Final Report of Minor Research Project

Project Title

Quaternary Geology and Morphotectonics of the Kayadhu River basin, Washim - Hingoli Districts, Maharashtra

Submitted to

Academic Planning Development Section,
Swami Ramanand Teerth Marathwada University,
Nanded-431606 (M.S.) India

By

Dr. Bhagwan Balasaheb Ghute *[M.Sc. SET, Ph.D.]*
Principal Investigator

Assistant Professor, Department of Geology

Shri Gajanan ShikshanPrasarak Mandal's
Toshniwal Arts, Commerce & Science College, Sengaon
Tq. Sengaon Dist. Hingoli- 431542 (M.S.) India

2020

LINGUISTIC MINORITY INSTITUTION
Establishment Year –1993
Shri Gajanan Shikshan Prasarak Mandal's
Ph.No.(02456) 202465, 250462

तोष्णीवाल कला, वाणिज्य व विज्ञान महाविद्यालय, सेनगांव ता. सेनगांव जि. हिंगोली

Toshniwal Arts, Commerce & Science College, Sengaon Tq. Sengaon Dist. Hingoli

Shri B. R. Toshniwal
President
9422176770

Shri U. M. Shelke
Secretary
9421866896

Shri. S. G. Talnikar
I/C Principal
8378888333

www.toshniwalcollege.ac.in **Re-accredited by NAAC with 'B' Grade** E-Mail: prin.taccs212@rediffmail.com

Ref.No:- TACSCS/2020-21/177 Date:- 05/10/2020

To,

The Deputy Registrar,

Academic Planning & Development Section,
Swami Ramanand Teerth Marathwada University,
Nanded-431606

Sub: Submission of Utilization certificate and final report of SRTM University Sponsored Minor Research Project.

- University approval No. and Date: APDS/Uni.MRP/Sci.& Tech.-Geology/2017-18/2962, Dated 21 March 2018.

Ref: 1. APDS/Uni. Grants/MRP /2019-20/3406, Dated on 25.02.2020
2. APDS/Uni. Grants/MRP-2017/2020-21/380, Dated on 22.07.2020

Respected Sir,

We are hereby sending the Utilization Certificate, details of the Statement of Expenditure and final report of the minor research project entitled "Quaternary Geology and Morphotectonics of the Kayadhu River basin, Washim - Hingoli Districts, Maharashtra" prepared by Dr. Bhagwan Balasaheb Ghute of Department of Geology of this college.

So, you are requested to kindly accept the same and oblige.

Thanking you

Yours Sincerely,

Dr. Bhagwan B. Ghute
(Principal Investigator)

Principal
I/c Principal
Toshniwal Art's Commerce & Science College, Sengaon

Encl:
1. Utilization Certificate
2. Two hardbound copies of the final report

स्वा.रा.ती.म.विद्यापीठ,नांदेड
केंद्रीय आवक / जावक कक्ष
0 8 OCT 2020
अनु.क्र. 11
सही:-

DECLARATION AND CERTIFICATE

I hereby declare and certify that, the Minor Research Project entitled "Quaternary Geology and Morphotectonics of the Kayadhu River basin, Washim-Hingoli Districts, Maharashtra" (APDS/Uni.MRP/Sci.& Tech.-Geology/2017-18/2962) is a bonafide record of research work carried out by me during the year April 2018 to March 2020. Further, I certify that the work presented in the report is original and carried out according to the plan in the proposal and guidelines of the Swami Ramanand Teerth Marathwada University, Nanded.

Gahute

PRINCIPAL INVESTIGATOR

ACKNOWLEDGMENTS

I would like to thank Swami Ramanand Teerth Marathwada University, Nanded for granting me this project under Minor Research Scheme.

Thanks are due to Dr. U. L. Sahu (Head, Department of Geology) and Mr. S. S. Markad (Assistant Professor, Fishery Science) for their cooperation during the tenure of the project.

I am grateful to Prof. Shaikh Md. Babar (Department of Geology, Dnyanopask College, Parbhani) for his continuous support and helpful comments during this project work.

I would also acknowledge Mr. T. U. Kendre (Assistant Professor, Chemistry), Mr. Gajanan Paighan, Mr. Gajanan Borkar, Mr. Sandip Kokate for their interest and cooperation in the fieldwork.

Ghute

PRINCIPAL INVESTIGATOR

CONTENTS

Annexure – I

SWAMI RAMANAND TEERTH MARATHWADA UNIVERSITY, NANDED

Annual/Final Report of the work done on the Minor Research Project.

(Report to be submitted within 6 weeks after completion of each year)

1.	**Project report No. 1st /2nd /Final**	:	Final Report
2.	**University letter Reference No.**	:	APDS/Uni.MRP/Sci.& Tech.-Geology/2017-18/2962, Dated 21 March 2018
3.	**Period of report**	:	From April 2018 to March 2020
4.	**Title of research project**	:	Quaternary Geology and Morphotectonics of the Kayadhu River basin, Washim-Hingoli Districts, Maharashtra
5.	**(a) Name of the Principal Investigator**	:	Dr. Bhagwan Balasaheb Ghute
	(b) School / Dept. and College where work has progressed	:	Department of Geology, Toshniwal Arts, Commerce and Science College, Sengaon Dist. Hingoli 431542
6.	**Effective date of starting of the project**	:	21st March 2018

7. Grant approved and expenditure incurred during the period of the report

a. Total amount approved Rs.	:	1,00,000.00 (One Lakh Rupees only)
b. Total expenditure Rs.	:	1,08,456.00 (Rupees One lakh Eight Thousand Four Hundred Fifty Six only)
c. Report of the work done	:	Separate sheet is attached

(Please attach a separate sheet)

i. Brief objective of the project:

The main objectives of the proposed study are as follows:

- To identify and classify the Quaternary deposits of River with reference to soil stratigraphy, morphostratigraphy and lithostratigraphy.
- To study the terrain characteristics such as shape, area, altitude, slope and profiles of the land and to explain the overall evolution of the basin.
- To study neotectonic activity if any in the form of lineament pattern and in the Quaternary sediments.
- To evaluate the Quaternary stratigraphic events of the area the detailed sedimentary sections are to be dated.

ii. Work done so far and results achieved and publications, if any, resulting from the work (Give details of the papers and names of the journals in which it has been published or accepted for publication) :

1. An Approach to Mapping Groundwater Recharge Potential Zones using Geospatial Techniques in Kayadhu River Basin, Maharashtra *Indian Journal of Agricultural Research* DOI: 10.18805/IJARe.A-5477

2. Morphotectonics of Kayadhu river basin in Washim-Hingoli-Nanded districts, Maharashtra: A spatial analysis (Accepted as book chapter under the imprint Springer book entitled "Geological and Geo-Environmental Processes on Earth")

iii. Has the progress been according to original plan of work and towards achieving the objective. if not, state reasons:

Of course. An effort takes place to complete this minor research project according to the original plan of the work and intended objectives are achieved.

iv. Please indicate the difficulties, if any, experienced in implementing the project: No

v. If project has not been completed, please indicate the approximate time by which it is likely to be completed. A summary of the work done for the period (Annual basis) may submit to the University on a separate sheet: Project has been completed, 31 March 2020

vi. If the project has been completed, please enclose a summary of the findings of the study. Two bound copies of the final report of work done may also be sent to the University: Status of the project- completed; Summary of findings with two bound copies of the final report of work done is enclosed.

vii. Any other information which would help in evaluation of work done on the project. At the completion of the project, the first report should indicate the output, such as (a) Manpower trained (b) Ph. D. awarded (c) Publication of results (d) other impact, if any: Two research articles are accepted for publication.

PRINCIPAL INVESTIGATOR
Principal Investigator
Dr. Bhagwan B. Ghute
(M.Sc. ... Ph.D.)

PRINCIPAL
I/C Principal
Toshniwal Art's Commerce & Science College, Sengaon

Annexure – II

SWAMI RAMANAND TEERTH MARATHWADA UNIVERSITY, NANDED

UTILIZATION CERTIFICATE

Certified that the grant of **Rs. 1,00,000/- (Rupees One Lakh only)** received from the S.R.T.M. University under the scheme of support for Minor Research Project entitled **"Quaternary Geology and Morphotectonics of the Kayadhu River basin, Washim - Hingoli Districts, Maharashtra"** in the subject Geology under faculty Science vide University letter No**. APDS/Uni.MRP/Sci.& Tech.-Geology/2017-18/2962, dated 21st March 2018** has been fully utilized for the purpose for which it was sanctioned and in accordance with the terms and conditions laid down by the University/ UGC.

PRINCIPAL INVESTIGATOR
Principal Investigator
Dr. Bhagwan B. Ghute
(M.Sc. ..., Ph.D.)

