	0.088
<i>Parthenium hysterophorus</i>	0.8	20.5	0.128	1.4	16.1	0.363	2.4	30.3	0.150	4.25	36.2	0.118	2	24.5	0.099
<i>Tridax procumbens</i>	1.9	39.1	0.119	-	-	-	-	-	-	0.5	5.1	0.500	0.7	9.9	0.175
<i>Euphorbia hirta</i>	0.25	7.5	0.25	0.25	3.4	0.200	-	-	-	0.35	4.3	0.350	1.55	20.6	0.097
<i>Oxalis corniculata</i>	0.15	6.5	0.15	-	-	-	-	-	-	1.6	15.6	1.177	0.25	4.4	0.250
<i>Bidens pilosa</i>	0.65	11.5	0.65	0.25	3.4	1.000	-	-	-	-	-	-	-	-	-
<i>Gnaphalium luteo-album</i>	0.25	7.5	0.25	0.35	7.5	0.133	0.35	5.9	0.350	-	-	-	-	-	-
<i>Peristrophe bicalyculata</i>	3.55	50.7	0.393	-	-	-	0.55	10.9	0.138	0.6	8.2	0.150	-	-	-
<i>Leptadenia reticulata</i>	0.35	8.5	0.35	-	-	-	-	-	-	-	-	-	-	-	-
<i>Andropogon munroi</i>	-	-	-	1.5	16.1	0.350	6.5	59.0	0.289	4.5	30.6	0.367	8.1	57.8	0.400
<i>Barleria strigosa</i>	-	-	-	0.35	4.0	1.400	-	-	-	-	-	-	0.15	2.3	0.600
<i>Nepeta hindostana</i>	-	-	-	1.4	10.8	1.600	-	-	-	-	-	-	-	-	-
<i>Cannabis sativa</i>	-	-	-	0.25	10.4	0.104	-	-	-	-	-	-	-	-	-
<i>Borreria articularis</i>	-	-	-	0.35	4.0	0.800	-	-	-	-	-	-	-	-	-
<i>Abrus precatorius</i>	-	-	-	1.4	16.1	0.200	0.2	4.9	0.200	-	-	-	-	-	-
<i>Debregeasia longifolia</i>	-	-	-	0.25	6.9	0.933	-	-	-	0.250	3.9	0.250	-	-	-
<i>Blepharis maderaspatensis</i>	-	-	-	0.35	9.3	0.125	-	-	-	-	-	-	-	-	-
<i>Lamium amplexicaule</i>	-	-	-	1.4	10.8	0.200	0.2	3.1	0.800	-	-	-	-	-	-
<i>Adiantum incisum</i>	-	-	-	1.4	12.6	0.350	-	-	-	2.45	19.6	0.233	0.8	10.4	0.200
<i>Brassica rugosa</i>	-	-	-	0.35	4.0	2.200	-	-	-	-	-	-	-	-	-
<i>Sida acuta</i>	-	-	-	0.25	3.3	0.600	-	-	-	-	-	-	-	-	-
<i>Cymbopogon martinii</i>	-	-	-	0.35	5.8	0.350	-	-	-	-	-	-	-	-	-
<i>Thysanolaena maxima</i>	-	-	-	1.4	12.6	0.400	-	-	-	-	-	-	-	-	-
<i>Phymbeyo zeylanica</i>	-	-	-	-	-	-	0.25	5.3	0.250	-	-	-	-	-	-
<i>Cryptolepis buchananii</i>	-	-	-	-	-	-	0.35	5.9	0.350	-	-	-	-	-	-
<i>Asparagus racemosus</i>	-	-	-	-	-	-	0.1	2.5	0.400	-	-	-	0.1	2.1	0.400
<i>Cynodon dactylon</i>	-	-	-	-	-	-	0.7	11.9	0.175	0.15	3.4	0.150	0.7	9.9	0.175
<i>Chenopodium album</i>	-	-	-	0.25	5.1	0.150	1.35	19.8	0.150	3.9	35.9	0.092	2	20.0	0.222
<i>Barleria cristata</i>	-	-	-	-	-	-	0.2	4.9	0.200	0.5	7.8	0.125	-	-	-
<i>Reinwardtia indica</i>	-	-	-	-	-	-	-	-	-	0.3	5.5	0.133	-	-	-
<i>Coccinia grandis</i>	-	-	-	-	-	-	-	-	-	0.25	3.9	0.250	-	-	-
<i>Ipomoea nil</i>	-	-	-	-	-	-	-	-	-	1	8.8	0.444	0.15	3.8	0.150
<i>Asclepias curassavica</i>	-	-	-	-	-	-	-	-	-	0.1	1.8	0.400	-	-	-

Table 4. Contd.

Species	Site-I			Site-II			Site-III			Site-IV			Site-V		
	Density	IV	A/F ratio	Density	IV	A/F ratio	Density	IV	A/F ratio	Density	IV	A/F ratio	Density	IV	A/F ratio
<i>Evolvulus alsinoides</i>	-	-	-	-	-	-	-	-	-	0.25	3.9	0.250	-	-	-
<i>Cissampelos pareira</i>	-	-	-	-	-	-	1.2	20.6	0.098	-	-	-	0.15	3.8	0.150
<i>Boehreria diffusa</i>	-	-	-	-	-	-	-	-	-	-	-	-	0.25	4.4	0.250
<i>Poa annua</i>	-	-	-	1.4	21.4	0.118	0.5	6.9	0.500	0.15	2.1	0.600	0.3	4.7	0.300
<i>Rubia manjitha</i>	-	-	-	-	-	-	-	-	-	-	-	-	0.65	9.6	0.163
<i>Anisochilus carnosus</i>	-	-	-	-	-	-	-	-	-	-	-	-	0.15	3.8	0.150

the species show regular distribution. In shrub layer (Table 3) and herb layer (Table 4), all the species were distributed contagiously.

Diversity indices

In tree layer (Table 5) among the sites, maximum diversity of tree was on site-V ($H=3.26$) and the minimum diversity on site-I ($H=0.39$). In shrub layer (Table 5), the maximum diversity was on site-V ($H=3.01$) and minimum on site-I ($H=1.84$). In herb layer (Table 5), the highest diversity was on site-II and lowest diversity on site-I. The concentration of dominance ranged from $CD=0.12-0.86$ (trees), $CD=0.15-0.31$ (shrubs) and $CD=0.08$ to 0.23 (herbs) (Table 5). In tree layer, the β -diversity ranged from $\beta=2.72$ (site-II) to $\beta=4.0$ (site-I), in shrub layer $\beta=3.10$ (site-III) to $\beta=4.0$ (site-I), in herb layer β -diversity from $\beta=4.93$ (site-IV) to $\beta=9.77$ (site II).

Similarity index

The similarity index of species was calculated between the zones of similar layers of vegetation. In the tree layer, the index of similarity was 88%

between the submergence and influenced zone. However, the similarity in shrubs layer was 91% and in herb layer was 58%.

DISCUSSION

Soil properties

In the physical properties of soil, moisture was 7.78%, WHC was 30.56, bulk density 1.28 g cm^3 . The low amount of moisture and WHC in submergence zone could be because of regular construction work where most of the trees were affected. The canopy cover was too low which enhanced evaporation in the soil. Lower canopy cover reduced organic matter input in soil which also reduced WHC. Among the soil particles, higher proportion was reported for sand. Silt and clay proportion was reported comparatively similar (Table 1).

In the chemical properties of soil, the average values of soil pH, SOC, P and K were reported to be 7.33, 0.23, 14.92 kg ha^{-1} and $103.07 \text{ kg ha}^{-1}$ respectively (Table 1). A study carried out by Kumar et al. (2010a) on the *Anogessius latifolia* forest of this same region, reported that SOC

ranged from 0.47 to 0.68%, phosphorus 9.67 to 10.56 kg ha^{-1} and potassium 141.87 to $172.48 \text{ kg ha}^{-1}$. The values of SOC and P of the present study were lower than the study carried out by Kumar et al. (2010a).

The reducing level of SOC and P in the present study might be due to high biotic pressure on the site and disturbances created on vegetation for dam construction and other activities.

Dominance and species composition

Among the sites, the average tree density and total basal cover was $584 \text{ plants ha}^{-1}$ and $16.24 \text{ m}^2 \text{ ha}^{-1}$, respectively. However, in shrub layer, the average density and total basal cover values were $14.18 \text{ plant } 25 \text{ m}^2$ and $0.424 \text{ cm}^2 25 \text{ m}^2$, respectively. A study carried out by Kumar et al. (2004), in sub-tropical forests of the Garhwal Himalaya, shows values of total density and total basal cover ranging from 832 to $884 \text{ trees ha}^{-1}$ and 14.30 to $24.83 \text{ m}^2 \text{ ha}^{-1}$, respectively. These values of density were quite higher than the present study, because of high biotic pressure on the forest by villagers for various requirement including dam development activities. Kumar et al.

Table 5. Species richness, species diversity (H), concentration of dominance (CD) and beta diversity of trees, shrubs and herbs on different sites in submergence zone of hydroelectric project.

Site	Species richness			Species diversity (H')			Concentration of dominance (CD)			beta diversity (β)		
	Trees	Shrubs	Herbs	Trees	Shrubs	Herbs	Trees	Shrubs	Herbs	Trees	Shrubs	Herbs
Site-I	2	4	10	0.39	1.84	2.63	0.86	0.31	0.21	4.0	4.0	6.66
Site-II	9	9	22	2.81	2.30	4.06	0.17	0.30	0.08	2.72	3.33	9.77
Site-III	13	9	16	3.09	2.51	2.88	0.15	0.23	0.22	3.22	3.10	5.81
Site-IV	10	10	18	2.80	2.98	3.23	0.16	0.14	0.14	3.22	3.33	4.93
Site-V	12	12	21	3.26	3.01	2.89	0.12	0.15	0.23	3.75	3.75	5.23

Table 6. Plant species and their ethno medicinal uses by surrounding inhabitants.

Tree species	Family	Status	Life form	Biodiversity value	Part used	Ailment
<i>Acacia catechu</i> (L.f.) Willd.	Mimosaceae	Fairly Common	T	Medicinal, timber	Bark	Diarrhoea, Dysentery, Bronchitis, Menstrual disorders
<i>Adina cordifolia</i> (Roxb.) Hook.f. ex Brandis	Rubiaceae	Common	T	Medicinal, Construction Furniture, Agricultural implements	Bark Roots	Diabetes Dysentery
<i>Abrus precatorius</i> L.	Fabaceae	Common	S	Medicinal	Roots Seed Powder and Paste	Bone fracture Cough, Oboritifacient, Fever, Rheumatic Arthritis, Dysentery
<i>Achyranthes aspera</i> L.	Amaranthaceae	Fairly common	H	Medicinal Beverage	Roots Leaf	Malarial fever Dropsy Bronchitis
<i>Adhatoda vasica</i> Nees	Acanthaceae	Fairly Common	S	Medicinal Vegetable	Roots Leaves Flowers	Cough, Cold Pulmonary infections Bronchitis & Fever
<i>Adiantum incisum</i> Forsk	Adiantaceae		H	-	-	-
<i>Aegle marmelos</i> (L.) Corr.	Rutaceae	-	T	Medicinal	Fruit Pulp	Digestive disorders
<i>Aerva sanguinolenta</i> (L.) Blume	Amaranthaceae	Common	S	Medicinal	-	Diuretic & Demulcent
<i>Andropogon munroi</i> C.B Clarke	Poaceae	Not common	H	Fodder	-	-
<i>Anisochilus carnosus</i> (L.f.) Wall. ex Benth	Lamiaceae	Fairly common	H	Medicinal	Plant extract	Cough Cold

T: Tree, S: shrub, H: herb.

Table 6. Contd.

Tree species	Family	Status	Life form	Biodiversity value	Part used	Ailment
<i>Anogeissus latifolia</i> (Roxb. ex DC.)	Combretaceae	Common	T	Construction Agricultural implements Tannin Black dye	-	-
<i>Asclepias curassavica</i> L.	Asclepiadaceae	Common	H	Medicinal	Roots , Latex	Causes Vomiting Cuts and wounds
<i>Asparagus racemosus</i> Willd.	Liliaceae	-	H	Medicinal	Roots	Antiseptic and Refrigerant
<i>Barleria cristata</i> L.	Acanthaceae	Fairly common	H	Medicinal, Beverage	Roots Leaves	Bronchitis Pneumonia Wound Swelling
<i>Barleria strigosa</i> Willd.	Acanthaceae	Common	H	Medicinal, Apiculture	Roots	Cough
<i>Bauhinia variegata</i> L.	Caesalpiaceae	Common	T	Medicinal, Construction Agricultural implements	Dried Leaves	Cough
<i>Bidens pilosa</i> L.	Asteraceae	Common	H	Medicinal, Fodder	Plant extract	Cough Bronchitis Leucoderma
<i>Blepharis maderaspatensis</i> (L.) Roth	Acanthaceae	Uncommon	H	-	-	-
<i>Boerhavia diffusa</i> L.	Nyctaginaceae	Common	H	Medicinal	Leaf	Eye complaints
<i>Borreria articularis</i> (L.,f.) F.N Williams	Rubiaceae	Common	H	Medicinal	Seeds Leaves	Diarrhoea, Dysentery Haemorrhoids
<i>Brassica rugosa</i> Prain	Brassicaceae	-	H	Medicinal, Vegetable	Seed oil	Body ache, Skin diseases , Cold
<i>Carissa opaca</i> Stapf ex Haines	Apocyanaceae	Frequent	S	Edible	-	-
<i>Cassia fistula</i> L.	Caesalpiaceae	Common	T	Medicinal	Bark Fruit pulp	Antiseptic, Asthama, Bronchitis, Skin Diseases
<i>Chenopodium album</i> L.	Chenopodiaceae	Common	H	Vegetable	-	-
<i>Cissampelos pareira</i> L.	Menispermaceae	Common	H	Medicinal	Leaves Roots	Constipation Gastric troubles, Psychotherapy Cough, Urinary troubles
<i>Coccinia grandis</i> (L.) Voigt	Cucurbitaceae	Common	H	Medicinal	Leaves, Roots Fruit, juice	Diabetes, Antiseptic and Gonorrhoea
<i>Colebrookia oppositifolia</i> J.E. Smith	Lamiaceae	Common	S	Medicinal	Leaf	Wounds
<i>Cryptolepis buchananii</i> Roem. and Schult.	Asclepiadaceae	Frequent	H	-	-	-
<i>Cymbopogon martinii</i> (Roxb.) Wat.	Poaceae	Common	H	-	-	-
<i>Cynodon dactylon</i> (L.) Pers.	Poaceae	Common	H	Medicinal	Roots	Fever and Internal injury

T: Tree, S: shrub, H: herb.

Table 6. Contd.

Tree species	Family	Status	Life form	Biodiversity value	Part used	Ailment
<i>Debregeasia longifolia</i> (Burm.f.) Wedd.	Urticaceae	Common	H	Fodder and Fibre	-	-
<i>Emblia officinalis</i> Gaert.	Euphorbiaceae	-	T	Medicinal Tannin	Fruit	Source of Vitamin C
<i>Eupatorium adenophorum</i> Spreng.	Asteraceae	Common	S	Medicinal	Leaves	Wounds
<i>Euphorbia hirta</i> L.	Euphorbiaceae	Common	H	Medicinal	Plant extract	Bronchial infection Asthama
<i>Euphorbia royleana</i> Boiss.	Euphorbiaceae	Fairly Common	S	Medicinal	Latex	Antiseptic and Germicidal
<i>Ficus benghalensis</i> L.	Moraceae	Fairly Common	T	Medicinal, Tent Poles Cart Yokes, Boats	Latex	Antidiabetic
<i>Ficus carica</i> L.	Moraceae	Common	T	Good fodder, fruit	Leaves, fruit	Fruits used as digestive purposes
<i>Ficus religiosa</i> L.	Moraceae	Common	T	Medicinal, Charcoal and Packing Cases	Bark	Bronchitis and Skin ailments
<i>Gnaphalium luteo-album</i> L.	Asteraceae	Common	H	-	-	-
<i>Grewia opositifolia</i> Buch.-Ham. ex D. Don	Tiliaceae	Common	T	Medicinal and Edible Ropes, Nets, Sacs Brushes and brooms	Fruit	-
<i>Holoptelea integrifolia</i> (Roxb.) Planch.	Ulmaceae	Abundant	T	Medicinal, Charcoal Construction and Fuel	Bark	Rheumatic Pain
<i>Ipomoea nil</i> (L.) Roth	Convolvulaceae	Common	H	Medicinal	Decoction of seeds	Fever Constipation
<i>Lamium amplexicaule</i> L.	Lamiaceae	Fairly common	H	-	-	-
<i>Lannea coromandelica</i> (Houtt.) Merr.	Anacardiaceae	-	T	Medicinal, Tannin Fuel, Fodder and Agricultural Implements	Bark	Diarrhoea
<i>Lantana camara</i> L.	Verbenaceae	Common	S	Medicinal and Fuel	Leaves	Insecticidal, Germicidal and Skin Ailments
<i>Leptadenia reticulata</i> (Retz.) Wight and Arn.	Asclepiadaceae	Rare	H	Medicinal	Leaves Roots and Plant extract	Skin ailments Antiseptic and Useful to control abortion
<i>Leucaena leucocephala</i> (Lam.) De Wit.	Mimosaceae	Not uncommon	T	Planted for soil conservation	-	-
<i>Mallotus philippensis</i> (Lam.) Muell.-Arg.	Euphorbiaceae	-	T	Dye, Anthelmintic, Purgative, Fuel and Match Boxes	-	-

T: Tree, S: shrub, H: herb.

Table 6. Contd.

Tree species	Family	Status	Life form	Biodiversity value	Part used	Ailment
<i>Mangifera indica</i> L.	Anacardiaceae	Abundant	T	Medicinal Edible and Construction	Bark, Seeds and Resin	Haemorrhage and Diarrhoea
<i>Mimosa himalayana</i> Gamble	Mimosaceae	Common	S	Medicinal and Fodder	Leaves	Cough, Cold Bronchitis and Urinary Complaints
<i>Murraya koenigii</i> (L.) Spreng.	Rutaceae	Common	S	Medicinal Flavouring	Bark, Leaves Roots	Insecticide and Piscicide
<i>Nepeta hindostana</i> (Roth.) Haines	Lamiaceae	Common	H	Medicinal	Plant extract	Cardiac tonic Fever and Gonorrhoea
<i>Oxalis corniculata</i> L.	Oxalidaceae	Common	H	Vegetable	-	-
<i>Parthenium hysterophorus</i> L.	Asteraceae	Common	H	-	-	-
<i>Peristrophe bicalyculata</i> (Retz.) Nees	Acanthaceae	Common	H	Medicinal	Plant paste	Wounds
<i>Phoenix humilis</i> Royle ex Becc. and Hook.f.	Arecaceae	Common	T	Edible, Fibre Brooms and Hats	-	-
<i>Plumbago zeylanica</i> L.	Plumbaginaceae	-	H	Medicinal	Roots	Skin diseases, Wounds
<i>Poa annua</i> L.	Poaceae	Common	H	-	-	-
<i>Randia tetrasperma</i> (Roxb.) Poir.	Rubiaceae		S	-	-	-
<i>Reinwardtia indica</i> Dumort.	Linaceae	Common	H	Apiculture and Mouth wash	Petals	Mouth wash
<i>Rhus parviflora</i> Roxb.	Anacardiaceae	Abundant	S	Medicinal Edible and Fuel	Leaves	Cholera
<i>Ricinus communis</i> L.	Euphorbiaceae	-	S	Castor oil	Seeds	Purgative and Laxative
<i>Rubia manjith</i> Roxb. ex Fleming	Rubiaceae	Common	H	Medicinal and Dye	Roots, Stem Flowers	Tonic, Astringent and Bacillary dysentery

T: Tree, S: shrub, H: herb.