PRINCIPAL
I/c Principal
Toshniwal Art's Commerce & Science College, Sengaon

SUBHASH D. POPALGHAT
M.NO.155579
CHARTERED ACCOUNTANT

SEAL AND SIGNATURE OF AUDITOR

UDIN: 20155579AAAA9006

Annexure – III

SWAMI RAMANAND TEERTH MARATHWADA UNIVERSITY, NANDED

STATEMENT OF EXPENDITURE IN RESPECT OF MINOR RESEARCH PROJECT

1. Name of Principal Investigator: Dr. Bhagwan Balasaheb Ghute

2. Dept. of University/College: Department of Geology, Toshniwal Arts, Commerce and Science College, Sengaon Dist. Hingoli 431542 (M.S.)

3. University approval No. and Date: APDS/Uni.MRP/Sci.& Tech.-Geology/2017-18/2962, 21 March 2018

4. Title of the Research Project: Quaternary Geology and Morphotectonics of the Kayadhu River basin, Washim - Hingoli Districts, Maharashtra

5. Effective date of starting the project: 21st March 2018

6. a. Period of Expenditure: From 01st April 2018 to 31st March 2020

b. Details of Expenditure:

S. No.	Item	Amount Approved Rs.	Expenditure Incurred Rs.
i	Books & Journals	15000.00	15067.00
ii	Equipment (please enclose the quotation)	30000.00	34737.00
iii	Contingency	20000.00	22072.00
iv	Field Work/Travel (Give details in the proforma at Annexure- IV).	35000.00	36580.00
v	Hiring Services	Nil	Nil
vi	Chemicals & Glassware	Nil	Nil
vii	Overhead	Nil	Nil
viii	Any other items (Please specify)	Nil	Nil
	Total	**1,00,000.00**	**108456.00**

1. It as a result of check or audit objective, some irregularly is noticed, later date, action will be taken to refund, adjust or regularize the objected amounts.

2. Payment @ revised rates shall be made with arrears on the availability of additional funds.

3. It is certified that the grant of Rs. 1,00,000.00 (Rupees One Lakh only) received from the University under the scheme of support for Minor Research Project entitled "Quaternary Geology and Morphotectonics of the Kayadhu River basin, Washim - Hingoli Districts, Maharashtra" vide University letter No. APDS/Uni.MRP/Sci.& Tech.-Geology/2017-18/2962 dated 21st March 2018 has been fully utilized for the purpose for which it was sanctioned and in accordance with the terms and conditions laid down by the University/UGC.

PRINCIPAL INVESTIGATOR
Principal Investigator
Dr. Bhagwan B. Ghute
(M.Sc. ..., Ph.D.)

SEAL AND SIGNATURE OF AUDITOR
SUBHASH D. POPALGHAT, CHARTERED ACCOUNTANT, M.NO.155579
UDIN: 20155579AAAA9006

PRINCIPAL
I/c Principal
Toshniwal Art's Commerce & Science College, Sengaon.

Annexure – V

SWAMI RAMANAND TEERTH MARATHWADA UNIVERSITY, NANDED

PROFORMA FOR SUBMISSION OF PROJECT DETAILS

1. **Name of the Principal Investigator:** Dr. Bhagwan Balasaheb Ghute
2. **School/ College:** Department of Geology, Toshniwal Arts, Commerce and Science, College, Sengaon Dist. Hingoli-431 542
3. **Subject:** Geology
4. **Project Title:** Quaternary Geology and Morphotectonics of the Kayadhu River basin, Washim-Hingoli Districts, Maharashtra.

a. **Objectives:**

The main objectives of the proposed study are as follows:

i) To identify and classify the Quaternary deposits of River with reference to soil stratigraphy, morphostratigraphy and lithostratigraphy.

ii) To study the terrain characteristics such as shape, area, altitude, slope and profiles of the land and to explain the overall evolution of the basin.

iii) To study neotectonic activity if any in the form of lineament pattern and in the Quaternary sediments.

iv) To evaluate the Quaternary stratigraphic events of the area the detailed sedimentary sections are to be dated.

b. **Methodology :** Separate sheet is attached

c. **Interpretation :** Separate sheet is attached

d. **Conclusions :** Separate sheet is attached

5. **Details of Financial Assistance**

Item	**Amount Approved Rs.**	**Amount Received Rs.**
Books & Journals	15000.00	15000.00
Equipment	30000.00	30000.00
Contingency	20000.00	20000.00
Field Work/Travel	35000.00	35000.00
Total	**1,00,000.00**	**1,00,000.00**

6. **Sanctioned Letter No. And Date:** APDS/Uni.MRP/Sci.& Tech.-Geology/2017 18/2962, Dated 21 March 2018.
7. **In case, the project completed weather the work on the project has been published:** Yes, Two research papers are are in the final stage of publication.

1. An Approach to Mapping Groundwater Recharge Potential Zones using Geospatial Techniques in Kayadhu River Basin, Maharashtra *Indian Journal of Agricultural Research* DOI: 10.18805/IJARe.A-5477

2. Morphotectonics of Kayadhu river basin in Washim-Hingoli-Nanded districts, Maharashtra: A spatial analysis (Accepted as book chapter under the imprint Springer book entitled "Geological and Geo-Environmental Processes on Earth")

8. Summary of report in about 1000 words may be attached: Yes attached

PRINCIPAL INVESTIGATOR
Principal Investigator
Dr. Bhagwan B. Ghute
(M.Sc. ... Ph.D.)

PRINCIPAL
I/C Principal
Toshniwal Art's Commerce &
Science College, Sengaon

Annexure – VI

SWAMI RAMANAND TEERTH MARATHWADA UNIVERSITY, NANDED

PROFORMA FOR SUBMISSION OF INFORMATION AT THE TIME OF SENDING THE FINAL REPORT OF THE WORK DONE ON THE PROJECT

1.	NAME AND ADDRESS OF THE PRINCIPAL INVESTIGATOR	:	Dr. BHAGWAN BALASHEB GHUTE
2.	NAME AND ADDRESS OF THE INSTITUTION	:	TOSHNIWAL ARTS, COMMERCE AND SCIENCE COLLEGE, SENGAON DIST. HINGOLI- 431542 (M.S.)
3.	UNIVERSTIY APPROVAL NO. AND DATE	:	APDS/Uni.MRP/Sci.& Tech.-Geology/2017-18/2962, 21 March 2018
4.	DATE OF IMPLEMENTATION	:	21st MARCH 2018
5.	TENURE OF THE PROJECT	:	TWO YEARS (MARCH 2018 TO MARCH 2020)
6.	TOTAL GRANT ALLOCATED	:	1,00,000.00 (RUPEES ONE LAKH ONLY)
7.	TOTAL GRANT RECEIVED	:	1,00,000.00 (RUPEES ONE LAKH ONLY)
8.	FINAL EXPENDITURE	:	1,08,456.00 (RUPEES ONE LAKH EIGHT THOUSAND FOUR HUNDRED FIFTY SIX ONLY)
9.	TITLE OF THE PROJECT	:	QUATERNARY GEOLOGY AND MORPHOTECTONICS OF THE KAYADHU RIVER BASIN, WASHIM-HINGOLI DISTRICTS, MAHARASHTRA
10.	OBJECTIVES OF THE PROJECT	:	

i. Brief objective of the project:

The main objectives of the proposed study are as follows:

- To identify and classify the Quaternary deposits of River with reference to soil stratigraphy, morphostratigraphy and lithostratigraphy.
- To study the terrain characteristics such as shape, area, altitude, slope and profiles of the land and to explain the overall evolution of the basin.
- To study neotectonic activity if any in the form of lineament pattern and in the Quaternary sediments.
- To evaluate the Quaternary stratigraphic events of the area the detailed sedimentary sections are to be dated.

11. WHETHER OBJECTIVES WERE ACHIEVED (GIVE DETAILS) : Yes

12. ACHIEVEMENTS FROM THE PROJECT: Two research papers are in the final stage of publication (UGC Recognised Journals)

13. SUMMARY OF THE FINDINGS (IN 500 WORDS):

The morpho-tectonic and morphometric analysis of Kayadhu river basin is carried out to interpret the landscape development and stream features of the river basin with the help of quantitative analysis of geomorphic indices and field observations. This analysis is based on relief and tectonic aspects such as elongation ratio (Re), hypsometric integral (HI), basin asymmetry factor (AF), transverse topographic symmetric factor (T), stream length gradient (SL) index, longitudinal profile and lineament and microseismicity in the area. The spatial analysis has been completed with the help of remote sensing and GIS techniques. The Kayadhu river is one of the major tributaries of the Penganga river in the Deccan trap area of Maharashtra. The calculated geomorphic indices of the river, which shows positive marker of tectonic inscription on drainage network. A moderate hypsometric integral value indicate that the basin is still under mature stage of erosion. Longitudinal profile of the stream also shows the presence of Knick points. The analysis points out south westward tilting of the drainage basins with asymmetry and lineament control on smaller tributaries of the Kayadhu drainage is observed. Overall assessment of morphotectonic analysis revealed that the area is influenced by tectonics.