Table 6. Contd.

Tree species	Family	Status	Life form	Biodiversity value	Part used	Ailment
<i>Sida acuta</i> Burm.f.	Malvaceae	Common	H	Medicinal and Fibre	Leaves Roots Stem	Demulcent Diuretic and Leucorrhoea
<i>Sida cordifolia</i> L.	Malvaceae	Common	H	Medicinal and Fibre	Roots Seed powder	Astringent, Diuretic, Tonic and Dyspepsia
<i>Solanum nigrum</i> L.	Solanaceae	Common	H	Medicinal and Edible	Fruit Plant extract	Liver, Piles Dysentery Diarrhoea, Fever Eye ailments
<i>Thysanolaena maxima</i> (Roxb.) O. Kuntze	Poaceae	Common	H	Fodder and Brooms	-	-
<i>Toona ciliata</i> M. Roem.	Meliaceae	Common	T	Construction Furniture and Dye	-	-
<i>Tridax procumbens</i> L.	Asteraceae	Common	H	Medicinal and Vegetable	Plant paste	Wounds and Cuts
<i>Woodfordia fruticosa</i> (L.) Kurz	Lythraceae	Common	S	Medicinal and Dye	Leaves Bark and Dried flowers	Febrifuge, Tonic and Haemorrhoids
<i>Ziziphus mauritiana</i> Lam.	Rhamnaceae	Fairly Common	S	Edible, Construction, Agricultural implements ,Apiculture	-	-

T: Tree, S: shrub, H: herb.

(2010a) also conducted a study on different aspects of *A. latifolia* forest, the density for trees ranged from 260 to 380 trees ha⁻¹ and for shrub ranged from 970 to 1790 shrubs ha⁻¹. In this study, the values of density were quite lower because of higher pressure especially by the villagers for their daily needs.

In the tree layer, the common species reported were *A. latifolia*, *Acacia catechu*, *Adina cordifolia*, *Cassia fistula*, *E. officinalis*, *Holoptelia integrifolia*, *Lannea coromandelica*, *Mallotus philippensis*. The

forest was dominated by *A. latifolia*. *Carissa opaca* was dominant in shrub layer with associated shrubs of *Abrus precatorius*, *Adhatoda vasica*, *Colebrookia oppositifolia*, *Lantana camara*, *Mimosa himalayana*, *Murraya koenigii*, *Rhus parviflora*, *Woodfordia fruticosa* and *Ziziphus mauritiana*. In herb layer, the common species noticed were *Solanum nigrum*, *Achyranthes aspera*, *Tridax procumbens*, *Euphorbia hirta*, *Oxalis corniculata*, *Barleria strigosa*, *Nepeta hindostana*, *Sida cordifolia*,

Solanum nigrum, *Poa annua*, *Bidens pilosa*, *Blepharis maderaspatensis*, *Chenopodium album*, *Adiantum incisum*, *Sida acuta*, *Asparagus racemosus*, *Cynodon dactylon*.

Among the sites, the trees density was highest in site-III however; the TBC was reported higher on site-II, while the lowest values of density and TBC of trees were reported on site-I (Table 2). In shrub layer, the highest density was on site-II and TBC on site-V (Table 3). Herb layer density was highest on site-V and lowest on site-I (Table 4).

Species richness

The maximum richness of species in tree layer was on site-III, because the site was located far from the inhabitant's area thus pressure on the forest was mild which favoured species richness. The minimum number of species was observed on site-I, because site-I was close to dam development site. Therefore, most of the species have been damaged by heavy machinery work and dust pollution created by machine as well as human activities such as movement of labour, rolling of stone, damping materials, etc. A study carried out by Yadav and Gupta (2005) in Rajasthan suggested that anthropogenic disturbances have adverse impact on the woody vegetation. They also suggested that species richness was higher in undisturbed forest as compared to partially disturbed forest. Kumar et al. (2010b) conduct a study in the same site of the dam project for conservation strategies of *A. latifolia* showing that various disturbance agents such as grazing, browsing, over-exploitation and major dam construction work in this valley affect the growth of *A. latifolia*. The dominant forest cover of this valley area is covered by *A. latifolia* which is main source of fuel, fodder and minor timber and highly disturbing by developing activities, that is, dam and road construction work. Boring et al. (1981) emphasized the positive role of mild disturbances in improving the regeneration of tree. Levin (1976) also indicated sever disturbance has deleterious effect on regeneration. Khan et al. (1986) reported that erosion action of torrential rains on slopes can also cause a decrease in the number of seedling during the rainy season. The long history of human interaction with plants, animals and environmental factors in the mountain region has a significant impact on the biological diversity at different levels. The topography, soil, climate and geographical location also influenced the vegetation diversity of the forest. In modern time, Himalayan forest ecosystems have witnessed great natural and biotic disturbances. Yadav and Gupta (2005) reported that the number of shrubs reduced with increasing level of anthropogenic disturbance on the forest sites.

Distribution pattern (%)

Among the vegetation layers, the distribution pattern of trees was contagious, random and regular. Although contagious distribution pattern of the species was common and in shrub layer, most of the species were distributed contagiously. However in herbs layer all the species on all sites were distributed contagiously. Odum (1971) stated that contagious distribution is the commonest pattern in nature and random distribution found only in very uniform environment and the regular distribution occurs where sever competition between the individuals exist (Panchal and Pandey, 2004; Kumar et al., 2010a). Regular and random distribution pattern of

the species reflect the high biotic pressure through grazing and lopping.

Species diversity (H') and concentration of dominance (CD)

The diversity values were 0.39-3.26 for tree layer, 1.84-3.01 for shrub layer. Kumar et al. (2004) also reported diversity value 2.76 for the sub-tropical forest of *A. latifolia* of this region in Garhwal Himalaya. Kumar et al. (2010a) carried a study on *A. latifolia* forest and reported diversity values 0.846 to 1.710 for trees and 1.943 to 2.847 for shrubs which are within the range values of the present study.

The concentration of dominance ranged from 0.12 to 0.86 (trees), 0.14 to 0.31 (shrubs). The values of CD reported by Riser and Rice (1971) and Knight (1975) ranged from 0.326 to 0.693 for trees and 0.185 to 0.719 for shrubs. These reported values of CD for trees are within the range of present study but shrub values were higher for the present study.

Similarity index

Similarity index is a comparison of the current vegetation on site. A similarity index determines how closely the plant community resembles. Similarity index is expressed as percentage of the reference community that is currently on an ecological site. The results suggest that the similarity between the sites for shrubs layer was higher followed by trees and shrubs. Thus it is indication that where the similarity index is low the species are diverse. Therefore diverse vegetation has diverse resources which are used by the local inhabitant for their need. In this comparison, the diverse species reported from submergence zone were *Phonex humilis*, *F. carica* (tree layer), *Sida acuta* (shrub layer) and *Achranthes aspera*, *Brassica rugosa*, *Cymbopogon martinii*, *Phymbeyo zeylanica*, *Asparagus racemosus*, *Barleria cristat*, *Coccinia grandis*, *Asclepias curassavica*, *Boehrvia diffusa* (herb layer) were only reported from the submergence zone, although the species are providing several needs to the local inhabitants. Resource consumption by local inhabitant from submergence zone. The resource consumption by local people from submergence zone is given in Table 6. A total of 71 species were recorded from the submergence zone having 65 genera and 37 families in the study area in which 18 species of trees having 17 genera and 12 families were recorded in the tree layer, and 15 species with 15 genera in 14 families were observed for shrub layer while in herb layer 38 species having 36 genera in 22 families were recorded (Table 7).

People use these resources, that is, fuelwood, fodder, timber, edible wild fruits, medicinal plants daily for human and animal uses and several other purposes from submergence. It is evident from the studies carried out by

Table 7. Total species, genera and families of plants in submergence zone of HEP.

Parameter	Trees	Shrubs	Herbs	Total
Species	18	15	38	71
Genera	17	15	36	65
Families	12	14	22	37

Table 8. Resource consumption by local inhabitant from submergence and influenced zones of HEP.

Zone	Forest resource use									
	Major						Minor			
	Fuel	Fodder	Timber	Grazing	Browsing	Agricultural implements	Medicinal value	Edible fruit	Religious purpose	Fiber
Submergence	High	High	High	Medium	Medium	Medium	Low	Low	Low	Low
Influenced	High	High	High	Medium	Medium	Medium	Low	Low	Low	Low

other workers (Ballabha, 2013; Tiwari, 2010) that the species are used by the villager for several purposes. Bahuguna et al. (2011) also carried out a study in this region and also suggested local villagers used different plant species for various purposes such as food, religious uses, perfume, medicinal, fodder, dye, household articles, agricultural implements, beverage, fuel, ornamental, narcotic, insecticide, etc. Although people are still utilizing forest resources from the adjacent influence zone (Table 8). Just after submergence of the present study area, the demand of the villagers/inhabitant will be directly shifted to the influenced zone, which will be comparatively double. This shifted pressure of inhabitant on influenced zone will rapidly degrade the resources and there will be rapid loss of biodiversity from the influenced zone.

Although the hydroelectric project stimulate economic growth, building of roads, schools, hospitals cultural and recreation facilities under

their plans but it has some negative impacts on biodiversity of the area.

Recommendations for conservation of biodiversity

The study on collected data revealed that the submergence zone is rich particularly in plant diversity as they are the source of different villagers need, but the developmental activities, the constructions of hydroelectric power projects are causing a great loss of plant diversity under the functioning of hydro project work and the most loss will occur after submergence of the area. The earlier studies are evident that hydroelectric power projects create environmental issues originating from submergence of large area including forest (Samant et al., 2007; Tiwari, 2010). The degradation of biodiversity in the Himalayan region has reached dangerously alarming state

(Gupta, 1960; Gaur, 1999). The catchment area of rivers supports a large number of plant species of human use and scientific interest, including highly potential medicinal herbs; these require special attention for conservation (Uniyal, 1968; Gaur et al., 1993; Tiwari, 2010).

The sustainability and efficiency of forest ecosystems being influenced by the hydroelectric power projects in river valleys can be restored by strengthening the knowledge on sustainable plant utilization (Tiwari, 2010). These evidences indicate that the submergence of hydroelectric project areas have been losing both plant and animals' biodiversity in alarming rate. The construction of HEP in the Himalayan and other regions of India are major threats to the biodiversity and are also losing habitat especially for those species under threatened categories.

Thus, the following suggestions should be adopted to conserve the valuable resources in the surrounding of the dam construction areas.

1. The area for dam construction should be selected where biological diversity is low.
2. Dam construction should be done where minimum area can be used.
3. Dam construction should be avoided where species are under threatened categories
4. Dam height should be reduced to minimize the loss of plant and animal diversity in submergence zone.
5. The heavy machinery work should be minimized to conserve species diversity.
6. The heavy vehicle movement in dam construction areas should be restricted except using few roads to minimize disturbances to the biodiversity.
7. The dumping of construction material should not be stored at plant diversity rich areas.
8. Blasting of dam construction work should be done where there is minimum disturbance of animals and birds.
9. Conservation techniques of plants through cultivation should be used for further sustainable use of the species.

Conclusion

The soil pH was slightly basic in nature. The soil organic carbon and potassium was lower, because of disturbance. Moisture (%) and WHC was also reported to be lower, because of various disturbances and developmental activities, where most of the trees were affected.

The people living close to the study area are dependent on the forest which is importance for their livelihood sustainability. The loss of vegetation diversity in submergence zone will affect the biodiversity of submergence zone as well as diverted pressure of inhabitant on influenced zone will also rapidly degrade the resources for the influenced/surrounding areas. Therefore, proper awareness program need to be carried out in the inhabitant area to restore vegetation through plantation and self-sustaining of vegetation by the co-operation of local inhabitant from further degradation of forest. Thus, the future sustainability of the forest can be maintained with the saving of traditional culture of the local inhabitants.

Conflict of Interests

The author(s) have declared that there is no conflict of interests.

REFERENCES

- Bahuguna YM, Jyotsana Sharma, Sumeet Gairola (2011). Int. J. Environ. Sci. 1(7):1448-1458.
- Ballabha R, Tiwari JK, Tiwari P (2013) Diversity and Indigenous uses of Tree species in the Vicinity of Srinagar Hydroelectric Power Project in Alaknanda valley of Garhwal Himalaya, India. Res. J. Agric. For. Sci. 1(1):6-10,
- Boring LR, Monk CD, Swank WT (1981). Early regeneration of a clear-cut southern Appalachian forest. Ecology 62:1244-1253.
- Chapin III FS, Zavaleta ES, Eviner VT, Naylor RL, Vitousek PM, Reynolds HL (2000). Consequences of changing biodiversity. Nature 405:234-242.
- Curtis JT (1959). The vegetation of Wisconsin. An ordination of plant communities, University Wisconsin Press, Madison Wisconsin, 657.
- Curtis JT, Cottam G (1956). Plant Ecology Work book laboratory field reference manual. Burgers publication co., Minnesota, 193.
- Curtis JT, McIntosh RP (1950). The Interrelation of certain analytic and synthetic Phytosociological characters. Ecology 31:434-455.
- Gaur RD (1999). Flora of the district Garhwal Horth West Himalaya. (With ethnobotanical notes) Transmedia Srinagar (Garhwal) - U. P. India.
- Gaur RD (2007). "Biodiversity and river valley projects in Uttarakhand", Proceedings of National Academy of Sciences India, 77 (BIII). 253-262.
- Gaur RD, Negi KS, Tiwari JK, Pant KC. (1993). Notes on the ethnobotany of five districts of Garhwal Himalaya. Ethnobot. 5:73-81.
- Gauthier S, Grandpre LD, Bergeron Y (2000). Differences in forest composition in two Boreal forest eco-regions of Quebec. Journal of Vegetation Science. 11:781-790.
- Jackson, M.L. (1958): Soil chemical analysis Prentice Hall, Inc., Engle Wood Cliffs, New Jersey, and U.S.A.
- Kershaw KK (1973): Quant. Dyn. Plant Ecol. 2nd edition, FLBS.
- Khan ML, Rai JPN, Tripathi RS (1986) Regeneration and survival of tree seedlings and sprouts in tropical deciduous and subtropical forest of Meghalaya, Indian. For. Ecol. Manag. 14:293-304.
- Kim KC, Weaver RD (1994). Biodiversity and landscapes. Cambridge University Press, New York, USA, 3-27.
- Knight DH (1975). A phytosociological analysis of species rich tropical forest on Barro Colorado Island, Panama. Ecolog. Monographs. 45:259-289.
- Kumar A, Ram J (2005). Anthropogenic disturbances and plant biodiversity in forest of Uttaranchal, Central Himalaya. Biodiv. Conserv. 14:309-311.
- Kumar M, Joshi M, Todaria NP (2010a). Regeneration status and plant bio-diversity in a sub-tropical forest of Garhwal Himalaya. J. For. Res. 21(4):439-444.
- Kumar M, Sharma CM, Rajwar GS (2004). A study on the Community structure and diversity of a sub-tropical forest of Garhwal Himalayas. Indian For. 130 (2):207-214.
- Kumar M, Sheikh MA, Rajwar GS (2010b). Conservation strategies for *Anogeissus latifolia* in the Srinagar Valley of Uttarakhand. India.-Int. J. Consev. Sci. 1(4):191-198.
- Levin SA (1976). Population dynamics models in heterogeneous environments.-Annual Review of Ecology and Systematics 7:227-310.
- Misra R (1968). Ecology Work Book. Oxford and IBM Publishing co. Calcutta, 244.
- Naithani BD (1984). Flora of Chamoli. Botnaical Survey fo India. Rajee Printers, New Delhi.
- Odum EP (1971). Fundamentals of Ecology (3rd ed). USA: W.B. Saunders Co., Philadelphia. p. 574.
- Panchal NS, Pandey AN (2004). Analysis of vegetation of Rampara forest in Saurashtra region of Gujarat state of India. Trop. Ecol. 45(2):223-231.
- Risser PG, Rice EL (1971). Diversity in tree species in Oklahoma Upland forests. Ecology 52: 876-880.
- Samant SS, Butola JS, Sharma A 2007. Assessment of Diversity, Distribution Conservation Status and Preparation of Management Plan for Medicinal Plants in the Catchment Area of Parbati Hydroelectric Project Stage-III in Northwestern Himalaya. J. Mount. Sci. 4(1): 034-056.
- Schulze ED, Mooney HA (1994). "Biodiversity and ecosystem function", Springer, New York, 25.
- Shannon CE, Wiener W (1963).The Mathematical Theory of Communication. University of Illinois press, Urbana.
- Sharma V (2006). "State of water resources in the country", In: Nautiyal, R., Nautiyal, P. (eds), "Compendium: Environmental Audit of Hydroelectric Projects for Sustainable Development", Printmedia, Srinagar (Garhwal), Uttarakhand, 1421.

- Simpson EH (1949). Measurement of Diversity. *Nature* 163:688.
- Singh JS (2002). The biodiversity crisis: a multifaceted review. - *Current Science* 82: 638-647.
- Singh JS, Kushwaha SPS (2008). Forest biodiversity and conservation in India. - *International Forestry Review*. 10(2): 292-304.
- Sørensen TA (1948). A method of establishing groups of equal amplitude in plant sociology based on similarity of species content, and its application to analyses of the vegetation on Danish commons. *Kgl Danske Vidensk. Selsk. Biol. Skr.* 5:1-34.
- Tiwari JK, Ballabha R, Tiwari P (2010). Diversity and Present Status of Medicinal Plants in and around Srinagar Hydroelectric Power Project in Garhwal Himalaya, India: Needs for Conservation Researcher 2(2):50-60
- UNEP (2001): "India: State of the Environment 2001", United Nations Environment Programme.
- Uniyal MR (1968) Medicinal Plants of Bhagirathi valley in Uttarkashi forest division, U.P. *Indian For.* 94:407-468.
- Walkley AE, Black JA (1934). An examination of the Degtiga vett. method for determining soil organic matter and proposed modification of the chronic acid titration method. *Soil Sci.* 37:29-38.
- Yadav AS, Gupta SK (2005). Effect of micro-environment and human disturbance on the diversity of woody species in the Sariska Tiger Project in India. *Trop. Ecol.* 48(1):125-128.

Full Length Research Paper

Comparative study of shrub diversity in lower Dachigam Kashmir Himalaya

Arif Yaqoob^{1*}, Mohammad Yunus¹ and G. A. Bhat²¹Department of Environmental Science, BBAU, Lucknow (U.P), India.²Department of Environmental Sciences, University of Kashmir, Srinagar (Jand K), Kashmir, India.

Received 20 August, 2013; Accepted 2 May, 2014

The present study was conducted in two different ecosystems, that is, Site I (village site) and Site II (protected site) in the lower part of Dachigam National Park (Jammu and Kashmir) in all seasons during 2010-2011. Site I is located towards the periphery of the National Park near habitations and is under heavy grazing pressures while Site II is located inside the National Park with mild interferences and is a controlled site. The values of diversity ($H=2.228$) as well as richness index ($R=0.867$) were higher for Site II while dominance index showed higher value at Site I ($C=0.113$). The evenness index showed more or less similar values for both sites (Site I = 0.497 and Site II = 0.499). The frequently occurring dominant shrub species during the study period based on importance value index (IVI) were *Plectranthus rugosa*, *Rosa webbiana*, *Indigofera heterantha*, *Cotoneaster nummularia* and *Daphnae oleoides* at Site I and *Indigofera heterantha*, *Clematis montana*, *Rosa macrophylla*, *Clematis grata* and *Rosa brunoni* at Site II. The abundance to frequency ratio (A/F) indicated that most of the species present contagious pattern of distribution.

Key words: Shrub, biodiversity, species, grazing, Dachigam.

INTRODUCTION

High biodiversity is seen as an insurance against the decline in ecosystem services, and should therefore be preserved (Yachi and Loreau, 1999). But, the current decline in biodiversity largely through human activities has given rise to global biodiversity crisis which is a cause of concern at the prospect of a rapidly accelerating loss of species, population, domesticated varieties, erratic rainfall, drying up of water resources, land instability and increased rates of erosion. More than half of the habi-

table surface of the planet has already been significantly disturbed by the human activity (Hannah and Bowles, 1995) which change overall community structure (Shaforth et al., 2002) and in turn can ultimately affect community and population dynamics. Conservation biologists warn that 25% of all species could become extinct during the next 20 to 30 years and we are on the verge of mass extinction of the species (Wilson, 1985). The cause for the loss of species is numerous but the most important is the loss

*Corresponding author. E-mail: arifmalik33@academicjournals.org.

of natural habitats. Biological diversity implies the variety of living organisms and includes diversity within species, between species and of ecosystems and the ecological processes of which they are a part (Gaston and Spicer, 2004). Species diversity is considered to be one of the key parameters characterizing ecosystems and a key component of ecosystem functioning (Hutchinson, 1959). Globally, biodiversity is changing at an unprecedented rate as a complex response to several human-induced changes (Vitousek, 1994). Such changes are a cause of concern for ethical, economical, ecological and aesthetic reasons, but they also have a strong potential to alter ecosystem services such as the prevention of soil erosion and maintenance of hydrological cycles, and ecosystem goods, like tourism and recreation. In addition to these services, biodiversity influences many ecosystems properties such as productivity, decomposition rates, nutrient cycling resistance and resilience to perturbations (Loreau et al., 2001). Forests are the primary source to rejuvenate productivity of land through recycling of nutrients, which make physical chemical conditions of the soils favourable for plant growth (Bargali et al., 1998). The natural factors both biotic and abiotic, deforestation, burning of ground vegetation, fodder extraction, livestock grazing, etc. have caused a considerable depletion of wild population of flora and fauna of the forest areas responsible for exploitation of forests (Bargali et al., 1998) and other severe anthropogenic activities on the ecosystem will lead to removal of vegetation, soil erosion and could subsequently lead to soil and habitat degradation. Thus, the current decline in biodiversity largely through human activities is a serious threat to our ecosystem. The study of floristic features and various environmental factors e.g. physiographic, climate, soil, etc., the community stability and the factors correlation with the vegetation can be reached, which is crucial in terms of forest communities development and rehabilitation (Basiri, 2003). Grazing areas have become less and less productive resulting from over stocking of livestock. Conflicts over the use of land have increased due to increased demand for land by different sectors of the economy.

Kashmir Himalaya, due to its rich repository of vegetation has attracted naturalists and botanists for more than two centuries (Dar et al., 2001). The vegetation study of Dachigam has been carried out by Kachroo and Singh (1976) which recognized different vegetation types based on habitat, form and density of dominant species. Although, the vegetation patterns are controlled by such factors as habitat, slope, exposure to sunlight and altitude, besides biotic factors, anthropogenic stresses followed by livestock browsing in shrub lands adversely affected the composition of vegetation, it is therefore important to conserve the vegetation of the study area. Therefore, the present study has been conducted to assess the seasonal variations in phyto-diversity and distribution pattern of shrubs in the studied sites.

METHODOLOGY

Study area

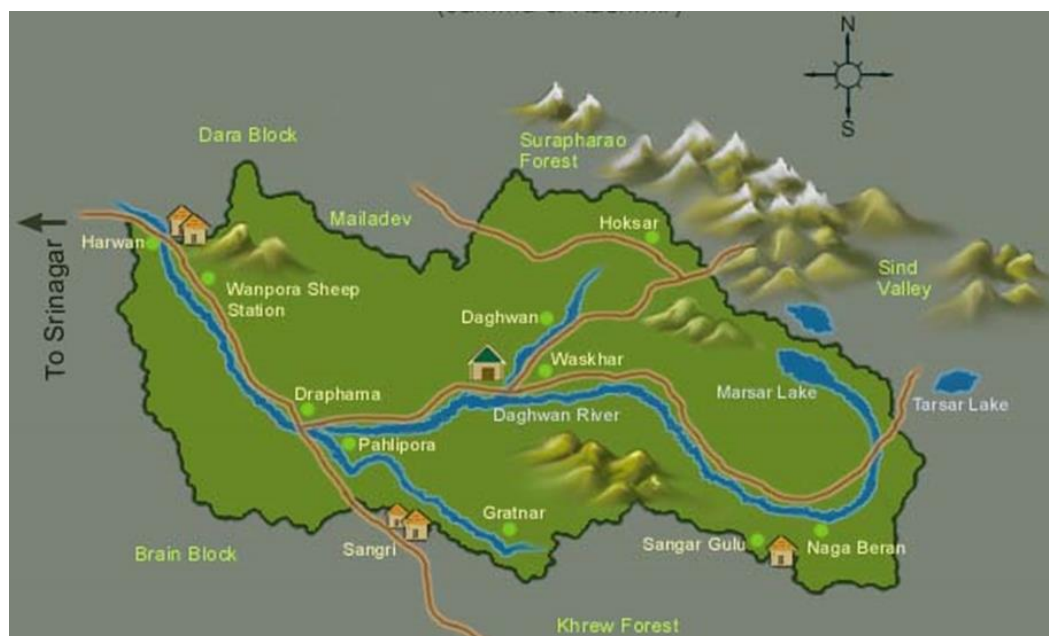
Dachigam National park is located between 34°5'-34° 10' N latitudes and 74°50'-75°10' E longitudes, covers an area of 141 km² and is about 22 km away from Srinagar City in Kashmir Valley. The area of Dachigam National Park was an exclusive hunting ground and protected area of the Maharaja of Jammu and Kashmir. But after independence, the area came under the control of forest department and in 1951, it was declared as a Wildlife Sanctuary. In 1981, the area was declared as National Park. The different forest types found in the area are: Temperate Moist Deodar forest, Temperate mixed deciduous forest, Cypress, Alder and blue Pine forest, Poplar and Salix forest, Open Scrub forest, Sub open Birch and fir forests, Sub open Scrub and pastures and moist open Scrub. Besides, the area forms a very good habitat of wild birds including Himalayan Monal, Chakur, Partridge, Himalayan griffon, Vulture, Indian Sparrow, Hawk, Asiatic cuckoo, open scrub Swift, Indian pied kingfisher, Golden oriole, Blue magpie, Black Bulbul, Babbler, etc. and wild animals like Kashmir Stag, Leopard, Jackal, Hill fox, Himalayan Black Bear, Snow Leopard, Human langur, Musk deer, Leopard Cat, Himalayan Marmot, Flying Squirrel, Himalayan mouse, etc. The study was carried out at lower Dachigam on seasonal basis in two different ecosystems viz.: site- I (village site falls towards the periphery but inside the official boundary of the park) and site- II (protected site located within the heart of the park) (Map 1).

Vegetation analysis

Numerous field surveys were conducted to study the community composition and other phytosociological characteristics at two selected sites during spring (March-May), summer (June-August), autumn (September-November) and winter (December-February) in 2010-2011. Phytosociological attributes of shrub species were studied by randomly laying 6 quadrats of 5 × 5 m size at each site (Sharma et al., 1983). Specimen of plant species encountered at each site during the study period was collected in flowering/fruiting stages and the specimens were identified at Centre of Plant Taxonomy Department of Botany, University of Kashmir. The plant material was processed using standard herbarium techniques (Rao and Jain, 1977). The vegetation data recorded quantitatively was analyzed for density, frequency and abundance following Curtis and McIntosh (1950). The relative values of these indices were determined using Phillips (1959). These values were summed up to get importance value index (IVI) of individual species (Curtis, 1959). The ratio of abundance to frequency (A/F) for different species was determined by eliciting the distribution pattern (Curtis and Cotton, 1956). Species diversity (H) was computed by using Shannon Wiener Information Index (Shannon-Wiener, 1963). Concentration of dominance was calculated according to Simpson (1949). The species richness or the variety component (R) was determined using Margalef (1958) while species evenness (E) and similarity index (S) both were determined using Pielou (1966) and Sorenson (1948), respectively.

RESULTS

A total of 13 shrub species were reported from site I (village site) and 22 shrub species from site II (protected site) (Tables 1 and 2). Same results were shown by Alhassan et al. (2006). Among all the species, *Plectranthus rugosa* showed highest values of density (35.23),



Map 1. Map of Dachigam National Park, Kashmir India.

Table 1. Community features of shrubs at site I of Dachigam National Park during different periods of study.

S/N	Species	D	RD	A	RA	F	RF	A/F	IVI	R.IVI
1	<i>Berberis lycium</i>	4.54	5.07	7.85	6.35	54.71	8.16	0.143	19.59	6.53
2	<i>Cotoneaster nummularia</i>	7.68	8.57	7.89	6.38	97.85	14.61	0.08	29.56	9.86
3	<i>Daphnae oleoides</i>	6.67	7.44	9.03	7.31	72.62	10.84	0.124	25.59	8.53
4	<i>D. mucronata</i>	1.91	2.13	5.75	4.65	33	4.92	0.174	11.72	3.91
5	<i>Indigofera heterantha</i>	12.49	13.94	13.85	11.21	89.37	13.34	0.154	38.49	12.83
6	<i>Lonicera quinquelocularis</i>	1.16	1.29	2.33	1.88	50	7.46	0.0466	10.63	3.54
7	<i>Parrotiopsis jacquemontiana</i>	0.16	0.17	1	0.81	16	2.38	0.0625	3.36	1.12
8	<i>Plectranthus rugosa</i>	35.23	39.34	35.62	28.84	97.87	14.61	0.363	82.79	27.59
9	<i>Rosa macrophylla</i>	1.5	1.67	9	7.28	16	2.38	0.562	11.33	3.78
10	<i>R. webbiana</i>	15.8	17.64	18.21	14.74	87.25	13.02	0.208	45.4	15.13
11	<i>Rhamnus purpureus</i>	0.33	0.36	2	1.62	16	2.38	0.125	4.36	1.45
12	<i>Spirea canscens</i>	0.33	0.36	2	1.62	16	2.38	0.125	4.36	1.45
13	<i>Ziziphus jujuba</i>	1.74	1.94	8.95	7.24	23.28	3.47	0.384	12.65	4.21
	Total	89.54	100	123.48	100	669.95	100	2.5511	300	100

Where D=density; RD=relative density; F=frequency; RF=relative frequency; A=Abundance; RA=relative abundance; IVI=importance value index; RIVI=relative importance value index.

abundance (35.62) and frequency (97.87%) at site I while at site II, *Indigofera heterantha* showed highest density values (65.54) as well as frequency values (100%) and *Clematis montana* showed highest abundance values (19.91). Out of the total shrub species encountered at both sites during different seasons, 16 species were highly dominant based on importance value index (IVI). Dominant species based on IVI during all seasons at site I were *P. rugosa* (82.79), *Rosa webbiana* (45.40), *I. heterantha*

(38.49), *Cotoneaster nummularia* (29.56), *Daphnae oleoides* (25.59), *Berberis lyceum* (19.59), *Zyzephus jajuba* (12.65) whereas at site II dominant species recorded were *I. heterantha* (56.73), *C.s montana* (29.61), *Rosa macrophylla* (23.69), *Clematis grata* (22.39), *Rosa brunoni* (20.06), *Jasminum officinale* (14.63), *B. lyceum* (13.97) and *Rubus niveus* (12.09). Different diversity indices recorded at both sites are presented in Table 3. The perusal of the data revealed that diversity index (H),

Table 2. Community features of shrubs at site II of Dachigam National Park during different periods of the study.

S/N	Species	D	RD	A	RA	F	RF	A/F	IVI	R.IVI
1	<i>Berberis lycium</i>	5.55	3.38	8.09	4.98	63	5.61	0.128	13.97	4.65
2	<i>Cotoneaster nummularia</i>	2.5	1.54	3.3	2.04	49.6	4.42	0.066	8	2.66
3	<i>C. insignis</i>	1.87	1.14	4.45	2.74	41.5	3.69	0.107	7.57	2.52
4	<i>C. accuminatus</i>	1.16	0.71	3.5	2.15	33	2.94	0.106	5.8	1.93
5	<i>Clematis grata</i>	11.05	6.79	14.91	9.19	72	6.41	0.207	22.39	7.47
6	<i>C. montana</i>	18.59	11.42	19.91	12.27	66.5	5.92	0.299	29.61	9.87
7	<i>Crataegus songerica</i>	0.36	0.21	2	1.23	16	1.42	0.125	2.86	0.95
8	<i>Indigofera heterantha</i>	65.54	40.28	12.23	7.54	100	8.91	0.122	56.73	18.92
9	<i>Jasminum humile</i>	1.38	0.85	3.77	2.33	33	2.94	0.114	6.12	2.04
10	<i>J. officinale</i>	6.55	4.02	9.23	5.69	55.31	4.92	0.166	14.63	4.87
11	<i>Lonicera quinquelocularis</i>	3.12	1.91	4.74	2.93	58	5.16	0.081	10	3.33
12	<i>L. aspersifolia</i>	1.83	1.12	3.63	2.23	50	4.45	0.081	7.8	2.6
13	<i>Rosa webbiana</i>	8.59	5.27	10.52	6.48	69.8	6.22	0.15	17.97	5.99
14	<i>R. macrophylla</i>	12.05	7.41	15.2	9.37	77.64	6.91	0.195	23.69	7.89
15	<i>R. brunoni</i>	9.75	5.99	12.6	7.76	70.75	6.31	0.178	20.06	6.69
16	<i>Rubus niveus</i>	3.79	2.32	9.63	5.93	43.2	3.84	0.222	12.09	4.03
17	<i>R. fruticosus</i>	1.74	1.06	4.16	2.57	41.5	3.69	0.101	7.32	2.45
18	<i>R. ellipticus</i>	1.66	1.02	3.33	2.05	50	4.45	0.0666	7.52	2.51
19	<i>R. ulmifolia</i>	2.16	1.32	6.5	4.01	33	2.94	0.1969	8.27	2.76
20	<i>Spiraea canscens</i>	0.83	0.52	2.5	1.54	33	2.94	0.075	5	1.66
21	<i>Sorbaria tomentosa</i>	0.33	0.21	1	0.61	33	2.94	0.0303	3.76	1.25
22	<i>Spastium junceum</i>	2.33	1.43	7	4.32	33	2.94	0.212	8.69	2.89
	Total	162.73	100	162.2	100	1122.8	100	3.0288	300	100

Where D=density; RD=relative density; F=frequency; RF=relative frequency; A=abundance; RA=relative abundance; IVI=importance value index; RIVI=relative importance value index.

Table 3. Spatial variation in diversity, richness, evenness, dominance and similarity indices of shrubs at different study sites.

Sites	Indices				
	Diversity(H')	Dominance (C)	Richness (R)	Evenness(E)	Similarity index
I	-1.4635553	0.234732295	0.490918016	-0.44057404	37.5
II	-2.228731579	0.078809577	0.867850098	0.499779292	

evenness index and richness index maximum value were obtained at site II ($H=2.228$, $E=0.499$ and $R=0.867$) than site I ($H=1.463$, $E=0.440$ and $R=0.490$). However, dominance index revealed an inverse trend to that of Shannon diversity with lowest values reported at site II ($C=0.078$) and highest at site I ($C=0.234$). Same were the findings of Kharkwal et al. (2004). The abundance to frequency ratio (A/F) indicated that most of the species at site I performed contagious pattern of distribution except *Lonicera quinquelocularis* showing random distribution while as at site II *Sorbaria tomentosa* showed slightly random distribution and the rest of the species showed a contagious type of distribution. The results are in consonance with the findings of Shadangi and Nath (2005).

DISCUSSION

Species diversity is considered to be one of the key parameters characterizing ecosystem and a major component of ecosystem functioning (Hutchenson, 1959). Species diversity, considered to be an outcome of the evolution of species in a biogeographic region is often a synthetic measure of the structure, complexity and stability of the ecosystem (Hubble and Foster, 1983). Species diversity is also important for the stability and proper functioning of ecosystems (Schlapfer et al., 1999), however, with increasing disturbance in the vegetation, the plant species diversity, richness and evenness are significantly reduced (Dar and Kaul, 1987). Diversity is a combination of two

factors: the number of species present, referred to as species richness and the distribution of individuals among species, referred to as species evenness or equability. Species diversity therefore, refers to the variation that exists among the different life forms. In the present study, general structure of vegetation depicts that the species number was greater at site II (22) than at site I (13). The reason for maximum number of species at site I could be due to more availability of soil moisture and other environmental factors present in this area due to more vegetation cover (Alhassan et al., 2006). Comparatively, results of Shannon diversity at both sites fall within the range of the study carried out by Kiss et al. (2004). The species diversity was lower at site I (1.463) than site II (2.228) owing to adverse climatic conditions at this site (Shadangi and Nath, 2005) or lower rate of evolution and diversification of communities (Fischer, 1960). However, highest species diversity at site II might be due to the moderate level of grazing or anthropogenic disturbances and invasion of new species (Connell, 1978). Several studies mentioned similar results pertaining to the present study emphasizing moderate level of grazing promoted species diversity (Rikhari et al., 1993). However, others like Lubchenco (1978) considered it as a positive force that might increase species diversity in the community by preventing competitive exclusion by dominant species. The highest values of dominance index at site I (0.234) and lowest values (0.078) at site II having inverse relationship with diversity index (H) were also reported by Kharkwal et al. (2004). The lower value of dominance at controlled forest site showed that dominance of shrub layer is shared by many species. The Pielou's indices at both sites were 0.440 (site I) and 0.499 (site II), indicating low dominance and more or regular distribution of shrub species at both sites. Lower richness values (0.490) at site I could be due to dry environmental conditions and also to slow growth rate, and maximum value (0.867) at site II could be due to favourable climatic conditions (Abdullah et al., 2009).

Species grow together in a particular environment because they have similar requirements for existence in terms of environmental factors such as light, temperature, water and soil nutrients and drainage etc. or they may also share the ability to tolerate the activities of animals and humans such as grazing, burning, cutting or trampling (Wood et al., 1994). It is generally argued that each individual species depends on some set of other species for its continued existence and the species have co-evolved in the ecosystem on which they depend (Paine, 1966). The loss of natural associations may be the probable reason for supporting low number of species (Walker, 1992). Ecological success, good power of regeneration and ecological amplitude of a species is governed by high IVI. Highest value of density and IVI by *P. rugosa* and *R. webbia* indicate their dominance due to environmental suitability and ability of the species to survive

grazing may be due to non-palatability or prickly nature, that is, adaptation against herbivory or maximum utilization of available resource by that species (Kukshal et al., 2009). Difference in the species composition from site to site is mostly due to microenvironmental changes (Mishra et al., 1997). Abundance and frequency ratio (A/F) ratio were in consonance with the study of Shadangi and Nath (2005), Greig-Smith (1957) etc., which reveals that most of the species were contagiously distributed whereas as regular distribution was reported almost negligible during present study. Dominance of contagious distribution may be due to the fact that the majority of species reproduce vegetatively in addition to their sexuality. Odum (1971) described that in natural conditions, contagious distribution is the most common type of distribution and is performed due to small but significant variation in environmental conditions while random distribution is found only in very uniform environment. The Sorensen's similarity index shows that lower degree of similarity between sites I and II may be due to the different habitat conditions, non adjacent location or varied biotic interference at these sites.

Conclusion

The study concluded that with increasing disturbance in the forest vegetation, the plant species diversity, richness and evenness are significantly reduced and increase in shrub diversity and evenness at protected site may be due to less competition and availability of more space and nutrients or due to less or controlled biotic stresses. There is an urgent need to improve the vegetation cover at site I which could be achieved through regular monitoring of livestock grazing and biotic interference in addition to providing alternate grazing sites for livestock that will certainly tend to regenerate the vegetation of such threatened areas. However, increasing human activities like fuel fodder collection, harvesting of medicinal herbs, burning of ground vegetation inside the national park needs prime and immediate attention for sustainability. It is further recommended that species with low IVI need to be restored on priority basis by providing protection which ultimately help in regeneration process to maintain diversity in the selected sites.