The geological map of area having three geological units such as Simple (aa type) basalt, compound (pahoehoe type) basalt and alluvial deposits in the study area. Simple aa type basalt covers 420.16 km2 area having low porosity and permeability compared with compound pahoehoe type basalt 1531.73 km2. Alluvium occupied 206.42 km2 area of the study area. Thematic layers such as rainfall, lineament density, slope, drainage Density, land use/land cover, geology, geomorphology and soil cover map layers were integrated on a GIS platform using the raster calculator in overlay in Kayadhu river basin.

The morphotectonics of the Kayadhu river basin, Maharashtra, India, was studied through the various geomorphic indices, using Arc GIS10.3 software with 30m resolution ASTER GDEM and LISS IV, IRS FCC data. Transverse topographic symmetry (T) calculated from transverse topographic profiles of 143.58 km drainage basin segments. Northern half part of the river migrates towards WSW and southern half part migrate towards South east, thus it implicates ground tilting as the driving mechanism of preferred migration. Longitudinal profile of the river indicates a number of knick points at a steep reaches in the profile caused by structural disturbance (uplift or lineaments), therefore these disturbances caused due to tectonic activities in the region over the development of river, which might have reflected as change in the gradient of along the longitudinal profile of Kayadhu river. The asymmetric integral value for the right bank of the basin. The absolute difference is 2.56 indicate that the basin has slight influence tectonic activity. The calculated hypsometric integral for the Kayadhu river is 0.31 shows basin is under the mature stage of erosional development. The lineament ranges from 03 to 19 km long and show a dominant NW-SE and NE-SE trend, consisting with geological structure, and hence there is possibility of recent crustal movement in this area. The whole analysis of the basin indicates, the path of the river is tectonically influenced at some location, but most part of the basin not experienced any major disturbances.

14. CONTRIBUTION TO THE SOCIETY (GIVE DETAILS) :

The Study area i.e. Kayadhu river basin and this is helpful for all what is the cause of seismic events since 2017. The digital data from IRS- P6 LISS -IV (70 km X 70 km) collected in 2016 in FCC format with high resolution and SOI toposheet map Nos. 56A/9, 56A/13, 56A/14, 56E/1, 56E/2, 56E/3, 56E/5, 56E/6, 56E/7, 56E/10, 56E/11 were used to meet the requirement of area under study. Digital satellite data were geometrically rectified and georeferenced by using Arc GIS 10.3 software for the preparation of various maps, landforms and processes of basin information is extracted from the satellite imagery, survey of India toposheet maps and extensive field visits are carried out. These maps are really useful for all the developments in the area.

15. WHETHER ANY Ph.D. ENROLLED/ PRODUCED OUT OF THE PROJECT : NO

16. NO. OF PUBLICATIONS OUT OF THE PROJECT (PLEASE ATTACH RE-PRINTS): Two Publications (Reprints are attached)

1. An Approach to Mapping Groundwater Recharge Potential Zones using Geospatial Techniques in Kayadhu River Basin, Maharashtra *Indian Journal of Agricultural Research* DOI: 10.18805/IJARe.A-5477

2. Morphotectonics of Kayadhu river basin in Washim-Hingoli-Nanded districts, Maharashtra: A spatial analysis (Accepted as book chapter under the imprint Springer book entitled *"Geological and Geo-Environmental Processes on Earth"*)

PRINCIPAL INVESTIGATOR
Principal Investigator
Dr. Bhagwan B. Ghute
(M.Sc. ..., Ph.D.)

PRINCIPAL
I/c Principal
Toshniwal Art's Commerce & Science College, Sengaon

Annexure – VII

UNDERTAKING

This is to certify that, the assets (Books, Journals and Equipments) Purchased / acquired out of grants received from the S.R.T.M. University, Nanded sanctioned to Dr. Bhagwan Balasaheb Ghute under the Minor Research Project entitled "Quaternary Geology and Morphotectonics of the Kayadhu River basin, Washim-Hingoli Districts, Maharashtra" in subject Geology under the Faculty Science worth Rs. 15,000/- (Book & Journals) and Rs. 30,000/-(Equipments) are deposited to the college on completion of project and will be used for all academic purpose, in future.

Also it is certify that, **"Funded by S. R. T. M. University, Nanded"** will be mentioned on all concerned Books, Journals and Equipments.

Hence, certified.

PRINCIPAL INVESTIGATOR
Principal Investigator
Dr. Bhagwan B. Ghute
(M.Sc. ..., Ph.D.)

PRINCIPAL
I/C Principal
Toshniwal Art's Commerce & Science College, Sengaon

Annexure – VIII

List of Books and Equipments Purchased under Research Project

1) Books

Sr. No.	Name of the Item	Payment	Amount (Rs)
1.	Books	Geological Society of India, Bangalore Bill No.694 dt. 26/06/2018 Bill paid by MGB, Sengaon Bank Transfer RTGS No. MAHGN18173427898 dt.22.06.2018	4550.00
2.	Book	Amazon.in, Sold by Repro Knowledgcast Ltd, Thane. Invoice No. XWAB -195204 dt.16/02/2019 Bill paid by Cash	1489.00
3.	Book	Amazon.in, Sold by Repro Knowledgcast Ltd, Thane. Order No. 405-0136208-2195570 dt.15/03/2019 Bill paid by Cash	1027.00
4.	Journal	Indian Journal of Remote Sensing, Dehradun Bill paid by MGB, Sengaon Bank Transfer RTGS No. MAHGN18204421383 dt.23.07.2018	3000.00
5.	Journal	Gondwana Geological Magazine, Nagpur Bill paid by MGB, Sengaon Bank Transfer RTGS No. MAHGN18204421405 dt.23.07.2018	5000.00
Total			**15067.00**

2) Equipments:

Sr. No.	Name of the Item	Payment	Amount (Rs)
1.	Printer (HP 1005)	Agrawal Computers, Jintur Invoice No.4682 dt.05/05/2018 Bill paid through MGB, Sengaon RTGS No. MAHGN18136420203 dt.16.05.2018	15350.00
2.	Garmin GPS (72H)	Aaditi Infotech B-3 First floor, Swapnil Apartment, Dhantoli, Nagpur 440012 Bill paid through MGB, Sengaon RTGS No. MAHGN18136420210 dt.16.05.2018	12803.00
3.	Satellite Imagery (LISS IV)	Pay and Account officer, NRSC, Hyderabad Bill paid through Demand Draft, IDBI, Bank Hingoli, DD No. 002291 dt.19.09.2018	6584.00
		Total	**34737.00**

PRINCIPAL INVESTIGATOR
Principal Investigator
Dr. Bhagwan B. Ghute
(M.Sc. ..., Ph.D.)

PRINCIPAL
I/c Principal
Toshniwal Art's Commerce & Science College, Sengaon

Annexure – IX

।। सा विद्या या विमुक्तये ।।
स्वामी रामानंद तीर्थ मराठवाडा विद्यापीठ, नांदेड
"ज्ञानतीर्थ" परिसर, विष्णुपुरी, नांदेड - ४३१६०६ (महाराष्ट्र)
SWAMI RAMANAND TEERTH MARATHWADA UNIVERSITY NANDED
"Dnyanteerth", Vishnupuri, Nanded - 431606 Maharashtra State (INDIA)
Established on 17th September 1994 – Recognized by the UGC U/s 2(f) and 12(B), NAAC Re-accredited with 'A' Grade

ACADEMIC PLANNING & DEVELOPMENT SECTION
Phone: (02462) 229242 Fax: (02462) 229574 website: srtmun.ac.in e-mail: apds.srtmun@gmail.com

APDS/Uni.MRP/Sci.& Tech.-Geology/2017-18/2962 March 21, 2018

To,
Dr. B. B. Ghute, Assit. Prof.,
Toshniwal ACS College,
Sengaon, Dist. Hingoli.

Sub: Minor Research Project of S.R.T.M.Uni.Nanded- release of first installment.

Dear Sir,

This is inform you that, Hon'ble Vice-Chancellor has approved Minor Research Project entitled "Quaternary Geology and morphotectionics of Kayadhu River basin Washim-Hingoli Districts, Maharashtra" in the subject **Geology** under the faculty of **Science & Techbnology** to be undertaken by you. The financial assistance of the University would be limited to **Rs.100000/-** (Rupees One Lakh only) for the project for a period of two years, subject to the conditions given below. An amount of **Rs.72500/-** (Rupees Seventy Two thousand Five Hundred only) is to be released as the first installment on submission of undertaking certificate.

Sr. No.	Purpose	Amount Sanctioned Rs.	Amount being released as 1st installment Rs.
	Non Recurring		**100%**
01	Books & Journals	15000	15000
02	Equipments (Imagery)	30000	30000
	Recurring		**50%**
03	Field work & Travel	35000	17500
04	Contingency (including special needs)	20000	10000
	Total	100000	72500

The grant is subject to the terms & conditions as mentioned below.

1. A certificate of Undertaking of the conditions governing the research project should be sent immediately to this office.
2. Utilization Certificate and detail report should be submitted time to time.
3. The proposed work will be evaluated Mid-termly and if satisfactory second installment will be released, failing which final installment will not be disbursed & the P.I. has to return the 1st installment with interest.
4. Date of implementation will be the date of sanctioned letter as mentioned in earlier letter.
5. P.I. has to submit the final Utilization Certificate and detail project report duly signed by Director and C.A. with publication within one month after completion of project. The research paper should be published in UGC recognized Journal/Peer revioured Journal. The copy of the published paper/ acceptance letter/communicated paper must be attached with final report.
6. Every correspondence regarding this scheme should be done though the Principal of the College.
7. You have to submit revised proposal based on comments given by expert.
8. All Pro-forma (Undertaking, U.C., Statement of Expenditure, Field work, Annual/final report etc.) is available on University website www.srtmun.ac.in. These proforma should be submitted in duplicate for office use.

-sd-
Dy. Registrar
Academic Planning & Development Section

Encl: Undertaking certificate
Copy to: 1. The Principal, Toshniwal ACS College, Sengaon, Dist. Hingoli.
2. The Finance & Account Officer, this University.

ANNUAL REPORT (ANNUAL BASIS) OF THE MINOR RESEARCH

First Year

- Process of purchasing equipments.
- Collection of data from satellite imageries, toposheets and other software use and library work for literature survey.
- Analysis of data, preliminary field surveys. Fieldwork for mapping, collection of field data and samples.
- The data collected in the field and laboratory work is now going to interprete the characteristic results which are going to preparation and submission of article manuscript for publication in UGC approved journal and preparation and submission of final report in the coming year.

Second Year

- Extensive fieldwork continues, processing of field data and for preparation of various geological maps based on imageries and GIS techniques.
- Data interpretation and submission of articles for publication, preparation and submission of report.
- The morphometric analysis of the Kayadhu river basin was carried out from the study of drainage network and contour pattern using the Survey of India topographical maps on 1:50000 scale.
- Generation of various thematic maps using Arc GIS software.
- Submitted Manuscript having queries from respective journals editors are resolved.
- Two research papers are in the final stage of publication in UGC approved journal.

Chapter 1

INTRODUCTION

Quaternary deposits of India constitute a major geological unit in different parts of the country, study of which is invested with much interest and significance because of its relevance to 'Present' and its contribution towards understanding the past environment. The Quaternary period witnessed a series of major climatic changes which had pronounced effect on the physical as well as the organic world.

The study area belongs to the eastern part of Deccan Basaltic Province of Maharashtra, India. The tectonics plays a very important role in the evolution of the drainage basin and it reflect on structural, fluvial and morphotectonic features of the basin. Evaluation of neotectonics depends upon the geomorphic indices, which marks on rock resistance, climatic changes and tectonic processes results into landscape evolution. The information about tectonic history of an area can be recovered by quantification of different morphotectonic indices, by using the techniques of remote sensing and GIS in different drainage basins by many workers including (Keller 1986; Krishnamurthy et al. 1996; Singh and Singh 1997; Obi Reddy et al. 2002; Nag and Chakraborty 2003; Narendra and Rao 2006; Pankaj and Kumar 2009; Javed et al. 2009; Babar et al. 2012; Vijith et al. 2015). It provides quantitative analysis of the river basin to understand initial ladders and the basin dynamics. Fluvial systems in the upland areas of the Deccan Trap have been studied by Rajguru and Kale (1985). The microseismicity in Nanded and Parbhani region studied (Babar et al. 2011; Kaplay et al. 2016). Tectonic evolution and neotectonic activity of an area can be studied by analysing the consequences of neotectonic activities over the drainage networks and basins which reflect minor and major changes in terrain morphology (Potter 1978; Salvany 2004; Garrote et al. 2008; Kothyari and Rastogi 2013; Ambili and Narayana 2014). Geomorphic indices are useful tools in evaluating tectonic activity in the area. Tectonic activities play a very important role in the morphological development of drainage basin and well reflected by structural, fluvial and morphotectonic parameters. The south eastern part of the Hingoli district of Deccan volcanic province has been experiencing micro- earthquake activity since 2016, approximately at a junction of Sirli Ghat Lineament and Wapti Lineament. In the present study the remote sensing and GIS approach have been used to enlighten the morphotectonics of a Kayadhu river basin.

1.1 Study area

The Kayadhu river is a tributary of the Penganga river originates from Angarwadi village south west part of the Washim district in Ajanta hill ranges (at an elevation 580 m), and flowing over the Deccan traps. The river flows from NW- SE direction and confluences to Penganga river near Chincholi Sangam village in Nanded district. N 20°00", E76°40" North West (Fig. 1). The river having maximum flow length is 143.58 km and total area of 2158.38 km^2. The maximum and minimum elevations are 605 and 390 m above mean sea level. The Kayadhu river is of seventh order with a dominant dendritic drainage pattern. The basin is located in low seismic intensity zone, the study area had microseismicity in last two years, some of them ≤3 with epicentre falling inside the river basin (Table 1).

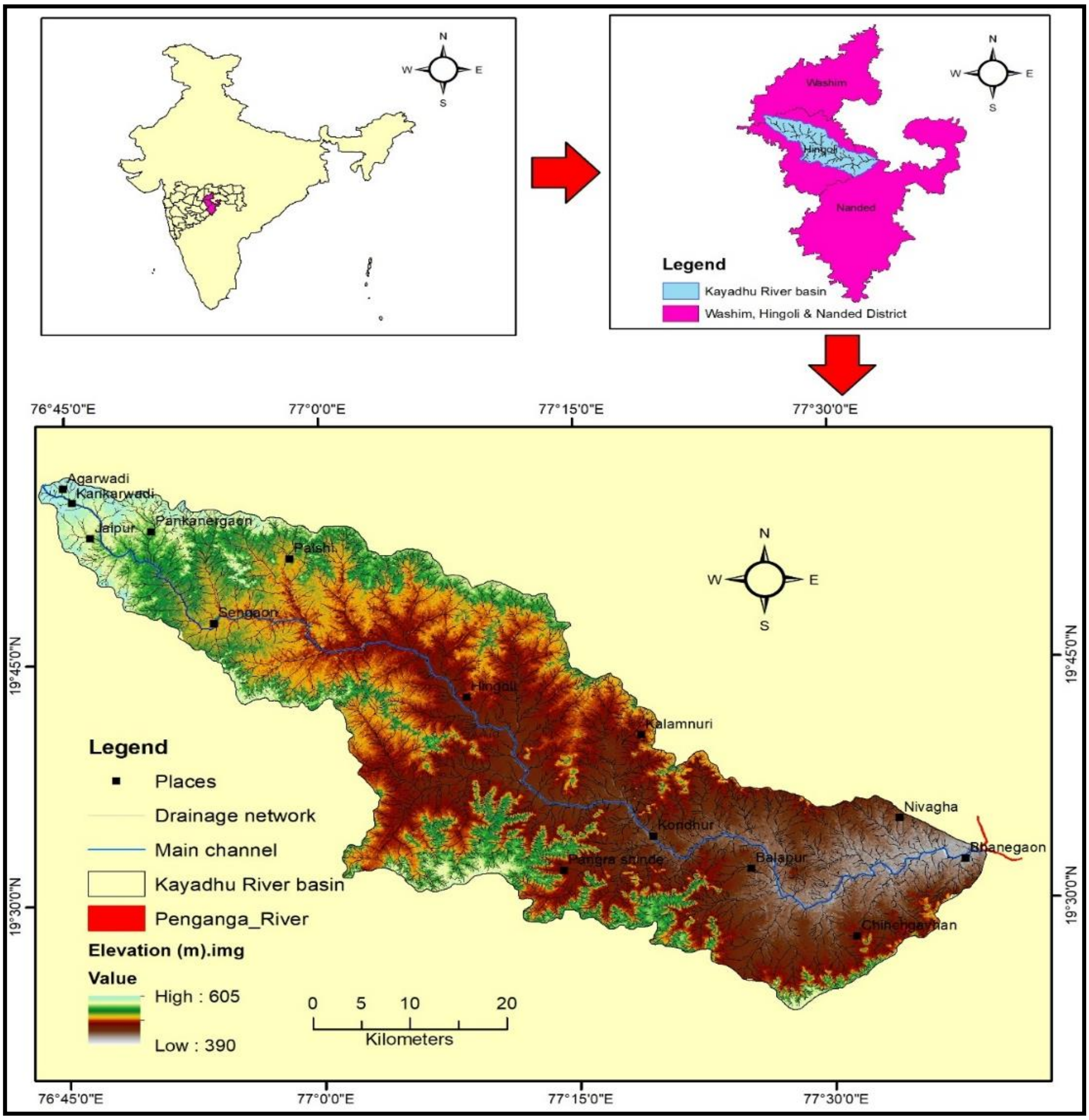

Fig. 1: Location map of the study area.