Conflict of Interests

The author(s) have not declared any conflict of interests.

REFERENCES

- Abdullah MB, Sanusi SS, Abdul SD, Sawa FBJ (2009). An Assessment of the Herbaceous Species Vegetation of Yankari Game Reserve, Bauchi, Nigeria. *Am-Eur. J. Agric. Environ. Sci.* 6(1):20-25.
- Alhassan AB, Chiroma AM, Kundiri AM (2006). Properties and

- classification of soils of Kajimaram oasis of Northeast Nigeria. *Int. J. Agric. Biol.* 8:256-261.
- Bargali K, Bargali SS, Singh RP (1998). Ecological relationship of *Bidens biternata* and *Galingsonga ciliata* in open and closed habitats. *Ind. J. Ecol.*, 25(2):107-113.
- Basiri R (2003). Ecological study on *Quercus libani* site by analyzing environmental features in Marivan. Ph. D Thesis University of Tarbiat Modarres.
- Connell JH (1978). Diversity in tropical forests and coral reefs. *Science*, 199:1302-1310.
- Curtis JT, Cotton G (1956). *Plant Ecology Workbook: Laboratory Field Reference Manual*. Burgess Publishing Co., Minnesota. p.193.
- Curtis JT, McIntosh RP (1950). The interrelation of certain analysis and systematic phytosociological characters. *Ecology* 31:434-455.
- Curtis JT (1959). The vegetation of Wisconsin: An ordination of plant communities. University of Wisconsin Press Madison, Wisconsin. p.657.
- Dar GH, Bhagat RC, Khan MA (2001). *Biodiversity of Kashmir Himalaya*. Valley Book House, Srinagar, J & K, India.
- Fischer AG (1960). Latitudinal variation in organic diversity. *Evolution* 14:64-81.
- Gaston KJ, Spicer JL (2004). *Biodiversity: an introduction*. 2nd ed. Oxford, Blackwell Science. p.191.
- Greig-Smith P (1957). *Quantitative plant ecology*, 2nd ed. Butterworth, London.
- Hannah L, Bowels I (1995). Global priorities. *Biol. Sci.* 45:122-132.
- Hubble SP, Foster RB (1983). Diversity of canopy trees in a neo-tropical forest and implications to conservation. *Tropical Rain Forest: Ecol. Manage.*, (Sutton L, T. C.) pp. 25-41
- Hutchinson GE (1959). Homage to Santa Rosalia, or why are there so many kinds of animals? *Am. Nat.* 93:145-159.
- Kachroo P, Singh G (1976). Forest flora of Srinagar and plants of neighbourhood. Bishen Singh Mahendra Pal Singh, Dehradun, India
- Kharkwal GP, Mehrotra RYS, Pangtey YPS (2004). Comparative study of herb layer diversity in pine forest stands at different altitudes of central Himalaya. *Appl. Ecol. Environ. Res.* 2(2):15-24.
- Kiss T, Sipos G, Bodis K, Barta K (2004). Community composition, species diversity, and secondary succession in grazed and ungrazed alpine meadows of the west Himalaya, India. *Int. J. Field work Stud.* 2:1.
- Kukshal S, Nautiyal BP, Anthwal A, Sharma A, Bhat AB (2009). Phytosociological investigation and life form pattern of grazing lands under pine canopy in temperate zone, Northwest Himalaya, India. *Res. J. Bot.* 4:55-69.
- Loreau M, Naeem S, Inchausti P (eds). (2002). *Biodiversity and ecosystem functioning*. Oxford, University Press. p.294.
- Lubchenco JL (1978). Plant species diversity in a marine inter-tidal community: importance of herbivore food preference and algae competitive abilities. *Am. Nat.* 112:23-29.
- Margalef R (1963). On certain unifying principles in Ecology. *Am. Nat.* 97:357-374.
- Mishra D, Mishra TK, Banerjee SK (1997). Comparative phytosociological and soil physico-chemical aspects between managed and unmanaged lateritic land. *Ann. For.* 5(1):16-25.
- Odum EP (1971). *Fundamentals of Ecology*. Saunders Co., Philadelphia.
- Paine RT (1966). Food-web complexity and species diversity. *Am. Nat.* 100:65-75.
- Phillips EA (1959). *Methods of vegetation study*. Henry Holt and Co. Inc; New York. p.318.
- Pielou EC (1966). Species diversity and pattern diversity in the study of ecological succession. *J. Theor. Biol.* 10:370-383.
- Rikhari HC, Negi GCS, Ram J, Singh SP (1993). Human-induced secondary succession in alpine meadow of Central Himalaya, India. *Art. Alp. Res.* 25:8-14.
- Schlapfer F, Schmid B, Seidl I (1999). Expert estimates about effects of biodiversity on ecosystem processes and services. *Oikos*, 84:346-352.
- Shadangi DK, Nath V (2005). Impact of seasons on ground flora under plantation and natural forest in Amarkantak. *Ind. For.* 131(2):240-250.
- Shaforth PB, Stromberg JC, Patten DT (2002). Riparian vegetation response to altered disturbance and stress regimes. *Ecol. Appl.* 12:107-123.
- Sharma SK, Geoga M, Prasad KG (1983). Forest vegetation survey and classification with special reference to South India. 1. Vegetation survey and quadrat analysis. *Ind. For.* 109(6):384-394.
- Simpson EH (1949). Measurement of diversity. *Nature* 163:688.
- Vitousek PM (1994). Beyond global warming: ecology and global change. *Ecology* 75:1861-1876.
- Walker BH (1992). Biodiversity and ecological redundancy. *Conserv. Biol.* 6:18-23.
- Wilson EO (1985). The biological diversity crisis. *Bio-science* 35:700-7006.
- Wood J, Low AB, Donaldson JS, Rebelo AG (1994). Threats to Plant Species Diversity through Urbanization and Habitat Fragmentation in the Cape Metropolitan Area, South Africa. In: Huntely BJ (Ed.) *Strelitzia 1, Botanical diversity in South Africa*. Proceedings of a Conference on the Conservation and Utilization of Southern African Botanical Diversity. Cape Town, September 1993. Pretoria: National Botanical Institute. pp: 259-274.
- Yachi S, Loreau M (1999). Biodiversity and ecosystem productivity in a fluctuating environment: The insurance Hypothesis. *Proc. Nat. Acad. Sci., USA.* 96:1463-1468.

Full Length Research Paper

Assessment of genetic diversity of a critically endangered important medicinal plant *Chlorophytum borivilianum* in different agro-climatic regions of India revealed by random amplified polymorphic primer (DNA Marker)

Baby Kumari*, M. A. Mallick and Govind K. Vyas

Bhabha Atomic Research Centre, Anushakti Nagar, Trombay, Mumbai, India.

Received 26 January, 2014; Accepted 26 May, 2014

Chlorophytum borivilianum (Family: Liliaceae), an important threatened medicinal herb is designated as 'Rare' in Red Data Book of Indian plants. In this study, random amplified polymorphic primer DNA (RAPD) markers were used to assess the genetic diversity in six genotypes of *C. borivilianum* collected from different geographical regions of Rajasthan, Madhya Pradesh and Jharkhand. Out of the 86 bands, 45 were found to be polymorphic and the level of polymorphism was 52.35% thus, revealing a high degree of polymorphism. The maximum polymorphism was obtained using primer number 108 that was 90.90% and least with primer number 102 that was 12.5%. The Jaccard's similarity coefficient ranged from 0.70 ± 0.186 . The maximum similarity value was noticed between SM3 and SM5 genotypes collected from KRD (M.P) and Maa Umayya farm (M.P.), respectively.

Key words: *Chlorophytum borivilianum*, genetic diversity, random amplified polymorphic primer DNA (RAPD), genotypes.

INTRODUCTION

World Health Organization (WHO) has estimated that more than 80% population of developing countries depends on herbal medicines for their basic healthcare needs (Canter et al., 2005). *Chlorophytum borivilianum* commonly known as "Safed Musli", a monocot belongs to liliaceae family, is a member of a special class of Ayurvedic herbs known as 'Rasayana' and falls into a group 'Vajikarna' that is Aphrodisiac (Marais and Reilly, 1978; Thakur and Dixit, 2008).

Safed Musli commands an exorbitant price for its

processed products both in indigenous and global markets. It is the latest sensation in the Indian herbal medicine, gaining wide acceptance over the global nutraceutical industries. It has been listed as an endangered species in "Red data book of Indian plants" by the Botanical Survey of India (Nayar and Shastry, 1998) and it is predicted that if steps for its conservation are not taken, the Indian forest will lose this valuable plant (Oudhia, 2001). National medicinal plants board (NMPB) New Delhi, has recognized Safed Musli as sixth important herb to be protected,

*Corresponding author. E-mail: baby.raai@gmail.com.

Table 1. *Chlorophytum borivilianum* samples from different locations of India.

S/N	Location	Sample name
1	SM-1 (Udaipur, Wild)	UW
2	SM-2 (Udaipur cultivated)	UC
3	SM-3 (KRD farm, MP cultivated)	KRD
4	SM-4 (MP wild)	MW
5	SM-5 (MaaUmiya Farm, Jamli MP, cultivated)	MU
6	SM-6 (Jharkhand, wild)	JK

promoted and preserved.

The genus includes more than 300 species, which are distributed throughout the tropical and subtropical parts of the world. Tropical and subtropical Africa is the probable centre of origin of the genus, where about 85% of the species are found in India. *C. borivilianum* is mainly distributed in Southern Rajasthan, North Gujarat, Western Madhya Pradesh and some part of Jharkhand and Bihar (Maiti and Geetha, 2005). Among 300 species, 13 species are reported in India and *C. borivilianum* is producing highest yield of saponin among all species.

Germplasm conservation is the major prospective of this rare medicinal herb along with other prospects. The focus of this study was to achieve the molecular diversity found in *C. borivilianum* for the selection of vigorous germplasm which produces highest quantity of saponin that is its major bioactive compound. The study was focused on major biodiversity region producing Safed Musli (wild and cultivated). The characterization of *C. borivilianum* germplasm has been based mainly on phenotypic characteristics. *C. borivilianum* shows wide morphological and agronomic variations for roots (Geetha and Maiti, 2002). However, divergence studies made on the basis of molecular markers provide precise information about phylogenetic descriptive and hierarchical account of individuals or groups of individuals.

The method of polymerase chain reaction with a set of arbitrary primers (RAPD-PCR) was used to determine the genetic variations and to estimate genetic diversity in collected germplasm of *C. borivilianum* sant and frend.

RAPD markers have caught the fancy of many individuals in the field of applied plant breeding. RAPD due to their low cost and high reproducibility have been used for different purpose, such as assessment of genetic variability, genetic relationship, identification of cultivars etc. in number of crop plants. This molecular marker is based on the PCR amplification of random locations in the genome of the plant. The number of amplification products is directly related to the number and orientation of the sequences that are complementary to the primers in the genome. RAPD was found to be simple and efficient among the available DNA based techniques (Welsh and McClelland, 1990; Williams et al., 1990) and furthermore sequence information is not needed (Gepts, 1993; Karp

et al., 1997). With the availability of this genetic tool, genetic diversity and genetic analysis can also be estimated (Chapco et al., 1992; Landry et al., 1993; Demeke et al., 1996; Li et al., 2004) Furthermore, RAPD techniques are advantageous because of their simple requirement of a small quantity of DNA and their ability to uncover a large number of polymorphisms (Cheng et al., 1997; Carelli et al., 2006). In this study, *C. borivilianum* accessions collected from the wild forests and organic farms of Madhya Pradesh, Rajasthan and Jharkhand were characterized using RAPD-random amplified polymorphic DNA markers, to study the molecular diversity among the collected accessions.

MATERIALS AND METHODS

Plant material

Six accessions of *C. borivilianum* (Safed Musli) from three different agro-climatic regions of India that is Madhya Pradesh (MP), Rajasthan (Udaipur) and Jharkhand (three cultivated and three wild) were used (Table 1).

DNA extraction

Plantlets grown from seeds on filter paper bridge were used for DNA extraction: 3 g leaves obtained from each variety of plants were homogenized in liquid nitrogen. DNA was isolated by Doyle and Doyle (1990) method with some modifications. Pellets were washed with 70% alcohol and dissolved in TE (Tris- Cl-EDTA) buffer after drying.

DNA quantification and dilution

The Quantification of DNA was carried out using Nano Drop ND 1000 spectrophotometer (NanoDrop Technologies, Wilmington, USA). The DNA was again re-quantified by running it through agarose gel (0.8%), 150 ml in 0.5 X TBE (Tris borate EDTA) buffer containing 0.5 µg/ml of ethidium bromide. 5 µl of DNA sample was loaded with a mixture of DNA loading dye, after electrophoresis gel was viewed under UV. Presence of single compact band at the corresponding position to λ phase DNA (Control) indicated high molecular weight of isolated DNA. The dilution was done with sterile distilled water to ensure that all of the DNA samples have equal concentration of 25 ng/µl.

RAPD polymerase chain reaction

For RAPD analysis, 50 primers from set # 1 obtained from the University of British Columbia, Vancouver, Canada were screened. Out of 50 primers, 15 primers were selected for the study and four primers were removed because of their monomorphic nature and poor reproducibility. PCR reactions were performed in final volume of 25 µl containing 2.5 µl of 10 X Assay Buffer ("Puregene, Gband"); 0.5 units of Taq DNA polymerase ("Bangalore Gene"), 0.5 µl (200 µM) each of dNTPs ("Puregene, Gband"), 10 pmols/reaction of random primers (British Columbia) and 1 µl (50 ng of template DNA). The PCR was performed in 'Biometra Thermo cycler' using the standard cycling parameters. Following the amplification, the PCR products were loaded on 1.2% agarose gel (Himedia, molecular grade), which was prepared in 1X TBE buffer containing

Table 2. DNA yield based on absorbance (260nm) obtained from various Safed Musli samples.

Safed Musli samples	Ratio of A ₂₆₀ /A ₂₈₀	Concentration of DNA (ng/μl)
SM-1 (Udaipur Wild, UW)	1.97	2595.40
SM-2 (Udaipur cultivated, UC)	1.89	532.37
SM-3 (KRD farm, Indore)	1.8	5043.08
SM-4 (MP wild, MW)	1.8	805.30
SM-5 (MaaUmiya Farm, Jamli MP, MU)	1.86	707.16
SM-6 (Jharkhand, JK)	2.1	671.62

0.5 μg/ml of the Ethidium Bromide. The amplified products were electrophoresed for 3 - 3.5 h at 100 V with cooling. After separation, the gel was viewed under UV trans-illuminator and photographed by digital camera.

Gel analysis and scoring of RAPD product

In order to score and preserve banding pattern, photograph of the gel was taken by a digital camera, under UV transilluminator. RAPD bands were designated on the basis of their molecular sizes (length of polynucleotide amplified). 200 bp ladders were loaded simultaneously with primer and product in the gel was used to estimate the molecular sizes. The distance run by amplified fragments from the well was translated to molecular sizes with reference to molecular weight marker. The presence of each band was scored as '1' and its absence as '0'. Faintly visible bands were not scored, but a major band corresponding to faint bands was considered for scoring.

Similarity matrix and cluster analysis

The statistical calculations were done using Free Tree programme version, 0.9.1.50 (Pavlicek et al. 1999). Similarity matrices, was constructed using the Jaccard's similarity coefficient values (Rhoif et al., 2000) to find out genotypic relationship. The average distance of a single variety from the rest of the genotypes was also calculated. The 0/1 matrix data obtained from RAPD primers was arranged to get separate similarity matrix which was subjected to unweighted pair-group method with arithmetic averages (UPGMA) analysis. This analysis generated dendrogram which was further compared using the Mantel matrix correspondence test (MxComp module of NTSyS).

RESULTS AND DISCUSSION

The present investigation included six accessions of *C. borivillianum* (Safed Musli) from three different agro-climatic regions of India that is Madhya Pradesh (MP), Rajasthan (Udaipur) and Jharkhand. In this work, we report on the results of genetic diversity in the collected *C. borivillianum* genotypes (cultivated and wild), using RAPD marker.

DNA isolation and RAPD analysis

A single sharp band corresponding to λDNA was

observed for all the samples of DNA on 0.8% agarose gel. The quality of DNA was determined as the ratio A₂₆₀/A₂₈₀ which ranged from 1.8 to 2.0, which is indicative of good quality plant DNA and ration was almost consistent, irrespective of the *C. borivillianum* samples. The concentration of DNA preparation varied from 0.6 to 5.04 μg/μl for SM-3 and SM-6 respectively (Table 2). This is because the stochastic nature of the band and banding pattern of DNA amplification with RAPD, reproducibility of the banding pattern has been found to change. Finally, only those bands were considered as polymorphic, which did not amplify in certain samples on repetition. The banding pattern generated by each primer was primer and species dependent and varied from 3-15 at 37°C annealing temperature. A total of 86 amplicons were obtained with 11 primers with an average of 7.8 bands per primer (Table 3).

Out of 86 bands, 45 were found to be polymorphic and the level of polymorphism was 52.35% (Table 3). The most informative primers were 101 and 108 with maximum polymorphic bands and least informative primer was 102 and 111 with 1 polymorphic band out of total 8 and 6 bands. The maximum polymorphism was obtained using primer number 108 that was 90.90 % and least with primer number 102 that was 12.5 %. None of the primer produced all monomorphic bands (Table 4).

This probability was calculated by Simpson's index as described by Hunter and Gaston (1988). The discriminatory power ranged from 0.35 to 1.0 for pattern generated by various primers. The discriminatory index of value one was obtained for the primers 129 and 160 which produced unique banding pattern for all the varieties (Table 4).

Genetic relationship among the varieties/lines

The pair wise genetic similarity estimates (Jaccard's coefficient) based on RAPD banding pattern were used for cluster analysis to present genetic relationship in the form of dendrogram (Figure 1). The similarity coefficient matrix was subjected to algorithm unweighted pair group method for arithmetic average analysis (UPGMA) to generate clusters. The Jaccard's pair wise similarity coefficient value for six Safed musli samples are presented in Table 5. The range of genetic similarity was found to

Table 3. List of arbitrary primers with total polymorphic amplicons and polymorphism generated for six Safed Musli samples.

Primers	Sequence 5'-3'	Total number of bands (a)	Total number of polymorphic band (b)	Polymorphism (%) b/a × 100
101	GCGGCTGGAG	8	7	87.5
102	GGTGGGGACT	8	1	12.5
105	CTCGGGTGGG	7	4	57.14
108	GTATTGCCCT	11	10	90.90
111	AGTAGACGGG	6	1	16.66
125	GCGGTTGAGG	6	3	50.00
127	ATCTGGCAGC	3	1	33.33
129	GCGGTATAGT	11	5	45.45
160	CGATTAAGAG	15	8	53.33
165	GAAGGCACTG	6	3	50.00
170	ATCTCTCCTG	5	2	40.00
		86	45	52.35

Table 4. Primer discriminative power (D).

Primer	D at 37°
101	0.54
102	0.60
105	0.88
108	0.74
111	0.35
125	0.88
127	0.74
129	1.00
160	1.00
165	0.88
170	0.61

Table 5. Jaccard's similarity coefficient for six Safed Musli genotypes based on RAPD profiling

Parameter	UW	UC	KRD	MW	MU	JK
UW	1.00					
UC	0.67	1.00				
KRD	0.73	0.71	1.00			
MW	0.74	0.68	0.71	1.00		
MU	0.76	0.69	0.80	0.79	1.00	
JK	0.68	0.68	0.64	0.71	0.67	1.00

be between 0.64 (KRD and JK) to 0.80 (KRD and MU). The average genetic similarity coefficient observed was 0.70 ± 0.186 .

Dendrogram based on UPGMA analysis spitted into three clusters, in which one cluster contains four Safed musli genotypes while two other clusters contain single genotype each. Cluster containing four genotypes were

UW, KRD, MU and MW while UC and JK clustered themselves as a single entry. UC spitted as a distinct entry at 0.68 Jaccard's similarity coefficient while JK spitted at 0.67 similarity coefficient. Sixteen genotype specific allelic positions were generated through seven primers out of 11 RAPD primers used. Maximum four allelic positions were obtained using the primer no. 108

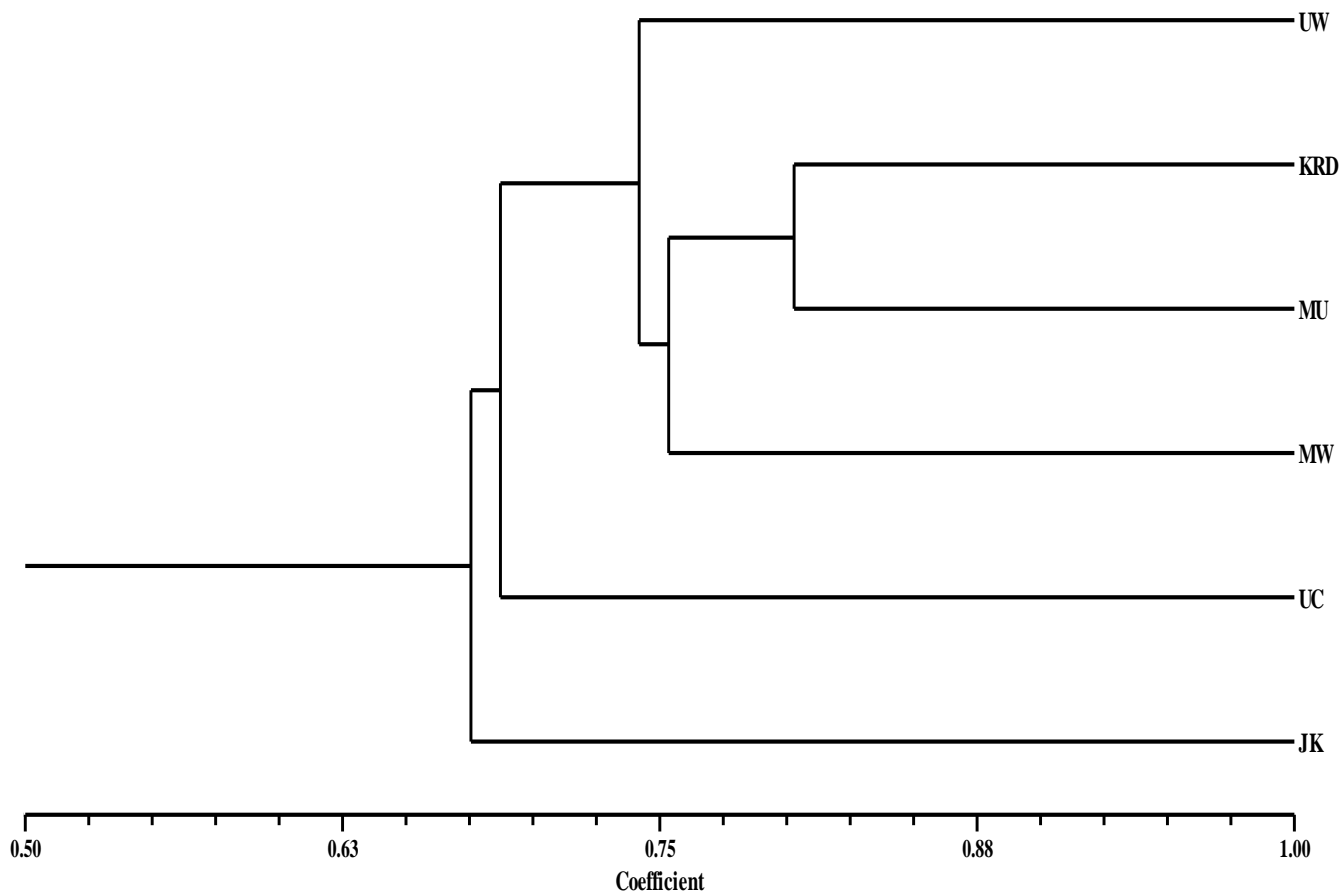


Figure 1. Dendrogram generated for six Safed musli genotypes using UPGMA cluster analysis based on Jaccard's similarity coefficient for RAPD data.

and 160. All the obtained specific allelic positions can be used for the variety identifications.

In this study, the extent of genetic diversity in cultivated and wild variety of *C. borivilianum*, obtained from central, western and eastern parts of India was determined using RAPD markers (Figure 2). Several reports are available to demonstrate the use of RAPD markers for determination of genetic variation in plants. Genetic diversity assessment of nine accessions of *C. borivilianum* from central India was studied by PCR based Molecular marker RAPD (Dwivedi and Sharma, 2011). Identification and assessment of genetic relationship in three *Chlorophytum* species of and two high yielding genotypes of *C. borivilianum* through RAPD markers were done (Sanghamitra et al., 2011). Tripathi et al. (2012) also observed genetic similarity using RAPD markers among *C. borivilianum* accessions collected from different places of Central India. Our results are also in agreements with other researchers. Shi et al. (2008) studied on the genetic diversity among cultivated and wild variety of *C. chinensis* using ISSR markers and found similar results as we found in our results that there is very less diversity among cultivated and wild variety of plant, although it can be said that geographical and agro climatic factors plays

important role in the genetic diversity.

Conclusion

The level of RAPD variation in the population of *C. borivilianum* has been investigated. RAPD variation was found in accessions of different agro climatic regions of India. It can be suggested that RAPD markers have the potential to detect genetic variability among different populations of *C. borivilianum*. RAPD marker will have impact on vigorous germplasm selection and its preservation. However, this study is not complete in terms of sample size and area coverage; hence a more extensive genetic diversity investigation including areas not covered yet should be done representing a population by as many collections as possible and awareness of the public about the importance, value of conservation and sustainable utilization of this plant genetic diversity should be promoted.

Conflict of Interests

The author(s) have not declared any conflict of interests.

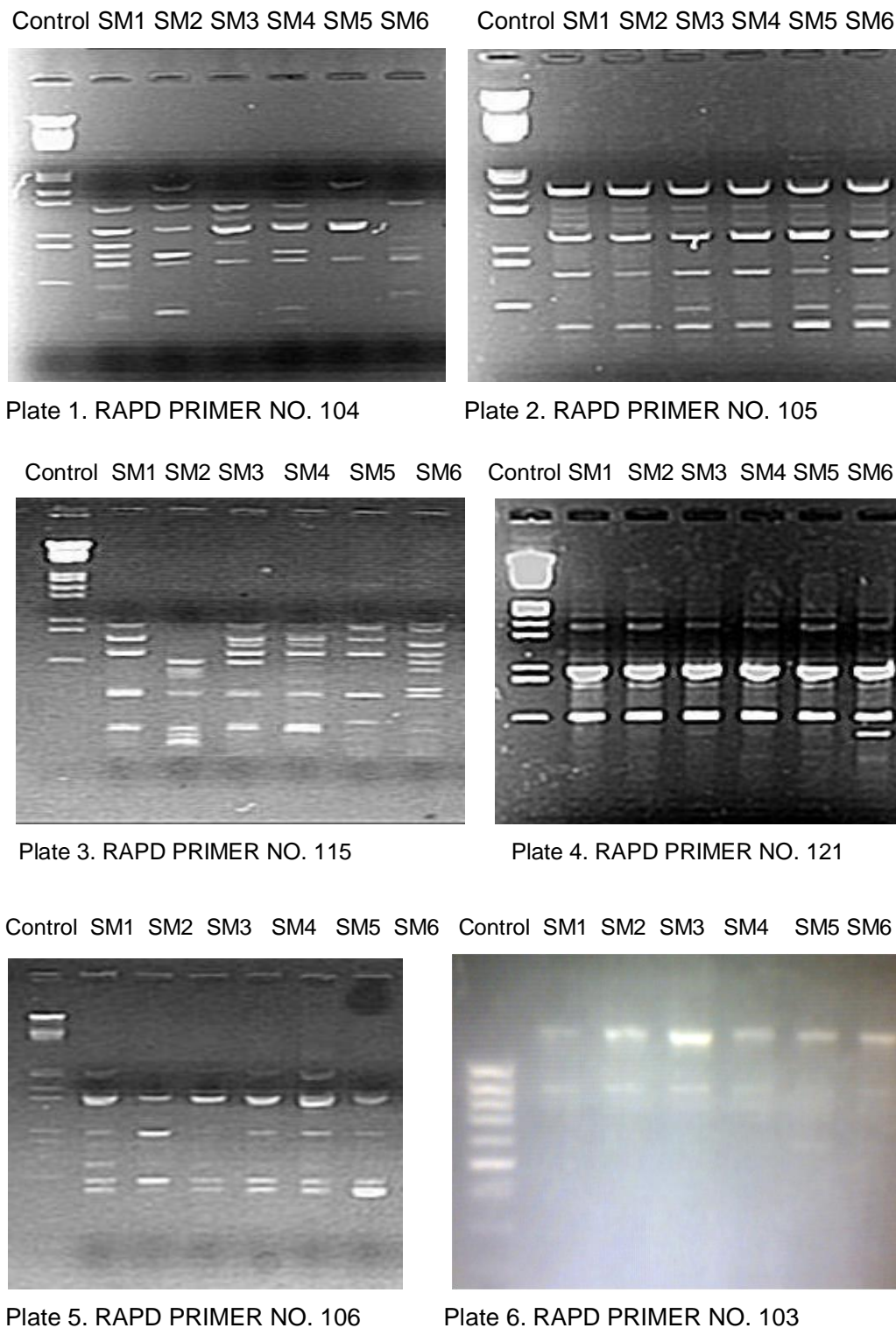


Figure 2. RAPD profiles of six *C. borvilianum* genotypes.

REFERENCES

Canter PH, Thomas H, Ernst E (2005). Bringing medicinal plants into cultivation: Opportunities and challenges for biotechnology. *Trends Biotechnol.* 23(4):180-185.

Carelli BP, Gerald L TS, Grazziotin FG, Echeverrigaray S (2006). Genetic diversity among Brazilian cultivars and landraces of tomato *Lycopersicon esculentum* Mill. revealed by RAPD markers. *Genet. Res. Crop Evol.* 53:395-400.

Chapco W, Ashton NW, Martel RK, Antonishyn N, Crosby WL (1992). A

- feasibility study of the use of random amplified polymorphic DNA in the population genetics and systematic of grasshoppers. *Genome* 35:569-574.
- Cheng KT, Chang HC, Su CH, Hsu FL (1997). Identification of dried rhizomes of *Coptis* species using random amplified polymorphic DNA. *Bot. Bull. Acad. Sin.* 38:241-244.
- Demeke T, Lynch DR, Kawchuk LM, Kozub GC (1996). Genetic diversity of potato determined by random amplified polymorphic DNA analysis. *Plant Cell Rep.* 15:662-667.
- Doyle JJ, Doyle JL (1990). Isolation of Plant DNA from fresh tissue. *Focus* 12:13-15.
- Dwivedi R, Devendra KS (2011). Assessment of genetic diversity among collected genotypes of *Chlorophytum borivillianum* using Random Amplified Polymorphic DNA (RAPD) markers. *Afr. J. Biotechnol.* 10(27):5268-5270.
- Geetha K, Maiti S (2002). Biodiversity in *Chlorophytum borivillianum* Santapau and Fernandes. *Plant Genet. Resour. Newsl.* 129: 52-53.
- Gepts P (1993). The use of molecular and biochemical markers in crop evolution studies. *Evol. Biol.* 27:51-94
- Karp A, Kresovich S, Bhat KV, Ayad WG, et al (1997). Molecular tools in plant genetic resources conservation: A guide to the technologies. In IPGRI Technical Bulletin No. 2. International Plant Genetic Resources Institute, Rome.
- Landry BS, Dextraze L, Boivin G (1993). Random amplified polymorphic DNA markers for DNA fingerprinting and genetic variability assessment of minute parasitic wasp species (Hymenoptera: *Mymaridae* and *Trichogrammatidae*) used in biological control programs of phthophagous insects. *Genome* 36:580-587.
- Li L, Xiaoying Z, Klocke E (2004). Variation in some *Lycopersicon esculentum* and *Capsicum annuum* cultivars revealed by RAPD and AFLP markers. *Guangxi Sci.* 11:249-257.
- Maiti S, Geetha KA (2005). Characterization, genetic improvement and cultivation of *Chlorophytum borivillianum*- an important medicinal plant of India. *Plant Genet Res* 3:264-272.
- Marais W, Reilly J (1978). *Chlorophytum* and its Related Genera (Liliaceae). *Kew Bulletin* 32(3):653-663.
- Nayar MP, Shastry, ARK (1998). *Chlorophytum borivillianum* In: Nayar MP, Shastry Ark (eds) Red data book of Indian plants. Botanical Survey of India, Calcutta, India 2:142.
- Oudhia P (2001). Problem perceived by Safed Musli (*Chlorophytum borivillianum*) grower of Chhattisgarh (India) region: a study. *J. Med. Arom. Plant Sci.* 22(4A)/23 (1A):396-399.
- Pavlicek A, Hrda S, Flegr J (1999). *Free -Tree*: freeware program for construction of phylogenetic trees on the basis of distance data and bootstrap/jackknife analysis of the tree robustness. Application in the RAPD analysis of genus *Frenkelia Folia Biol. (Praha)* 45:97-99
- Rholf FJ (2000). NTSYS-pc. Numerical taxonomy and multivariate analysis system, version 2.02. Exeter software. New York.
- Sanghamitra S, Tarun KP, K.A. Geetha, Satyabarata Malthi (2011). Identification and assessment of genetic relationship in three *Chlorophytum* species of and two high yielding genotypes of *C. borivillianum* through RAPD markers. *Biologia* 66(2):244-250.
- Shi W, Yang CF, Chen JM, Guo YH (2008). Genetic variation among wild and cultivated populations of the Chinese medicinal plant *Coptis chinensis* (Ranunculaceae). *Plant Biol.* 10:484-491
- Thakur M, Dixit VK (2008). A Review on Some Important Medicinal Plants of *Chlorophytum* spp. *Pharmacogn. Rev.* 2(3):168-172.
- Tripathi N, Saini N, Nair P, Tiwari S (2012). Lack of genetic diversity of a critically endangered important medicinal plant *Chlorophytum borivillianum* in Central India revealed by AFLP markers. *Physiol Mol Biol Plants.* Apr 2012; 18(2):161-167.
- Welsh J, McClelland M (1990). Fingerprinting genomes using PCR with arbitrary primers. *Nucleic Acids Res.* 18:7213-7218.
- Williams JG, Kubelik AR, Livak KJ, Rafalski JA, Tingey SV (1990). DNA polymorphisms amplified by arbitrary primers are useful as genetic markers. *Nucleic Acids Res.* 18:6531-6535.

Full Length Research Paper

Physico-chemical parameters and Ichthyofauna diversity of Arasalar Estuary in Southeast coast of India

C. Raju^{1*}, G. Sridharan¹, P. Mariappan¹ and G. Chelladurai²

¹Research Department of Zoology, Rajash Serfoji Government College, Thanjavur, Tamilnadu, India.

²Department of Zoology, Kamaraj College, Tuticorin, Tamilnadu, India.

Received 27 August, 2014; Accepted 14 November, 2014

Physico-chemical changes may have the tendency to accumulate in the various organs of estuarine organisms, especially fish which may in turn enter into the human metabolism through consumption causing serious hazards. Hence, the present study was carried out to determine the physico-chemical characteristics of water and Ichthyofauna in Arasalar Estuary in Southeast coast of India for the period of one year from September 2012 to August 2013. The environmental parameters such as, temperature, pH, salinity, dissolved oxygen (DO), silicate, nitrate and phosphate were observed at the Department of Zoology, Rajash Serfoji Government College, Thanjavur, Tamil Nadu, India. During the period of study, air temperature varied from 28.8 to 35°C. The surface water temperature also varied from 25 to 31.5°C. The monthly mean values of hydrogen ion concentration of water varied from 7.1 to 8.2. The salinity of water varied from 5.5 to 34‰. Dissolved oxygen in Arasalar estuary varied from 3.5 to 7.2 mg/l. The total phosphorus varied from 0.29 to 2.15 µg/l. The nitrate varied from 0.47 to 3.75 µg/l. The silicate content varied from 28.25 to 198.74 µg/l. Totally, 866 fishes were collected belonging to 4 orders and 5 families. *Mystusgulis* was found to be the dominant species (25.40%) in the study area.

Key words: Arasalar estuary, physico-chemical parameters, ichthyofauna diversity.

INTRODUCTION

Estuaries have very high potential for fishery development in the wild, therefore, are considered as the potential source for feeding, spawning and nursery ground for most of the finfishes and shellfishes. The faunal distribution and productivity of estuary depend on various physico-chemical factors such as temperature, pH, salinity, DO and micro nutrients such as nitrate, phosphate and silicate. Several investigations have been

carried out on the physico-chemical features of southeast Indian estuaries and Uppanar estuary (Nedumaran et al., 2011). The fluctuation of physico-chemical characters in estuarine environment has a profound influence on the occurrence of the juveniles of fish stocks. The fish communities of the Australian estuary have been investigated (Loneragon et al., 1986; Blaber et al., 1989; Morton, 1989; Moyle et al., 1986). The Arasalar Estuary is located on

*Corresponding author. rajuzoology@yahoo.com.

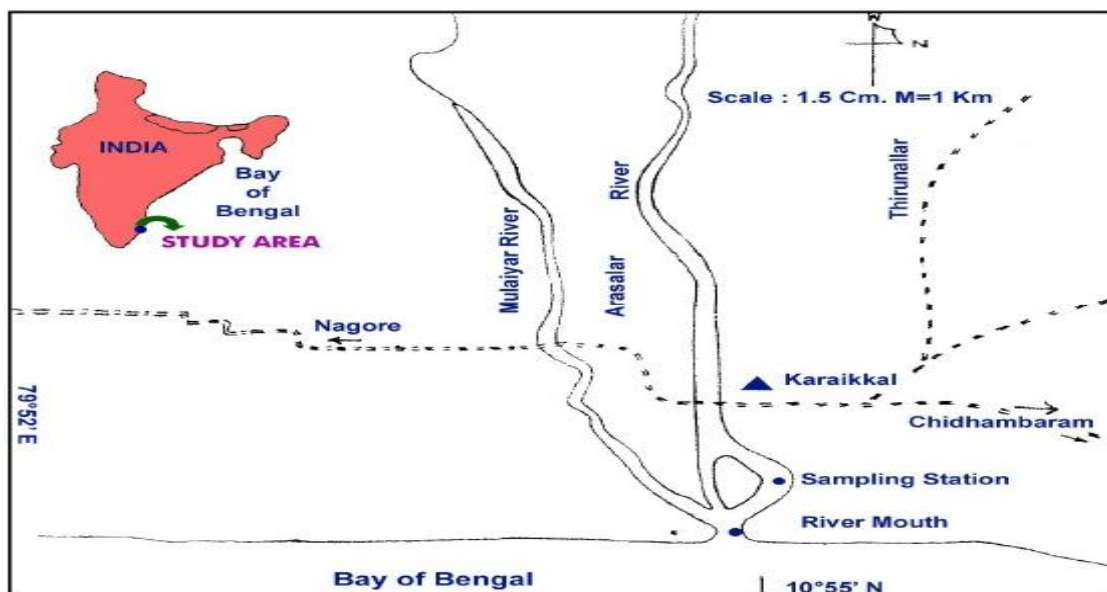


Figure 1. Study area map.

eastern side, 100 km away from Rajah Serfoji Government College, Thanjavur, Tamil Nadu, India. It is assumed that the combination of anthropogenic activities and the discharge of domestic sewage into the estuary might influence the biodiversity of the estuarine system. The water quality and biological diversity of this estuarine area are deteriorating, mainly due to rapid increase in human settlement, industrialization and sanitation (Ragothaman and Patil, 1995). Few work has been published on the physico-chemical characteristics in relation to ichthyofaunal diversity in Arasalar Estuary, hence the present study was conducted to study the physico-chemical parameters and distribution of ichthyofauna in the Arasalar Estuary, southeast coast of India.