Table 1: Details of micro seismic events (IMD 2017; 2018; 2020)

Sr. No.	YYYYMMDD	HHMMSS	Latitude	Longitude	Depth	Magnitude
1	20181104	185214	19.6 N	76.9E	15	2.5
2	20180913	034902	19.7 N	76.9E	10	2.5
3	20170816	063523	19.5 N	77.2E	10	3.0
4	20200602	070900	19.5 N	77.1E	10	3.4

Rivers are the most active and sensitive elements of fluvial landscape. If uplift (tectonic/ isostatic) has occurred in the Quaternary period, it should be amply reflected in the drainage basin, valley and network properties of the Kayadhu river. Because of presence of some neotectonic activity and microseismic activity are the main objective of the present study is to analyse the morphotectonic activity of the Kayadhu river basin. The detailed morphotectonics analysis has been carried out.

Chapter 2

MATERIALS AND METHODS

For the present study the analysis is based on the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Digital Elevation Model (DEM), derived from ASTER data collected from the website of Global Digital Elevation Model (GDEM). The digital data from IRS- P6 LISS -IV (70 km X 70 km) collected in 2016 in FCC format with high resolution (Fig. 2) and SOI toposheet map Nos. 56A/9, 56A/13, 56A/14, 56E/1, 56E/2, 56E/3, 56E/5, 56E/6, 56E/7, 56E/10, 56E/11 were used to meet the requirement of area under study. Digital satellite data were geometrically rectified and georeferenced by using Arc GIS 10.3 software for the preparation of various maps, landforms and processes of basin information is extracted from the satellite imagery, survey of India toposheet maps and extensive field visits are carried out.

2.1 SATELLITE DATA:

For the present study the Indian Remote Sensing (IRS P6) LISS IV satellite data was used to delineate Kayadhu River. The digital data was false colour composite (FCC) on 1:50,000 scale. The SOI toposheets and digital satellite data were geometrically rectified and geo-referenced and merged using Arc GIS 10.3.

2.2 DATABASE GENERATION:

By understanding the objectives, methodology and study area details have led to the identification of different variables to meet the objectives. Various maps have been prepared for proper assessment of Quaternary geology and geomorphology of Kayadhu river sub-basin which are given below:

1. Drainage Map
2. Geology Map
3. Lineament Map
4. Geomorphology Map
5. Slope Map
6. Contour Map
7. Digital Elevation Map

The detailed methodology applied for preparing the individual maps i.e. base map, geological map, geomorphological map, structural map, slope map etc is discussed in detail in the following paragraphs:

2.3.1 Preparation of Base Map:

The base map has been prepared by using the Survey of India toposheet map No56A/9, 56A/13, 56A/14, 56E/1, 56E/2, 56E/3, 56E/5, 56E/6, 56E/7, 56E/10, 56E/11 on the scale 1: 50,000 supplemented with IRS-P6 LISS-IV satellite imagery (FCC-geocoded) on the scale 1: 50,000. The base map contained the following details:

- Streams and water bodies (*Drainage pattern*)
- Villages

2.3.2 Preparation of Geological Map:

The synoptic view and multispectral nature of the satellite image helps in discrimination and mapping of different lithological units. The geological mapping is carried out with reference to detailed fieldwork in the Kayadhu river basin in Washim, Hingoli and Nanded districts.

For the preparation of geological map, following materials are used:

- Geological Quadrangle Map of Washim, Hingoli and Nanded districts.
- Information extracted from the satellite imagery
- Survey of India toposheet

2.3.3 Preparation of Lineament Map:

Lineaments are extracted from drainage pattern and vegetation shows prominent trends of feature observation on IRS P6 LISS IV satellite image. Lineaments in Kayadhu basin area were extracted through manual lineament extraction techniques (Weerasekara et al. 2014). Many non-geological structures, such as roads and channels, cause errors in the analysis of lineaments. These features are eliminated from the resultant layer.

2.3.4 Preparation of Geomorphological Map:

Geomorphological mapping involves the recording of surface form, near-surface materials and evidence of surface processes. Accurate geomorphological maps can provide valuable information about the ground conditions from which hazard and vulnerability assessments are made. As such, it is important that due consideration is given to the mapping approach before work begins to ensure that it is appropriate for the specific study. The flexibility of the geomorphological mapping method makes it a powerful tool in the hands of an operator experienced in the final application. Synoptic view of satellite imagery facilitates better appreciation of geomorphology and helps in mapping of different landforms and their assemblage. The photo interpretation criteria such as tone, texture, shape, size, location, association, physiography, genesis of the landform, nature of the rocks, associated geological structure etc are used for identification of different landforms/ geomorphic units. The SOI toposheets provide topographic information required to interpret the geomorphology from the satellite imagery. The important geomorphic surfaces/ landforms identified are:

i. Present Floodplain
ii. Older Alluvial plain
iii. Pediments
iv. Pediplains
v. Highly Dissected plateau
vi. Denudational Hills

2.3.5 Preparation of Slope Map and Contour Map:

Slope and Contour map indicates the topography of an area with an analysis of topographic features as they have influenced and may continue to influence land development.

2.3 MORPHTECTONIC PARAMETERS:

The morphtectonic parameters of the Kayadhu river basin was carried out from the study of drainage network and contour pattern using the Survey of India topographical maps on 1:50000 scale.

Table 2: Formulae and References for morphotectonic parameters

Parameters	Formulae and References
Elongation Ratio	$Re=2\sqrt{Ff}/\pi$, (Schumm 1956)
Drainage basin asymmetry (AF)	AF=100(Ar/At), (Hare and Gardner 1985)
Transverse topographic symmetry (T)	T=Da/Dd, (Cox et al. 2001)
Hypsometric Analysis	HI= (elevation mean- elevation minimum) / (elevation maximum- elevation minimum) Keller and Pinter 1996
Longitudinal Profile	(Schumm 1986)
Stream length gradient (SL) index	$SL=(\Delta H/\Delta L)L$ (Hack 1973)

Chapter 3

GEOLOGY

Over the past three decades several research groups have studied Deccan basalts over the entire length of Western Ghats (Mahoney et al, 1982, Cox and Hawkesworth, 1984, Beane et al, 1986, Devey and Lightfoot, 1986, Devey and Cox, 1987, Lightfoot and Hawkesworth, 1988, Khadri et al, 1988 and Subbarao et al 1988, 1994). Most of these investigations were confined to the better exposed part of the Deccan in the west, which offer thick sections of lava piles (3000 m) for examination. In comparison, the eastern and central part of the Deccan has not been investigated in similar details. The investigations in this region are essentially restricted to few and far apart areas (Shrivastava, et al, 1988, Subbarao et al, 1994, De, 1994, Sen and Cohen, 1994, Deshmukh et al, 1996, Nair et al, 1996 and Yedekar et al, 1996). Moreover these studies in eastern and central part are concentrated towards Satpura and Malwa plateau area and rare in Ajanta and Balaghat plateau area.

Geologically the river basin comprises simple (aa type) and compound (pahoehoe type) basalt flows (Fig. 2) of nearly horizontal lava formations. These flows have been formed due to fissured type of lava eruption during late Cretaceous to early Eocene period (Muley et al. 2012). These basalt flows belonging to the Ajanta Formation, that are stratigraphic equivalent of upper Ratangad Formation of the Wai sub-group of west Maharashtra comprising compound flows (Godbole et al. 1996; Kaplay et al. 2016;).

Simple basalt flows are thick and extensive. The general characteristics of these flows are observed based on its variation from top to the bottom and degree of compaction and jointing pattern. The top surface of the basalt flows is rather undulating or weathered up to some thickness due to hydrothermal alteration, purple or greyish coloured and vesicular in nature. The middle and lower portions of the flows are free from vesicles and amygdules and they occurs as thick and compact. Joints, which are contractions cracks, developed during cooling and solidification of lava always occurs in the middle and lower portion of the flow (Muley et al. 2010). The red bole bed or Tachylitic bands or paleo sole or marker bed occurs between consecutive flows (Babar et al. 2010).

The outpouring of low viscous lava through a large number of outlets result in to the compound flows (Bondre et al. 2000; Bondre et al. 2004; Duraiswami et al. 2003; Duraiswami et al. 2008). These lava flows are large, irregular and having a huge lateral extent (Duraiswami et al. 2002; Duraiswami et al. 2008). The flows are marked by the presence of vesicles and amygdules. The vesicles are filled with secondary minerals like Zeolites, calcite, silica chlorophaeite etc to form the amygdules (Babar et al. 2010).

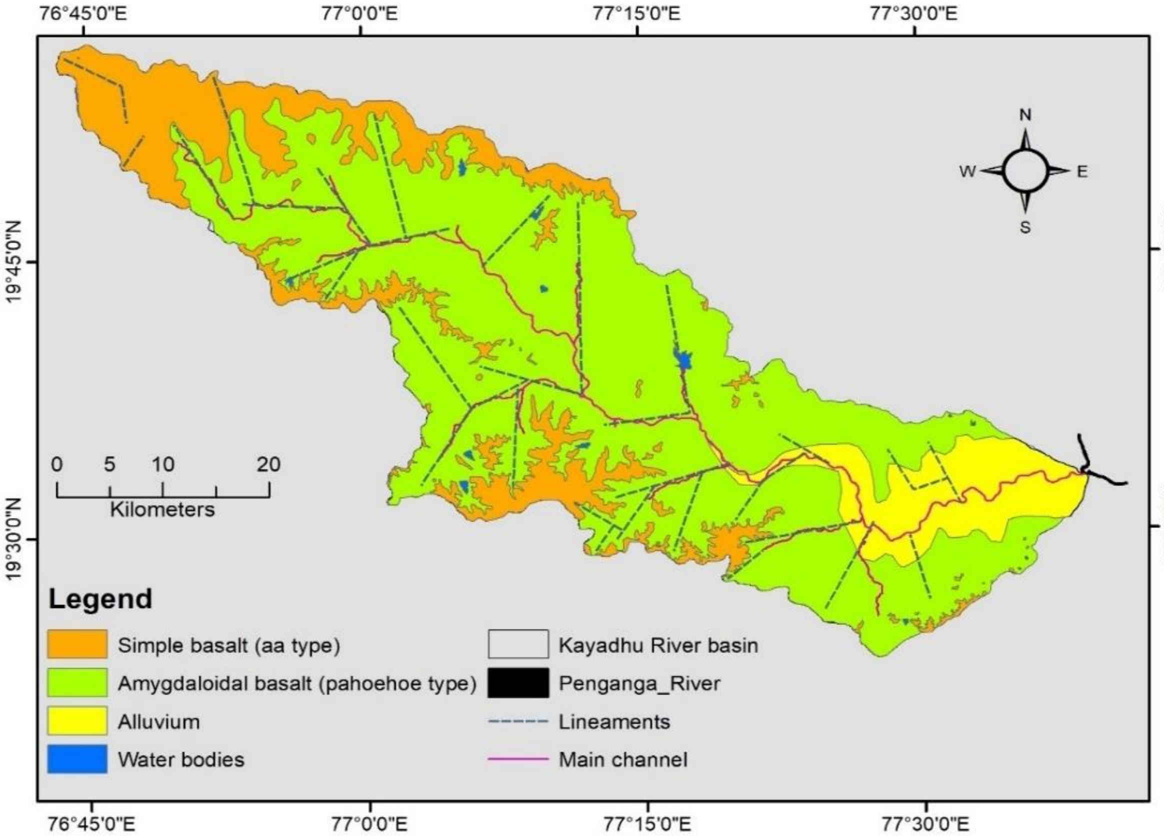

Fig. 2: Geological map of study area

Chapter 4

GEOMORPHOLOGY AND MORPHOTECTONICS

Geomorphology has been defined as the scientific study of surface features of the earth's surface involving interpretative description of landforms, their origin and development and nature and mechanism of geomorphological processes which evolve the landforms with a view that " all landforms can be related to a particular geological process, or set of processes, and that the landform thus developed may evolve with time through a sequence of forms dependent in part, on the relative time a particular process has been operating" (Easterbrook, 1969). In a simple way geomorphology is also defined as the systematic description and analysis of landscapes and the processes that changed them (Bloom, 1979).

Geomorphologically, the study area is identified by various landforms (Fig. 3) such as older alluvial plain, present flood plain, pediments, pediplains, highly dissected plateau and denudational hills. Among these landforms older alluvial plain, present flood plain and pediplains have more potential for groundwater recharge, but the highly dissected plateau and denudational hills are not suitable for water augmentation because of the steep slope.

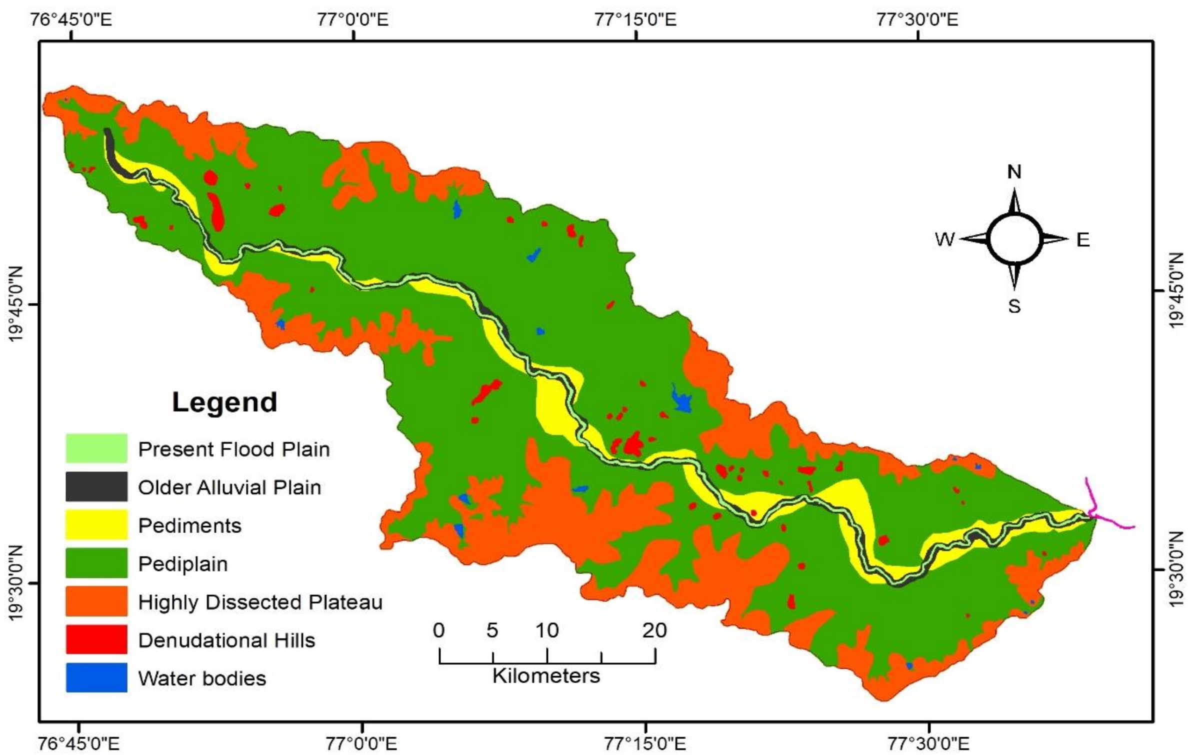

Fig. 3: Geomorphological Map of Kayadhu River Basin

4.1 DRAINAGE PATTERN

In this area the main drainage pattern is dendritic with some minor variations. Though the main drainage pattern is dendritic but sub dendritic, rectangular and sub-parallel are also observed in a few patches (Fig. 4).

4.2 MORPHOMETRIC ANALYSIS OF KAYADHU RIVER BASIN

In the present study morphometric analysis of Kayadhu river basin is carried out. The drainage basin is a natural hydrologic entity that covers a specific areal extent of land from which rain water flows to a defined channel or stream at any particular point. The morphometric attributes like bifurcation ratio, length ratio, basin area, basin configuration, drainage density, stream frequency, relief aspects and hypsometric integrals are calculated.

4.3 Linear Aspect

The linear aspects of morphometric analysis of river basin includes stream order, stream length, mean stream length, stream length ratio and bifurcation ratio.