MATERIALS AND METHODS

Study area

Arasalar Estuary is situated at Karaikkal (Lat. 10° 55' N and Long. 79° 52' E) of the Bay of Bengal, southeast coast of India (Figure 1). In the present investigation, monthly samplings were carried out from September 2012 to August 2013.

Analysis of physico-chemical parameters

Water and air temperature was measured using a standard Celsius thermometer with the accuracy of $\pm 0.5^\circ\text{C}$. The pH of water was recorded in the field by using Elico pH meter (model – LI-120). The Mohr-Knudsen titration procedure and Winkler's method was followed for salinity and dissolved oxygen quantification,

respectively (Strickland and Parsons, 1972). For analysis of nutrients, surface water samples were collected in clean polyethylene bottles and kept in an ice box and transported immediately to the laboratory. The water samples were filtered using a Millipore filtering system and analyzed for total phosphorus, nitrate and silicate by adopting the standard methods described by Strickland and Parsons (1972).

Collection and identification of fin fishes from Arasalar Estuary

In order to estimate the fishery potential, a cast net measuring 2.5 m length, with a mesh size varying from 7 mm at the base and 15 mm at the apex was employed for the collection of fish throughout the period of study. The net was hauled ten times during every collection at each sampling site. The collected specimens were identified up to species level. The fin fishes were identified by using the description and key given by Day (1889a, b) and Nelson (1976).

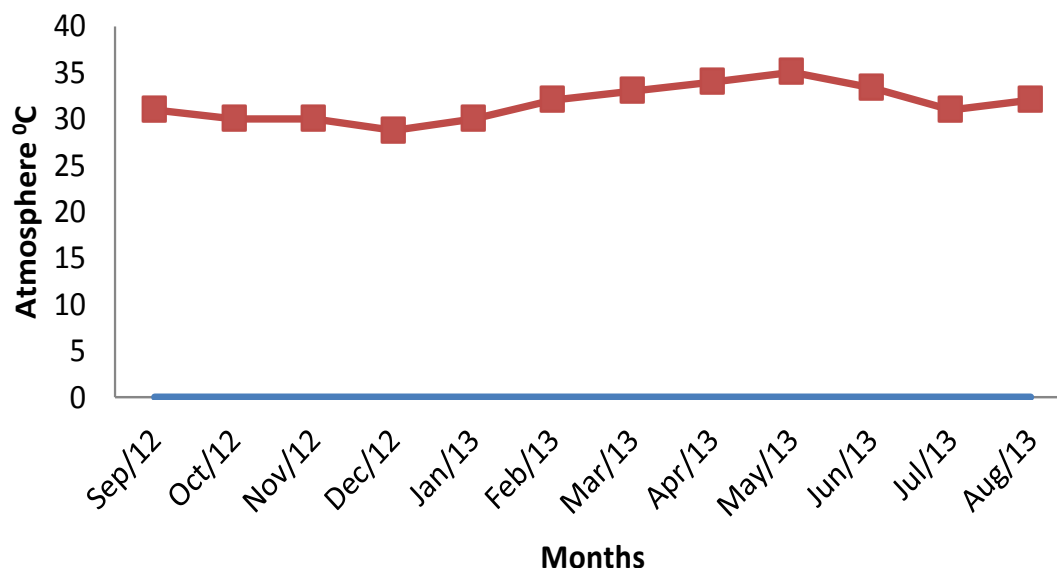
RESULTS

Physico-chemical parameters

Monthly variation in meteorological and physico-chemical parameters namely: the correlation coefficient (r) values between the environmental parameters like air and surface water temperature, pH, salinity, dissolved oxygen, phosphate; nitrate and silicate content in Arasalar estuarine water were recorded for a period of one year from September 2012 to August 2013 (Table 1). The north east monsoon in Tamil Nadu brings very heavy rain during the October, November and December months. The pattern of rainfall facilitates the divisions of the year into post monsoon (January - March) summer

Table 1. Correlation coefficient (r) values between the environmental parameters.

Parameters	At. temp.	W. temp.	pH	Salinity	DO	Silicate	Phosphorous	Nitrate
At. temp.	1							
W. temp.	0.7618	1						
pH	0.8244	0.7918	1					
Salinity	0.8396	0.714	0.88582	1				
DO	-0.608	-0.721	-0.6831	-0.6439	1			
Silicate	-0.745	-0.639	-0.7843	-0.9036	0.8024	1		
phosphorous	-0.647	-0.781	-0.6643	-0.7924	0.765	0.8457	1	
Nitrate	-0.827	-0.786	-0.8295	-0.9144	0.8518	0.9042	0.8356368	1

**Figure 2.** Monthly variations of Atmospheric temperature during September 2012 to August 2013.

(April – June), pre monsoon (July – September) and monsoon (October – December). During the study period, air temperature varied from 28.8 to 35°C, the minimum was recorded during monsoon season (December 2012) and maximum during the summer season (May 2013) (Figure 2). The surface water temperature varied from 25 to 31.5°C. The minimum surface water temperature was recorded during monsoon season (November 2012) and maximum was recorded during the summer season (May 2013) (Figure 3). The monthly mean values of hydrogen ion concentration of water varied from 7.1 to 8.2. Maximum values of pH were observed in the summer season (May 2013) and minimum values were recorded in the monsoon seasons (December 2012) (Figure 4). The salinity in Arasalar estuary varied from 5.5 to 34%. Minimum salinity (5.5% was recorded during monsoon (November 2012) and was slowly built up during post

monsoon, and attained maximum value (34%) during summer seasons (May 2013) (Figure 5). Dissolved oxygen in Arasalar estuary ranged from 3.5 to 7.2 ml/l, while the minimum DO was recorded during the month of June, 2013, maximum value occurred in the month of November (2012) (Figure 6). For dissolved phosphorus, the monthly values recorded in Arasalar estuary ranged from 0.29 to 2.15 µg/l. The total phosphorus was minimum in the month of June, 2012 and maximum during the month of November, 2012 (Figure 7). The nitrate varied from 0.49 to 3.75 µg/l. Minimum was recorded during the month of June, 2013 and the maximum during the month of October, 2012 (Figure 8). The monthly variation of silicate recorded in Arasalar estuary varied from 28.25 to 98.94 µg/l. Minimum silicate was recorded during the month of May, 2013 and maximum during the month of November, 2012 (Figure 9).

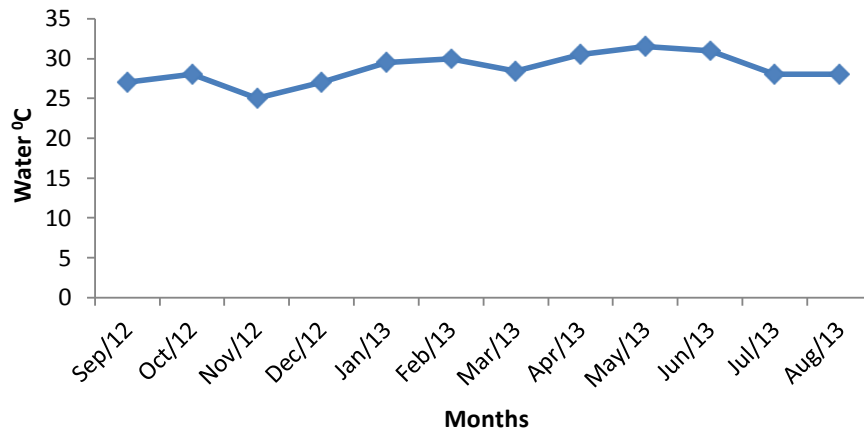


Figure 3. Monthly variations of Water temperature during September 2012 to August 2013.

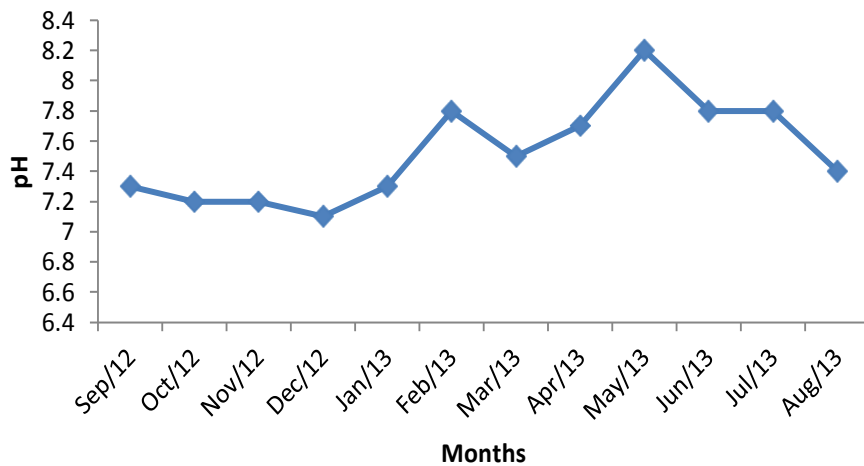


Figure 4. Monthly variations of pH during September 2012 to August 2013.

Ichthyofauna diversity of Arasalar Estuary

A total of 866 fishes were collected, they belong to 4 orders and 5 families in the study area (Figure 10). *Mystus gulio* accounted for about 25.40% and *Liza parsia* was the second dominating fish contributing 21.94% of the total. *Mugil cephalus* occupied the third rank with 20.20%. *Sillago sihama* with 17.89% *Chanos* with 6.69% and *Oreochromis mossambicus* with 7.85% ranking fourth, fifth and sixth species.

DISCUSSION

The monthly variations in meteorological and physico-chemical parameters such as, rainfall, air and surface

water temperature, pH, salinity, dissolved oxygen, phosphate, nitrate and silicate contents in Arasalar estuarine waters were recorded for a period of one year from September 2012 to August 2013. The surface water temperature largely depends on the intensity of solar radiation, evaporation, freshwater influx, cooling and mixing due to currents and tidal flow. Surface water temperature also showed a similar trend of monthly variation as that of air temperature and the high values were reported during the summer season (May, 2013) and lower values during the monsoon season (December, 2012). The gradual increase in water temperature from monsoon to summer is directly related to atmospheric conduction and radiation. Similar findings were reported by Thangaraj (1984). During the study period, air temperature varied from 28.8 to 35°C. The minimum was recorded during monsoon season

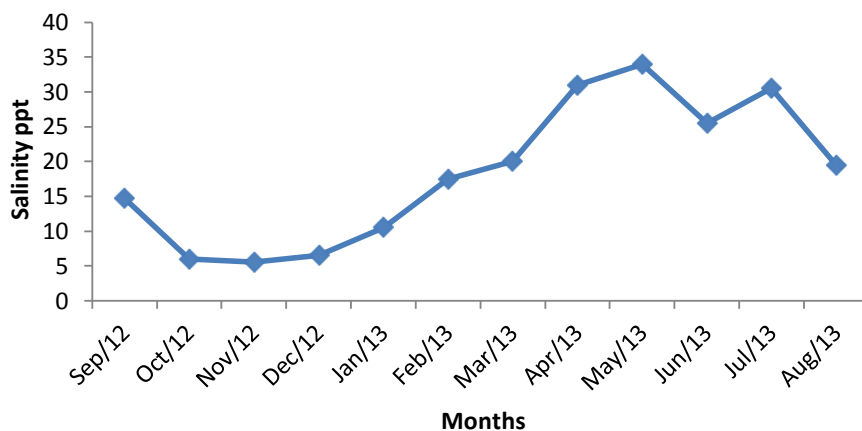


Figure 5. Monthly variations of Salinity during September 2012 to August 2013.

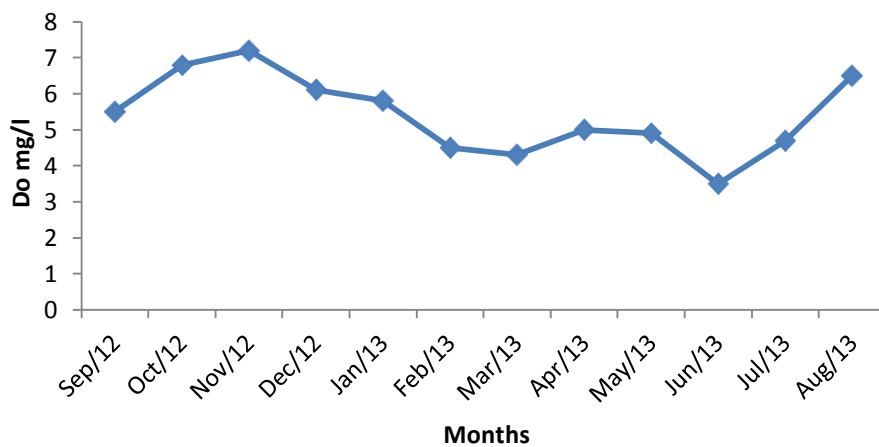


Figure 6. Monthly variations of Dissolved oxygen during September 2012 to August 2013.

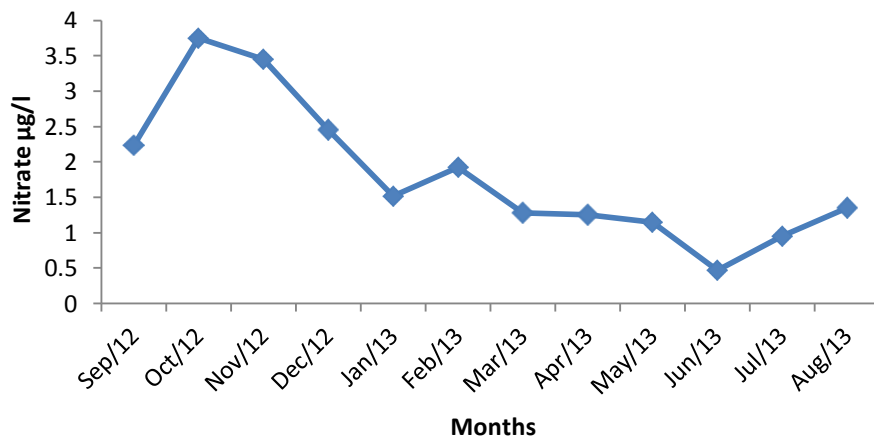


Figure 8. Monthly variations of Atmospheric temperature during September 2012 to August 2013.

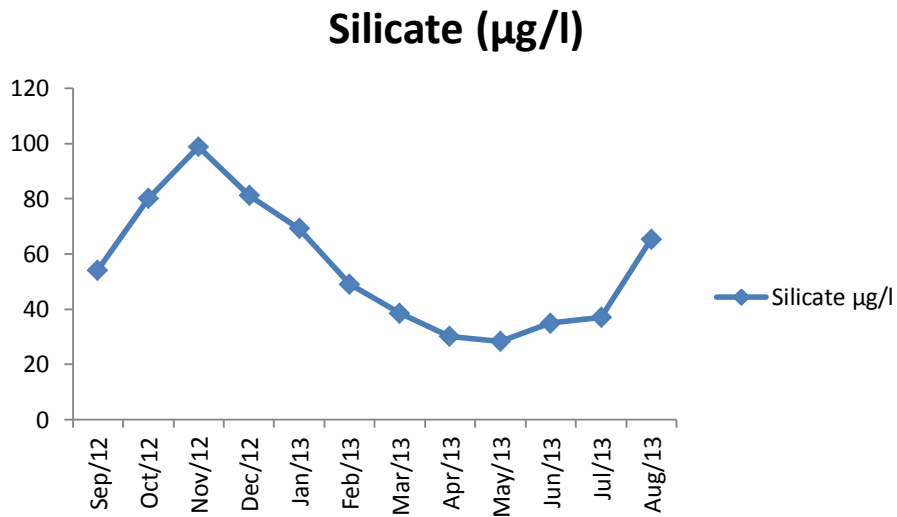


Figure 9. Monthly variations of Silicate during September 2012 to August 2013.

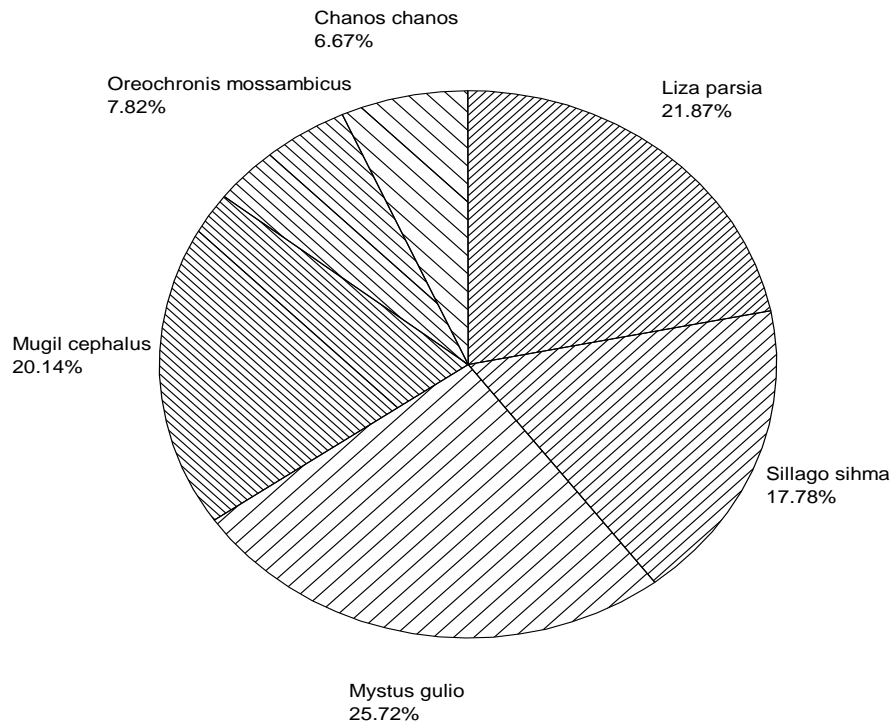


Figure 10. Diversity of Ichthyofauna in Arasalar Estuary during September 2012 to August 2013.

(December, 2012) and maximum during the summer season (May, 2013). Dissolved oxygen is one of the most important parameters, which reflects the physical and biological processes of water. The dissolved oxygen content depends upon the photosynthetic activities,

monsoonal floods and the turbulence caused by winds (Nedumaran et al., 2011). In the present study, the dissolved oxygen concentration was low during summer and high during monsoon period. During 2012, the dissolved oxygen concentration was low as compared to

2013, which may perhaps be due to low rainfall recorded during that period. The trend noticed in the present study is in accordance with the findings of hydrology and heavy metals (Rajasegar, 2003). The seasonal variation of salinity in Arasalar estuary is graphically represented in Figure 3. A marked seasonal change in salinity was observed throughout the study period. Minimum salinity was recorded during monsoon (December, 2012) and increased slowly during post monsoon, and attained maximum value during summer seasons (May, 2013). Salinity acts as a prime factor among the most important environmental parameters in the distributions of living organisms (Chandra Mohan and Sreevanivas, 1998). The salinity variation in the exchange of ions and nutrients is because of the tidal flow and is low during the monsoon season in the Arasalar estuary. The present study is in conformity with the earlier reports from Vellar estuary (Palpandi, 2011; Singbal, 1976) Uppanar backwaters (Murugan and Ayyakannu, 1991; Soundarapandian et al., 2009). The monthly mean values of hydrogen ion concentration of water varied from 7.1 to 8.2. Maximum values of pH were observed in the summer season (May, 2013) and minimum values were recorded in the monsoon seasons (December, 2012). The minimum values of pH during monsoon in the study area may be controlled by the influence of freshwater discharge, rainfall and the decomposition of organic matter as stated by Ragothaman and Patil (1995) and Upandhayay (1998). The photosynthetic activity may cause high pH, because of bicarbonate degradation by carbonic anhydrase associated with photosynthesis (Rajkumar et al., 2009). In the present study, the total phosphorus and nitrate were found to be higher during monsoon periods and decreased slowly from summer onwards. High concentration of total phosphorus during monsoon season is due to heavy rainfall, decomposition of particulate organic matter, industrial effluents and from the agricultural discharges from the adjacent lands there are serious omissions. Such monsoonal maximum and summer minimum in the total phosphorus concentration was also reported from Vellar estuary (Chandran and Ramamoorthi, 1984).