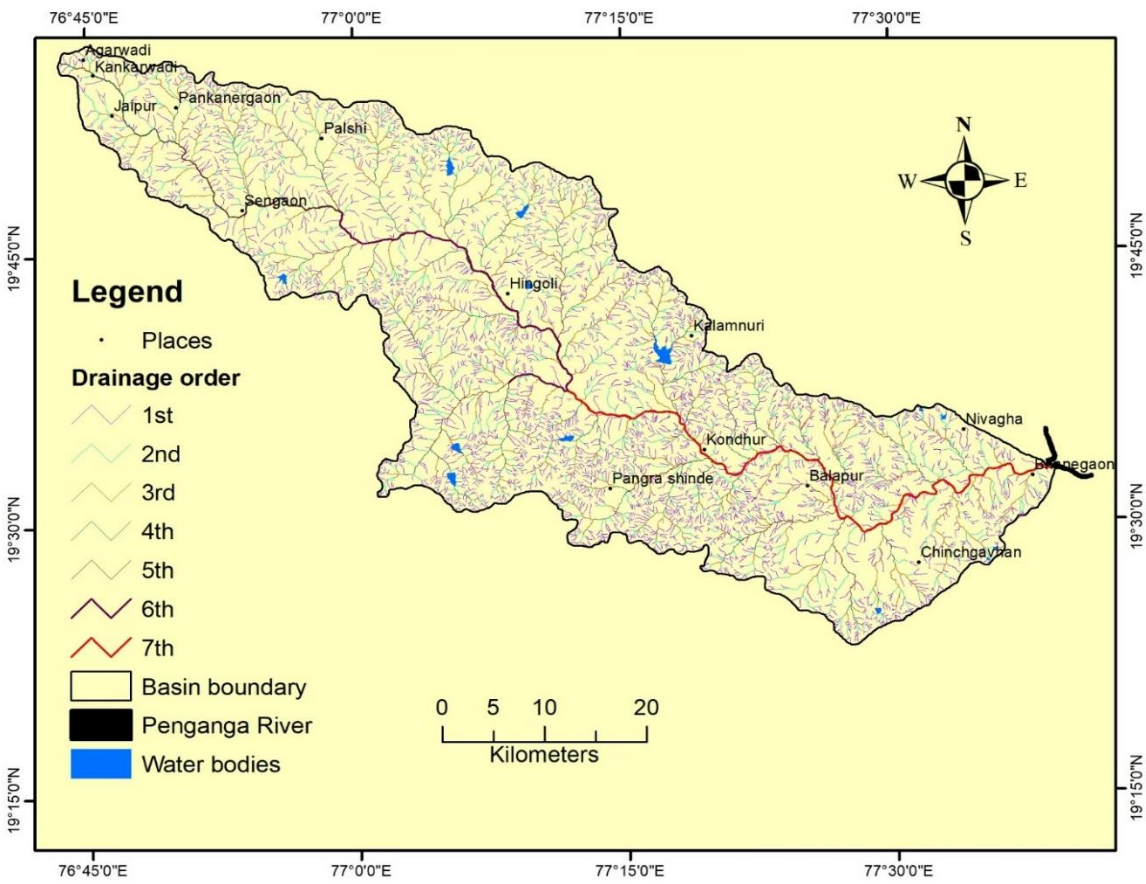

Fig. 4: Drainage Network map of Kayadhu river basin

4.3.1 Stream Order

Strahler's system of stream ordering is followed in the study of Kayadhu river because of its simplicity and slightly modification where the smallest, unbranched fingertip streams are designated as 1^{st} order, the confluence of two 1^{st} order channels give a channels segments of 2^{nd} order, two 2^{nd} order streams join to form a segment of 3^{rd} order and so on. When two channel of different order join then the higher order is maintained. The trunk stream is the stream segment of highest order. It is found that Kayadhu River is of 7^{th} order (Fig. 4).

4.3.2 Stream Length

The stream length (Lu) has been computed based on the law proposed by Horton. Stream length is one of the most significant hydrological features of the basin as it reveals surface runoff characteristics. The stream of relatively smaller length is characteristics of areas with larger slopes and finer textures. Longer lengths of streams are generally indicative of flatter gradient. Generally, the total length of stream segments is maximum in first order stream and decreases as stream order increases. The numbers of streams are of various orders in a watershed are counted and their lengths from mouth to drainage divide are measured with the help of GIS software (Table 3).

4.3.3 Mean Stream Length

The mean stream length is a characteristic property related to the drainage network and its associated surfaces (Strahler, 1964), .The mean stream length has been calculated by dividing the total stream length of order by the number of stream. The mean stream length of study area is 0.65 for first order, 0.92 for second order, 2.26 for third order, 4.24 for fourth order, 8.32 for fifth order, 21.81 for sixth order and 66.73 for fifth order. The mean stream length of stream increases with increase of the order (Table 3).

4.3.4 Stream Length Ratio

The stream length ratio can be defined as the ratio of the mean stream length of a given order to the mean stream length of next lower order and has an important relationship with surface flow and discharge (Horton, 1945). The RL values between streams of different order in the basin reveal that there are variations in slope and topography. The length ratio, which is the ratio of the mean length of the streams of a given order to the mean length of the streams of the next lower order, was then calculated for each pair of order and varies from 0.327 and 0.705 (Table 3).

Table 3: Bifurcation Ratio and Length Ratio Kayadhu River

Stream order	No. of Stream	Bifurcation Ratio	Total Stream Length	Mean Stream Length (Km)	Length Ratio
1	3818		2470.57	0.65	
		3.86			0.705
2	990		909.05	0.92	
		4.25			0.406
3	233		526.62	2.26	
		3.95			0.534
4	59		249.94	4.24	
		4.92			0.509
5	12		99.8	8.32	
		6			0.381
6	2		43.61	21.81	
		2			0.327
7	1		66.73	66.73	
Total	**5115**		**4366.32**		

4.3.5 Bifurcation Ratio

Bifurcation ratio (Rb) may be defined as the ratio of the number of stream segments of given order to the number of segments of the next higher order (Schumn 1956). Horton (1945) considered the bifurcation ratio as an index of relief and dissections. Strahler (1957) demonstrated that the bifurcation ratio shows a small range of variation for different regions or different environmental conditions, except where the geology dominates. It is observed that Rb is not the same from one order to its next order. The Kayadhu River basin have values of bifurcation ratio of the basin are between 3.86 and 6 (Table 3).

4.4 Aerial Aspects

It deals with the total area projected upon a horizontal plane contributing overland flow to the channel segment of the given order and includes all tributaries of lower order. It comprises of drainage density, drainage texture, stream frequency, form factor, circularity ratio, elongation ratio and length of overland flow.

4.4.1 Drainage density (Dd)

Horton (1932), introduced the drainage density (Dd) is an important indicator of the linear scale of land form elements in stream eroded topography. It is the ratio of total channel segment length cumulated for all order within a basin to the basin area, which is expressed in terms of Km/Km^2. The drainage density, indicates the closeness of spacing of channels, thus providing a quantitative measure of the average length of stream channel for the whole basin. It has been observed from drainage density measurement made over a wide range of geologic and climatic type that a low drainage density is more likely to occur in region and highly resistant of highly permeable subsoil material under dense vegetative cover and where relief is low. High drainage density is the resultant of weak or impermeable subsurface material, sparse vegetation and mountainous relief. Low drainage density leads to coarse drainage texture while high drainage density leads to fine drainage texture (Strahaler, 1964).The average drainage density (Dd) of study area is 2.02 Km/Km^2 indicating moderate drainage densities (Fig. 5).

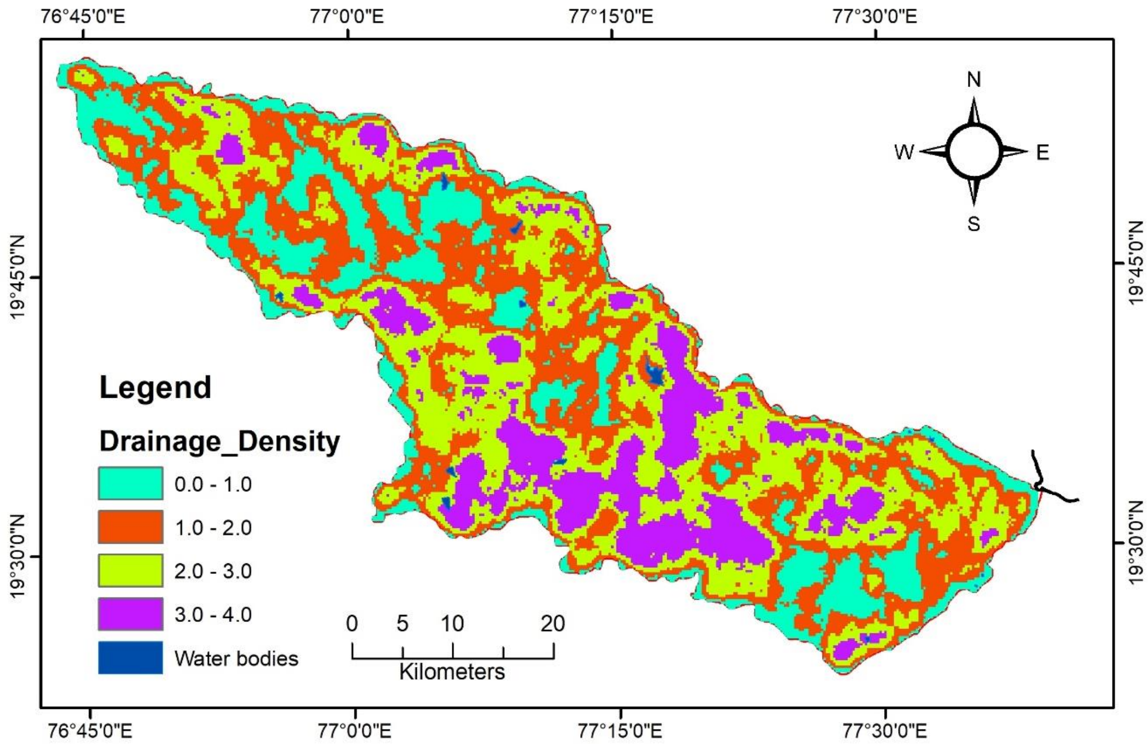

Fig. 5: Drainage Density map of Study area

4.4.2 Stream Frequency (Fs)

Stream frequency (Fs), is expressed as the total number of stream segments of all orders per unit area. It exhibits positive correlation with drainage density in the watershed indicating an increase in stream population with respect to increase in drainage density. The Fs for the basin is 2.37 (Table 4).