The peak values of silicate observed during monsoon may be attributed to the heavy fresh water influx and land run off which carries silt and other silicon deposits from upper to reach the river. Observations similar to the present study were reported earlier (Qasim et al., 1969; Ansari and Rajagopal, 1974) in Cochin back waters (Nair et al., 1983), Ashtamudi estuary (Praba Devi, 1986) and Coleroon estuary. The silicate concentration also showed negative relationship ($r = -0.9036$) with salinity, which was also noted earlier in Vellar estuary (Chandran and Ramamoorthi, 1984; Thangaraj, 1984) and in Kerala backwaters (Sarala Devi et al., 1983). The diversity is an important tool to study a variety of species in a particular area and to evaluate the abundance of individuals within each species (Ramaiyan et al., 1986). In the present

study, totally 866 fishes belonging to only five species was observed in the study area which may be due to the stable environmental condition at the study area. Similarly, high diversities were observed by Morton (1989) in the Cochin waters and in the Vellar estuary (Chandran, 1982), and they attributed this is to the stable environmental condition. The diversity values observed in the present study were comparable to the results of Shanmugam (1985) and Chandrasekaran (1986) in Vellar estuary. The conclusion of the present study is that physico-chemical parameters influence the Ichthyofaunal diversity and Arasalar estuary are not extremely pollutant but at the same time there is possibility of gradual addition of heavy metals in due course. It reveals that the estuarine environment is largely influenced by the annual cycle of monsoon.

Conflict of Interests

The authors have not declared any conflict of interests.

REFERENCES

- Ansari SA, Rajagopal MD (1974). Distribution of mud phosphate in the Cochin backwater. *Mahasagar, Bull. Natl. Inst. Oceanogr.* 7:69-72.
- Blaber SJM, Brew DT, Salini JP (1989). Species composition and biomass of fishes in different habitats of a tropical northern Australian estuary; their occurrence in the adjoin sea and estuarine dependence. *Est Coastal and Shelf Sci.* 29:509-531.
- Chandran R, Ramamoorthy K (1984). Hydrobiological studies in the Chandran R (1982). Hydrobiological studies in the gradient zone of the Vellar estuary. Ph.D. Thesis, Annamalai University, 95pp.
- Chandrasekaran V (1986). Studies on prawn and finfish seed resources of the Pichavaram mangrove region (Southeast Coast of India). Ph.D. Thesis, Annamalai University, 218pp.
- Day F (1889b). The fauna of British India, including Ceylon and Burma, Fishes – II, *Taylor and Francis*, London, 509pp.
- Day F (1889a). The fauna of British India including Ceylon and Burma. Fishes-I, *Taylor and Francis*, London, 548pp.
- gradient zone of Vellarestuary, Part-I: Physico-chemical parameters. *Mahasagar-Bull. Natl. Inst. Oceanogr.* 17(3):133-140.
- Loneragon NR, Potter IC, Lenanton RCJ, Caputi N (1986). Saptial and seasonal differences in the fish fauna in the shallows of a large Australian estuary. *Mar. Biol.* 92:575-586.
- Morton RM (1989). Hydrology and fish fauna of canal developments in an intensively modified Australian Estuary. *Estuar. Coastal Shelf Sci.* 28(1):43-58.
- Moyle B, Robert A. Daniels, Bruce Herbold and Donald M. Baltz (1986). Patterns of distribution and abundance of a non coevolved assemblage of estuarine fishes in California. *Fish. Bull.* 84(1):105-118.
- Murugan A, Ayyakannu K (1991). Ecology of Uppanar backwaters, Cuddalore-II nutrients *Mahasagar-Bull. Natl. Inst. Oceanogr.* 24(2):103-108.
- Nair NB, Abdul Azis PK, Dharmaraj K, Arunachalam M, Krishnakumar K, Balasubramanian NK (1984). Ecology of India estuaries: Part V: primary productivity of Ashtumudi estuary, South West coast of India. *Proc. Indian Acad. Sci. Sci.* 93(1):2-23.
- Nedumaran TP, Perumal R, Rajaram (2011). Physico-chemical characteristic features of the Uppanar estuary, south east coast of India, *J. Ecotoxicol. Environ. Monit.* 21(1):1-11.
- Qasim SZ, Wellershaus S, PMA. Bhattathiri SAH. (1969). Organic production in a tropical estuary. *Proc. Indian. Acad. Sci.* 69B:51-94.

- Ragothaman G, Patil T (1995). Studies on the physico-chemical parameters and phytoplankton of Narmada estuary. *Enviromedia*. 14(2):221-226.
- Rajasegar M (2003). Physico-chemical characteristics of the vellar estuary in relation to shrimp farming. *J. Environ. Biol.* 24:95-101.
- Rajkumar M, Perumal P, Ashok Prabu V, Vengadeshperumal N, Thillai Rajasekar K (2009). Phytoplankton diversity in Pichavaram mangrove waters from south-east coast of India. *J. Environ. Biol.* 30:489-498.
- Ramaiyan V, Purushothaman A, Natarajan R (1986). Check list of estuarine and marine fishes of parangipettai (Porto Novo) Coastal waters. *Matsya*. 12(13):1-19.
- Sarala Devi K, Sankaranayanan VN, Venugopal P (1991). Distribution of nutrients in the Periyar river estuary. *Indian J. Mar. Sci.* 20:49-54.
- Shanmugam S (1985). Studies on finfish and shellfish seed resources of the Vellar estuary (Southeast Coast of India). Ph.D. Thesis, Annamalai University, India. 176pp.
- Singbal SYS (1976). Diurnal variation of some physico-chemical factors in the Mandovi estuary of Goa. *Mahasagar-Bull Natl. Inst. Oceanogr.* 9:27-34.
- Soundarapandian P, Preamkumar T, Dinakaran GK (2009). Studies on the physico-chemical characteristics and nutrients in the Uppanar estuary of Cuddalore, south east coast of India. *Curr. Res. J. Biol. Sci.* 1(3):102-105.
- Strickland JDH, Parson TR (1972). A practical hand book of seawater analysis. *Bull. Fish Res. Bd. Canada.* 67-311pp.

Full Length Research Paper

Population structure and regeneration status of *Prunus africana* (Hook.f.) Kalkm. after selective and clear felling in Kibale National Park, Uganda

Arthur A. Owiny* and Geoffrey M. Malinga

Department of Biology, University of Eastern Finland, P. O. Box 111, FI-80101 Joensuu, Finland.

Received 31 July, 2014; Accepted 7 November, 2014

Prunus africana is a globally threatened indigenous medicinal tree species, and food for many primates. Its population has declined in Sub-Saharan Africa due to unsustainable harvest and poor protection. In this study, we determined the population density, population structure and regeneration status of *P. africana* in the former clear felled, selectively logged and primary forests of Kibale National Park, and assessed the effects of dense cover of *Acanthus pubescens* on its regeneration. Trees were measured from 180 randomly established plots. The densities of *P. africana* seedlings and saplings differed significantly among the three forests while that of poles and mature trees did not. The density of seedlings was significantly higher in the selectively logged than in primary forests. The density of saplings was higher in clear felled than in selectively logged forests. Tree density was not negatively affected by *A. pubescens* cover. Clear felled areas had a more stable population structure with better regeneration, while selectively logged and primary forests had unstable population structures with poor recruitment potential. Our results show that *P. africana* regenerates more in intensively disturbed forest areas than less disturbed or primary forests, highlighting the importance of regenerating forests in the conservation of *P. africana*.

Key words: *Acanthus pubescens*, density, disturbance, population dynamics, regeneration, restoration, size class distributions, succession, tropical forest.

INTRODUCTION

African cherry (*Prunus africana* (Hook.f.) Kalkm.) is a globally vulnerable tropical tree species (IUCN, 2013), included as Appendix II by CITES in 1995 (Cunningham et al., 1997), and by FAO panel of Experts on Forest

Genetic Resources as a species with maximum action priority in Africa (Navarro-Cerrillo et al., 2008). The population of mature sized trees has declined in many Sub-Saharan African forests due to subsistence and large

*Corresponding author. E-mail: owinyiarthur@yahoo.com. Tel: +256788557572.

Author(s) agree that this article remain permanently open access under the terms of the [Creative Commons Attribution License 4.0 International License](https://creativecommons.org/licenses/by/4.0/)

Abbreviations: CITES, Convention on International Trade on Endangered Species; FAO, Food and Agriculture Organization; IUCN, International Union for the Conservation of Nature; RAC, regenerating age classes; SCD, size class distribution.

scale bark harvests for medicinal trade (Stewart, 2009; Jimu, 2011; Jimu et al., 2012). In Cameroon, Stewart (2009) showed that the number of surviving trees reduced in all size classes as a result of past harvesting. In Kibale National Park (KNP), a mean density of only 0.4 trees per ha has been reported (Chapman and Chapman, 1997). Moreover, *P. africana* is a highly preferred food source for many primates and frugivorous birds (Chapman and Chapman, 2002; Fashing, 2004).

Despite its threatened status, few tropical studies have examined its density, population structure, size class distributions and regeneration status as recommended by CITES, (2006) (but see, Fashing, 2004; Eilu and Obua, 2005; Kasenene, 2007a). Knowledge of tree population structure and density is important for understanding the status of regeneration of the species (Tesfaye et al., 2010). Kasenene (2007a) found significantly higher densities of *P. africana* saplings and poles in logged than in the unlogged coniferous forest of KNP.

Furthermore, the reproduction process of *P. africana* is not well documented. According to Farwig et al. (2006) and Berens et al. (2013), many seeds fall under the tree crown after heavy fruiting and are likely dispersed by frugivorous birds and monkeys. Despite massive seed production, its recruitment into the reproductive size classes is limited (Hall et al., 2000). The regeneration of *P. africana* is generally very low or sporadic (Stewart, 2003), reproducing best in large gaps and forest margins (Njunge, 1996; Ndam, 1996), probably due to lower predation rates at gaps and forest margins.

Tree regeneration processes, like seedling establishment, spatial distribution and population structure, might also be influenced by past disturbances, logging methods, colonizing vegetation, gap sizes, canopy cover, seed reproduction and dispersal (Vieira and Scariot, 2006; Bognounou et al., 2010). These factors can determine seedling recruitment, which is a critical part in tree regeneration, because they can determine the rates of regeneration, growth forms and composition of mature populations. For example, in Kibale forest, the opportunistic woody herb, *Acanthus pubescens* Engl. (Acanthaceae) can colonize and dominate large canopy gaps created by logging. The resulting dense herb cover might interfere with the tree seedling establishment, growth and survival (Chapman et al., 1999; Paul et al., 2004; Lawes and Chapman, 2006), due to changes in light and nutrient availability (Duclos et al., 2013).

In this paper, we assessed the population and regeneration status of *P. africana* in the former clear felled coniferous plantation, selectively logged and primary forests. The specific objectives were to: 1) determine the population densities of seedlings, saplings, poles and mature individuals of *P. africana* in the clear felled, selectively logged and primary forests; 2) assess the size-class distributions and regeneration status of *P. africana* in the different forest areas; and 3) determine the effects of dense cover

of *A. pubescens* on the regeneration of *P. africana*. We predicted that the recruitment rate of *P. africana* would be higher in the former clear felled and selectively logged areas than in the primary forest areas (Fashing, 2004). We expected to find higher densities (individual/ha) within the former clear felled and selectively logged than in the primary forest areas. We also anticipated that the densities of *P. africana* would negatively correlate with the cover of *A. pubescens* (Chapman and Chapman, 2004).

MATERIALS AND METHODS

Study area

This study was conducted in the Kanyawara compartments of Kibale National Park (KNP), located 20 km south-east of Fort Portal, western Uganda (0°13'-0°41' N and 30°19'-30°32' E). The park covers approximately 795 km². Rainfall is highly variable, but generally bimodal with peaks between March–May and September–November (Struhsaker, 1997). Mean annual rainfall at Kanyawara averages 1547 mm year⁻¹ and annual means for daily minimum and maximum temperatures are 14.9 and 20.2°C (1990–2001), respectively (Chapman et al., 2005).

The study sites were located in four regenerating aged forests of the former clear felled coniferous plantation, hereafter referred to as 'clear felled areas', RAC9, RAC11, RAC14, RAC19, name indicating the approximate years since clear felled (Table 1, Nyafwono et al., 2014; Malinga et al., in press); three natural forest compartments selectively logged at varied intensities between 1967 and 1969 (K13, K14 and K15); and two primary forest compartments (K30 and K31). Compartment K13 was heavily logged (50% basal area reduction) during 1968–69 and treated with aboricide, Finopal (2:1 mixture of 2,4-D and 2, 4, 5-T). K15 was heavily logged from 1968 to 1969 (40% basal area reduction), whereas K14 was lightly selectively harvested in 1969 with basal area reduction of 25–27%. The primary forest compartment K30 had only two to three trees per hectare felled by pit sawyers in 1970 with minimal impact, while K31 was not harvested (Struhsaker, 1997). Logging activities resulted into large canopy gaps and forest tracts at various levels of disturbances and degradation (Kasenene, 2007b).

Study species

P. africana (Hook. f.), also known as African cherry, belongs to the subfamily Prunoideae in the Rosaceae family and genus *Prunus*. It is an evergreen canopy tree species that can grow between 25 to 30 m in height (Hall et al., 2000). It is distributed primarily in montane and middle-elevation forests of Sub-Saharan Africa (Hall et al., 2000, Stewart, 2009). The leaves are simple, alternately arranged, and elliptic to oblong or slightly ovate. The flowers are small, creamy white, androgynous, wind pollinated and are distributed in axillary racemes of 3.5–8 cm long (Lovett et al., 2006). The fruit is a red or red-brown ellipsoid drupe, 0.7 cm long and 1.1 cm in diameter (Hall et al., 2000; Lovett et al., 2006), and is dispersed by birds and monkeys (Fashing, 2004).

Study design and tree measurement

The Kanyawara forest area in KNP was classified and mapped a priori into nine differently aged successional forests by inspection of Landsat images (Malinga et al., in press). In each of the nine aged

Table 1. Mean density (individuals ha⁻¹) of *P. africana* in different size classes among the different forests areas.

Variable	Mean density (individuals ha ⁻¹)			Kruskal-Wallis test		
	Clear felled	Selectively logged	Primary forest	χ^2	df	P
Seedlings	11.25 ± 4.36	16.67 ± 5.40	0	6.53	2	0.04
Saplings	7.50 ± 3.99	0	0	9.05	2	0.01
Poles	3.44 ± 1.52	0.42 ± 0.41	0.63 ± 0.63	4.41	2	0.13
Mature trees	2.81 ± 1.37	6.25 ± 2.65	0.31 ± 0.31	2.46	2	0.29

successional forest, the location of 20 sampling plots was randomly established using a relative grid system, based on the actual sizes of RACs (RAC9-RAC19), and others (K13, K14, K15, K30 and K31) approximately on the same sized areas as RACs. At each GPS location, study plots were established with sides oriented to north (40 m) and east (20 m) direction. If the plot extended into foot trails or inaccessible points such as steep slopes, it was re-oriented perpendicular from that direction.

In each plot, we counted the number of individuals and measured for either stem diameter (saplings, poles and mature trees) or diameter above the root collar for seedlings (Kent and Coker, 1992). The species was identified by a trained botanist at the Makerere University Biological Field Station (MUBFS) Mr. Richard Sabiti, and voucher specimens have been deposited at MUBFS. The diameter of saplings, poles and mature trees were measured at the 1.3 m height, that is, diameter at breast height (DBH). Tree diameters of mature trees (diameter class > 20 cm), poles (diameter class 10–20 cm), saplings (diameter class 5–10 cm) and seedlings (diameter class 0–5 cm) were measured in nested plots of 40 × 20, 20 × 20, 20 × 10 and 10 × 10 m, respectively. At each plot, we visually estimated the percentage cover of *Acanthus pubescens* as follows: 0, <1% = 1, <10% = 10, <20% = 20, <30% = 30, etc. Because of low tree observations, in each aged successional forest, plots were regrouped into three forest areas based on previous history of disturbance, namely; clear felled (RAC9, RAC11, RAC14 and RAC19, logged between 9 to 19 years ago (80 plots)); selectively logged (K13, K14 and K15, logged 42-43 years ago (60 plots)); and primary forests (K30 and K31 (40 plots)), respectively.

Data analysis

For each of the three forest areas, we assessed the densities (individuals ha⁻¹) of *P. africana* in each size class (seedlings, saplings, poles and mature trees). A non-parametric Kruskal-Wallis test was used to compare *P. africana* densities in each size class among forests, since the data were not normally distributed. Whenever differences were significant, Mann-Whitney *U* test as a pair wise comparison was used. All analyses were conducted with IBM SPSS Statistics, Version 19.

To examine the population structure (distribution of individuals in the different size classes) and regeneration patterns of *P. africana*, in each of the three forests, tree counts were converted into densities (individuals ha⁻¹) (Venter and Witkowski, 2010). Population structure and regeneration status of *P. africana* was analyzed by computing the slope of regression of size class distribution (SCD) as proposed by Condit et al. (1998) and Lykke (1998). Tree diameters were categorized into thirteen size classes: [0.1 to 5], [5.1 to 10.0], [10.1 to 15.0], [15.1 to 20.0], [20.1 to 25.0], [25.1 to 30.0], [30.1 to 35.0], [35.1 to 40.0], [40.1 to 45.0], [45.1 to 50.0], [50.1 to 55.0], [55.1 to 60.0] and [> 60.0 cm]. The linear regression slope of SCD was calculated with the size-class distribution midpoint (*d*) as the independent variable and the number of

individuals (*N_i*) in each size class as the dependent variable. In order to obtain straight line plots (Obiri et al., 2002), *N_i* was transformed by $\ln(N_i + 1)$ because some size classes were without individuals. The regression was calculated between *d_i* and $\ln(N_i + 1)$ (Lykke, 1998; Obiri et al., 2002; Venter and Witkowski, 2010). SCD slopes of regressions were used as indicators of recruitment and population structure (Obiri et al., 2002; Mwavu and Witkowski, 2009; Tabuti, 2007; Venter and Witkowski, 2010). Negative slopes indicate good recruitment, with proportionally more individuals in smaller than in larger size-classes. A flat distribution with a slope of zero indicate approximately equal numbers of individuals in smaller and larger size-classes, while positive slopes indicate unstable or poor recruitment with more trees found in larger than in smaller size classes (Obiri et al., 2002). The steepness of the slope was further used to describe the recruitment trends in the different forest areas. Steep negative slopes indicate better recruitment than shallow slopes (Lykke, 1998; Mwavu and Witkowski, 2009).

To test for the associations between *A. pubescens* cover at each study plot, and its influence on *P. africana* tree density, spearman rank correlation was calculated. We used Kruskal-Wallis test to compare the distribution of *A. pubescens* cover between the clear felled, selectively logged and primary forests, since the data was not normally distributed.

RESULTS AND DISCUSSION

Population densities of *P. africana* in the different forest areas

We recorded significant differences in the densities of *P. africana* seedlings and saplings across the three forest areas (Table 1). The densities of poles and mature trees did not differ significantly across the three forest areas (Table 1). According to the pairwise tests, seedling densities differed, and were significantly higher in the selectively logged than in the primary forests (Mann-Whitney *U* test, $z = -2.552$, $P = 0.011$, Figure 1). Sapling density also differed, and were significantly higher in the clear felled than in the selectively logged forests ($z = -2.342$, $P = 0.019$), but no significant difference was found for sapling density between selectively logged and primary forests ($P = 1.00$, Figure 1). The high density of *P. africana* seedlings and saplings recorded in the selectively logged or clear felled areas in comparison with the primary forests support several previous studies indicating that *P. africana* can regenerate well in the more disturbed or forest gaps than in less disturbed forests (Kiama and Kiyirapi, 2001; Ndam, 1996; Fashing, 2004). This suggests that the tree is a light demanding secondary forest species.

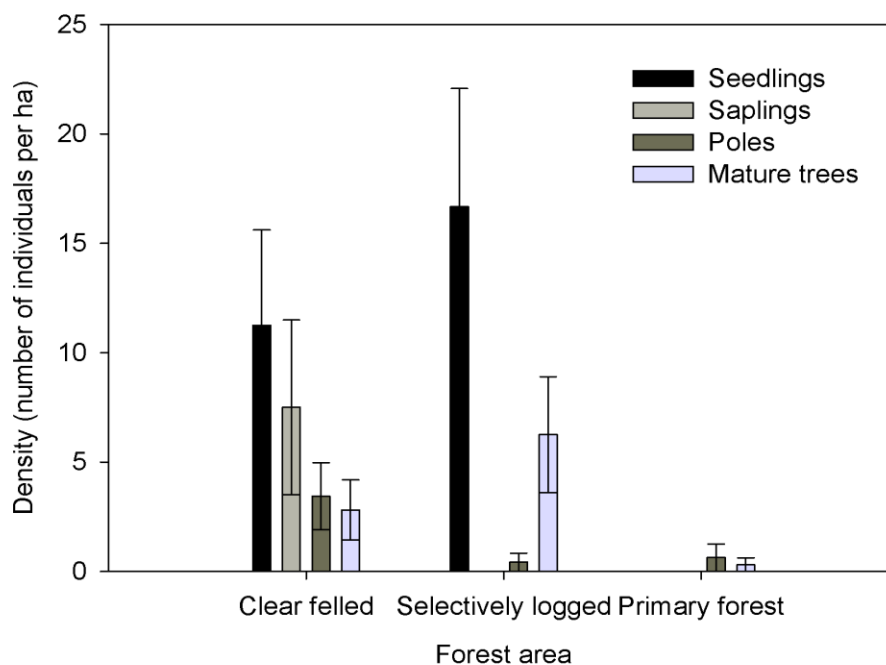


Figure 1. Population density (individuals ha⁻¹) of *P. africana* in the clear felled, selectively logged and primary forest areas in KNP.

Population structure and recruitment in different forests

Our results indicated that *P. africana* population structure in clear felled areas had a significant negative SCD slope (Slope = -2.176, $r^2 = 0.77$, $P < 0.001$, Figure 2) and an inverse *J*-shaped size class distribution, with a considerably smooth decline in the number of individuals from smaller to larger size classes (Figure 2). Such a trend is an indication of a healthy and stable population that are naturally replacing themselves through good recruitment (Condit et al., 1998; Mwima and McNeillage, 2003; Muoghalu, 2006; Tabuti, 2007). In contrast, the population structures of *P. africana* in the selectively logged and primary forests had positive slopes (Figure 2) which is indicative of an unstable population with a poor recruitment potential, that is, there are more individuals in the larger than in the smaller size classes. Such recruitment bottlenecks can weaken the population structure which might lead to local extinction of species (Obiri, et al., 2002; Tabuti and Magula, 2007; Gwali et al., 2009). The higher rates of recruitment of *P. africana* in clear felled areas might partly be due to higher rates of seed dispersal or seed banks in clear felled as compared to the selectively logged or primary forests (Farwig et al., 2006; Tesfaye et al., 2010). Previous studies have shown that *P. africana* trees in disturbed areas are visited more by dispersal agents, e.g., birds and monkeys than those in the primary forest (Chapman and Chapman, 2004; Farwig et al., 2006). The poor

regeneration recorded in the primary or selectively logged forests could be attributed to insufficient light penetrating the forest floor (Fashing, 2004; Jimu et al., 2012).

Influence of *A. pubescens* cover on the regeneration of *P. africana*

At plot level, the cover of *A. pubescens* differed significantly between the clear felled, selectively logged and primary forests (Kruskal-Wallis test, $\chi^2 = 12.75$, $df = 2$, $P = 0.002$). Despite significant variations between forests, the cover of *A. pubescens* was positively associated with density of *P. africana* (Spearman correlations; $\rho = 0.21$, $P = 0.004$) suggesting that, the increase in *A. pubescens* cover might not affect regeneration of *P. africana* as we expected. In KNP, dense *A. pubescens* cover occurs in logged sites and canopy gaps. This herb cover limits forest regeneration by slowing down tree seedling establishment, growth and survival by altering the light and nutrients availability to tree seedlings (Lawes and Chapman, 2006; Duclos et al., 2013). The high tolerance of *P. africana* to *A. pubescens* cover might be a result of its ability to grow relatively fast or establish in shade (Kiama and Kiyirapi, 2001; Meunier et al., 2010). Our result suggest that *P. africana* might be an ideal species for forest restoration activities in logged areas dominated by extensive *A. pubescens* cover like in KNP.

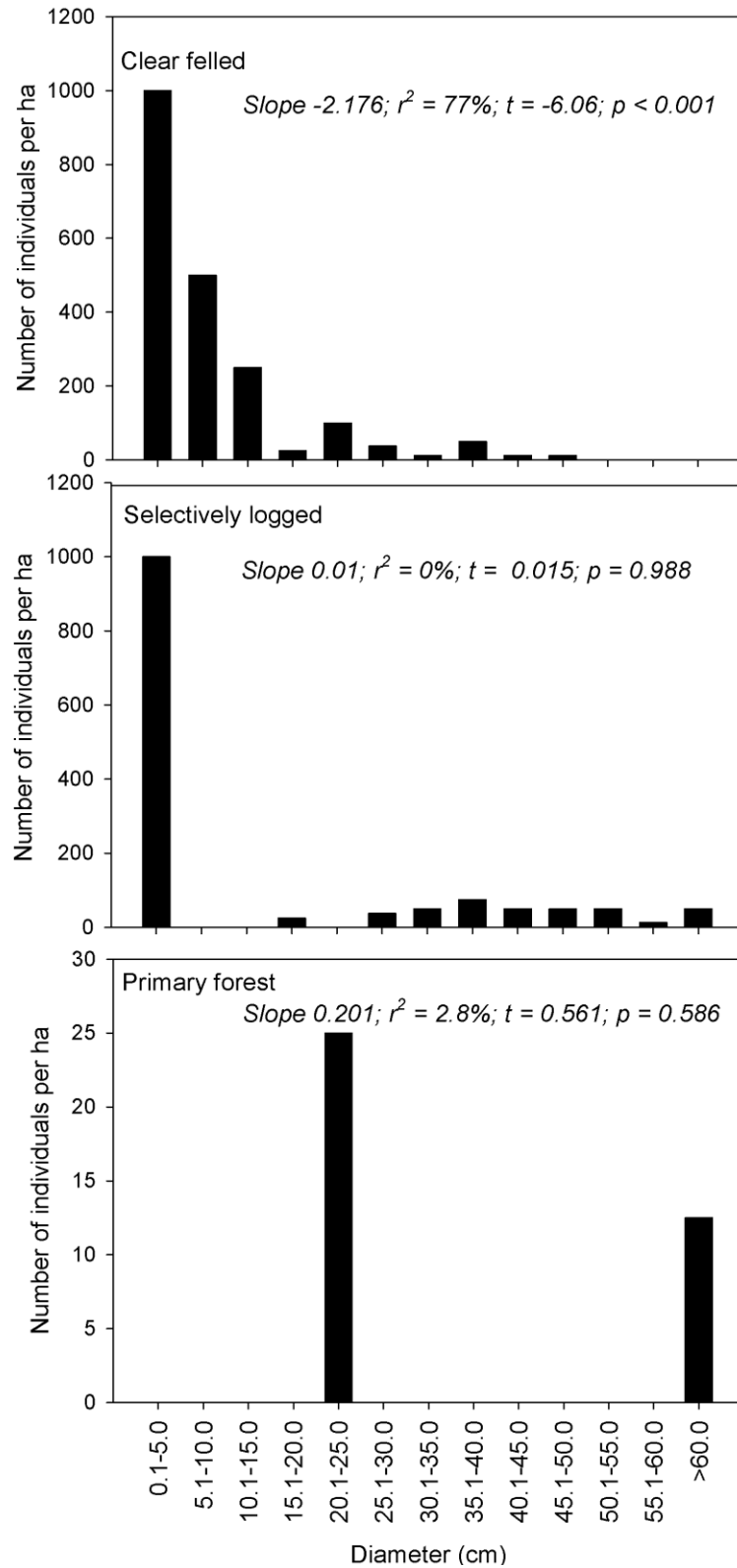


Figure 2. Size class distribution plots of *P. africana* in the clear felled, selectively logged and primary forest areas of KNP. The y-axis represents the individuals (ha^{-1}) while the x-axis is tree diameter size class in 5 cm intervals from 0.1 to 60 cm.

Conclusion

In this study, we showed that clear felled and selectively logged areas support proportionally higher densities of *P. africana* seedlings and saplings than primary forests suggesting that it is a light demanding species. Additionally, our results show that *A. pubescens* cover does not negatively affect the regeneration of *P. africana* in KNP. Clear felled areas had a stable population structure, with good recruitment potential, whereas that in the selectively logged and primary forests was unstable and had poor regeneration. This indicates that *P. africana* requires relatively heavy disturbances in order for it to regenerate, high-lighting the importance of the studied regenerating forests in the conservation of the tree species.

Conflict of Interests

The authors declare that there is no conflict of interest.

ACKNOWLEDGEMENTS

The study was funded by the Finnish Academy of Science, (SA no: 138899 to Roininen Heikki) under the Tropical forest Biodiversity recovery project. Permission to conduct this study was granted by the Uganda Wildlife Authority and the Uganda National Council of Science and Technology. We thank R. Sabiti for his help with field work.

REFERENCES

- Berens DG, Griebeler EM, Braun C, Chituyi BB, Nathan R, Böhning-Gaese K (2013). Changes of effective gene dispersal distances by pollen and seeds across successive life stages in a tropical tree. *Oikos* 122:1616-1625.
- Bognounou F, Tigabu M, Savadogo P, Thiombiano A, Boussim IJ, Oden PC, Guinko S (2010). Regeneration of five *Combretaceae* species along a latitudinal gradient in Sahelo-Sudanian zone of Burkina Faso. *Ann. For. Sci.* 67:306.
- Chapman CA, Chapman LJ (1997). Forest regeneration in logged and unlogged forests of Kibale National Park, Uganda. *Biotropica* 29:396-412.
- Chapman CA, Chapman LJ (2002). Foraging challenges of red colobus monkeys: influence of nutrients and secondary compounds. *Comp. Biochem. Physiol. A* 133:861-875.
- Chapman CA, Chapman LJ (2004). Unfavorable successional pathways and the conservation value of logged tropical forest. *Biodivers. Conserv.* 13:2089-2105.
- Chapman CA, Chapman LJ, Kaufman L, Zanne AE (1999). Potential causes of arrested succession in Kibale National Park, Uganda: growth and mortality of seedlings. *Afr. J. Ecol.* 37:81-92.
- Chapman CA, Chapman LJ, Struhsaker TT, Zanne AE, Clark CJ, Poulsen JR (2005). A long-term evaluation of fruiting phenology: importance of climate change. *J. Trop. Ecol.* 21:31-45.
- Condit R, Sukumar R, Hubbell SP, Foster RB (1998). Prediction of population trends from size distributions: a direct test in a tropical tree community. *Amer. Nat.* 152:495-509.
- Convention on International Trade in Endangered Species of wild fauna and flora (CITES) (2006). Evaluation of the harvest of *Prunus africana* bark on the Bioko Island (Equatorial Guinea): guidelines for a management plan. *Review of significant trade in specimens of Appendix-II species. Sixteenth meeting of the Plants Committee*, Peru. PC16 Doc. 10.2.1, pp. 13.
- Cunningham M, Cunningham AB, Schippmann U (1997). Trade in *Prunus africana* and the Implementation of CITES. German Federal Agency for Nature Conservation, Bonn.
- Duclos V, Boudreau S, Chapman CA (2013). Shrub cover influence on seedling growth and survival following logging of a tropical forest. *Biotropica* 45:419-426.
- Eilu G, Obua J (2005). Tree condition and natural regeneration in disturbed sites of Bwindi Impenetrable Forest National Park, southwestern Uganda. *Trop. Ecol.* 46:99-111.
- Farwig N, Böhning-gaese K, Bleher B (2006). Enhanced seed dispersal of *Prunus africana* in fragmented and disturbed forests? *Oecologia* 147:238-252.
- Fashing PJ (2004). Mortality trends in the African cherry (*Prunus africana*) and the implications for colobus monkeys (*Colobus guereza*) in Kakamega Forest, Kenya. *Biolo. Conserv.* 120:449-459.
- Gwali S, Okullo P, Hafashimana D, Byabashaija DM (2009). Diversity and composition of trees and shrubs in Kasagala forest: a semi-arid savannah woodland in central Uganda. *Afr. J. Ecol.* 48:111-118.
- Hall JB, O'Brien EM, Sinclair FL (2000). *Prunus africana*: a monograph. School of Agricultural and Forest Sciences Publication Number 18, University of Wales, Bangor. pp.104.
- IUCN (2013). IUCN Red List of Threatened Species. Version 2013.1. <http://www.iucnredlist.org>.
- Jimu L (2011). Threats and conservation strategies for the African cherry (*Prunus africana*) in its natural range-A review. *J. Ecol. Nat. Environ.* 3:118-130.
- Jimu L, Ngoroyemoto N, Mujuru L (2012). Structural diversity and regeneration of the endangered *Prunus africana* (Rosaceae) in Zimbabwe. *Afr. J. Ecol.* 51:102-110.
- Kasenene JM (2007a). Impact of exotic plantations and harvesting methods on the regeneration of indigenous tree species in Kibale forest, Uganda. *Afr. J. Ecol.* 45 (Suppl. 1):41-47.
- Kasenene JM (2007b). Post logging structural changes and regeneration of *Olea welwitschii* (Knobl) Gilg and Schellemb in the Kibale National Park, Uganda. *Afr. J. Ecol.* 45 (Suppl. 3):109-115.
- Kent M, Coker P (1992). *Vegetation Description and Analysis, a practical approach*, Belhaven Press, London, UK.
- Kiama D, Kiyapi J (2001). Shade tolerance and regeneration of some tree species of a tropical rain forest in Western Kenya. *Plant Ecol.* 156:183-191.
- Lawes MJ, Chapman CA (2006). Does the herb *Acanthus pubescens* and/ or elephants suppress tree regeneration in disturbed Afrotropical forest? *For. Ecol. Manage.* 221:278-284.
- Lovett JC, Ruffo CK, Gereau RE, Taplin JRD (2006). *Field Guide to the Moist Forest Trees of Tanzania*, The Society for Environmental Exploration, UK and the University of Dar es Salaam, Tanzania.
- Lykke AM (1998). Assessment of species composition change in savanna vegetation by means of woody plants' size class distributions and local information. *Biodivers. Conserv.* 7:1261-1275.
- Malinga GM, Valtonen A, Nyeko P, Roininen H (2014). High resilience of galling insect communities to selective and clear-cut logging in a tropical rainforest. *Int. J. Trop. Insect Sci.* (in press).
- Meunier Q, Lemmens R, Morin A (2010). *Alternatives to exotic species in Uganda: Growth and cultivation of 85 indigenous trees*. GraphiConsult (U) Ltd, Kampala, Uganda. pp. 152.
- Muoghalu JI (2006). Tree species population dynamics in a secondary forest at Ile-Ife, Nigeria after a ground fire. *Afr. J. Ecol.* 45:62-71.
- Mwavu EN, Witkowski ETF (2009). Population structure and regeneration of multiple-use tree species in a semi-deciduous African tropical rainforest: implications for primate conservation. *For. Ecol. Manage.* 258:840-849.
- Mwima PM, McNeilage A (2003). Natural regeneration and ecological recovery in Bwindi Impenetrable National Park, Uganda. *Afr. J. Ecol.* 41:93-98.
- Navarro-Cerrillo RM, Clemente M, Padrón E, Hernandez-Bermejo E,

- Garcia-Ferrer A, Kasimis N (2008). Forest structure in harvested sites of Afromontane forest of *Prunus africana* (Hook.f.) Kalkm. in Bioko (Equatorial Guinea). *Afr. J. Ecol.* 46:620-630.
- Ndam N (1996). Recruitment patterns of *Prunus africana* (Hook f.) Kalkman on Mount Cameroon: a case study at Mapanja. In: *A Strategy for the Conservation of Prunus africana on Mount Cameroon*. Technical Papers and Workshop Proceedings.
- Njunge JT (1996). Species composition and regeneration at South Nandi forest, Kenya. PhD thesis, University of Wales, Bangor. pp. 216.
- Nyafwono M, Valtonen A, Nyeko P, Roininen H (2014). Butterfly community composition across a successional gradient in a human-disturbed Afro-tropical rainforest. *Biotropica* 46:210-218.
- Obiri J, Lawes M, Mukolwe M (2002). The dynamics and sustainable use of high value tree species of the coastal Pondoland forests of the Eastern Cape Province, South Africa. *For. Ecol. Manage.* 166:131-148.
- Paul JR, Randle AM, Chapman CA, Chapman LJ (2004). Arrested succession in logging gaps: is tree seedling growth and survival limiting? *Afr. J. Ecol.* 42:245-251.
- Stewart KM (2003). The African cherry (*Prunus africana*): Can lessons be learned from an over-exploited medicinal tree? *J. Ethnopharmacol.* 89:3-13.
- Stewart KM (2009). Effects of bark harvest and other human activity on populations of the African cherry (*Prunus africana*) on Mount Oku, Cameroon. *For. Ecol. Manage.* 258:1121-1128.
- Struhsaker TT (1997). Ecology of an African Rain Forest: Logging in Kibale and the Conflict between Conservation and Exploitation, University Press of Florida, Gainesville, FL.
- Tabuti JRS (2007). The uses, local perceptions and ecological status of 16 woody species of Gadumire Sub-county, Uganda. *Biodivers. Conserv.* 16:1901-1915.
- Tabuti JRS, Mugula BB (2007). The ethnobotany and ecological status of *Albizia coriaria* Welw. ex Oliv. in Budondo Sub-county, eastern Uganda. *Afr. J. Ecol.* 45:126-129.
- Tesfaye G, Teketay D, Fetene M, Beck E (2010). Regeneration of seven indigenous tree species in a dry Afromontane forest, southern Ethiopia. *Flora* 205:135-143.
- Venter SM, Witkowski ETF (2010). Baobab (*Adansonia digitata* L.) density, size-class distribution and population trends between four land-use types in northern Venda, South Africa. *For. Ecol. Manage.* 259:294-300.
- Vieira DLM, Scariot A (2006). Principle of natural regeneration of tropical dry forests restoration. *Restor. Ecol.* 14:11-20.



International Journal of Biodiversity and Conservation

Related Journals Published by Academic Journals

- *Journal of Ecology and the Natural Environment*
- *African Journal of Environmental Science and Technology*
- *African Journal of Biology and Environment*
- *Journal of Environmental Microbiology and Microbial Ecology*
- *International Journal of Marine Biology and Ecology*

academicJournals