4.4.3 Circulatory Ratio (Rc)

Circularity Ratio is the ratio of the area of a basin to the area of circle having the same circumference as the perimeter of the basin (Miller, 1953). It is influenced by the length and frequency of streams, geological structures, land use/ land cover, climate and slope of the basin.

The Rc value of basin is 0.29 and it indicating the basin is characterized by low relief and drainage system seems to be less influenced by structural disturbances (Table 4). The high value of circularity ratio shows the late maturity stage of topography.

4.4.4 The Length of Overland Flow (Lg)

The Length of Overland Flow (Lg) is the length of water over the ground surface before it gets concentrated into definite stream channel (Horton, 1945). Lg is one of the most important independent variables affecting hydrologic and physiographic development of drainage basins. The length of overland flow is approximately equal to the half of the reciprocal of drainage density. This factor is related inversely to the average slope of the channel and is quiet synonymous with the length of sheet flow to a large degree. The Lg value of study area is 0.2 (Table 4).

Table 4: Morphometric parameters of Kayadhu River Basin

Parameters	Values
Total stream length-L (Km)	4366.32
Total basin area-A (Km^2)	2158.30
Total no. stream-(N)	5115
Basin perimeter-P (Km)	306
Maximum basin length - MBL (Km)	109.58
Form factor-F	0.18
Elongation ratio-E	0.48
Circularity ratio-Rc	0.29
Drainage density (Km/Km^2)	2.02
Stream frequency-($Streams/Km^2$)	2.37
Highest point on the basin parameter (m)	605
Height of the basin mouth (m)	390
Maximum basin relief (H)	215
Relif ratio – H/MBL	1.96
Length of overland flow (L) Km.	0.2
Infiltration Number	4.79

4.3 MORPHOTECTONIC ANALYSIS OF KAYADHU RIVER BASIN

4.3.1 Elongation ratio (Re)

According to Schumm (1956) elongation ratio Re, is the ratio of diameter of a circle of the same area as the basin to the maximum basin length Table 2. The ratio ranges between 0.60 and 1.0 over a wide diversity of climate and geology. The varying slopes of the basin can be classified with the help of elongation ratio, i.e. circular (0.9-1.0), oval (0.8-0.9), less elongated (0.7-0.8), elongated (0.5-0.7) and more elongated >0.5 (Kale and Shejwalkar 2008). The elongation ratio of Kayadhu river is 0.48 (Table 4), which represents that the basin is more elongated in shape with low relief.

4.3.2 Drainage basin asymmetry (Af)

Drainage basin asymmetry, used to evaluate local and regional scale tectonic tilting produced asymmetry of the drainage networks and the basin, corresponds to the orientation of the basin axis (Hare and Gardner 1985; Cox 1994; Keller and Pinter 2002; Garrote et al. 2008; Giaconia et al. 2012; Özkaymak and Sözbilir 2012; Vijith et al. 2015). The asymmetry factor can be represented as the percent of the area of the basin that is found on the right bank side of the main stream (while looking downstream) to the whole area of the basin and is defined as:

$$AF=100(Ar/At) \quad \text{(I)}$$

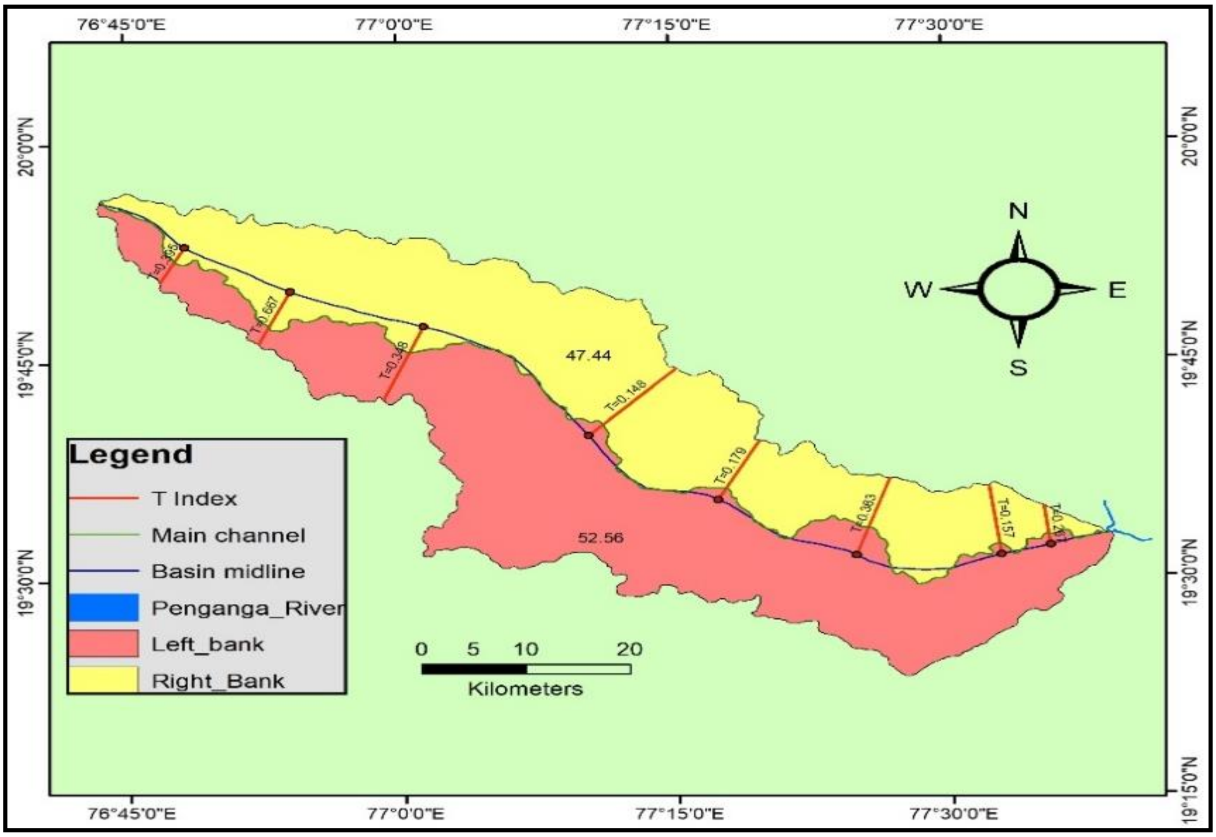

Fig. 6: Map showing transverse tographic symmetric factor (T) and drainage basin asymmetry (Af)

Where Ar is the area of the basin to the right of the trunk stream and At is the total area of the drainage basin (Hare and Gardner 1985). This index identifies tectonic tilting of a drainage basin and characterizes its asymmetry or symmetry, as it is sensitive to rotations normal to the axis of main stream (Tsodoulos et al. 2008; Özkaymak and Sözbilir 2012). Under stable settings of a drainage network formation, the index will be equal to 50%, AF close to 50% shows little or no tilting perpendicular to the direction of the trunk channel. AF, which is significantly above or below 50%, results from drainage basin tilting (tilting left downstream for >50% and tilting right downstream for <50%), either due to active tectonics or lithologic control. The asymmetry factor has been calculated for Kayadhu river is found to be 47 indicating a slightly asymmetrical basin (Fig. 6).

4.3.3 Transverse topographic symmetry factor (T)

The transverse topographic symmetry factor is used to determine possible lateral tilting and preferred stream migration in the basin (Cox et al. 2001). This index is used to provide important asymmetry information in larger drainage system and rapid uplift in the regions. The basin midline would be the location of a river that is symmetrically placed with respect to the basin divide. It also indicates the migration of the drainage system perpendicular to the principal axis of the basin due to internal fluvial processes or external forces (Keller and Pinter 2002; Salvany 2004). The T factor Table 2 can be calculated by using equation:

$$T = Da/Dd \qquad \text{(II)}$$

Where, Da is distance from midline of the drainage basin to the midline of the active meander belt. Dd is the distance from the basin midline to basin divide. In general, the T values ranges from 0 to 1 and T values close to 0 signifying symmetrical basin and stream is in the middle of the drainage basin, while values close to 1 indicate highly asymmetric basin and stream migrates laterally away from the centre of the basin margin. The T index Table 2 for the Kayadhu river (Fig. 6) shows strong asymmetry (average is 0.315). From the values of T index (Table 5), we can interpret the cause of asymmetry depends on tectonic disturbances or neotectonic structural features.

Table 5: Topographic transverse symmetric (T) factor calculated for the selected segments in the main stream

Segments	1	2	3	4	5	6	7	8
T	0.267	0.157	0.363	0.170	0.148	0.348	0.667	0.395
Direction of Shift	WNW	WNW	ENE	ENE	NE	WSW	WSW	WSW

4.3.4 Stream length gradient Index (SL)

It is one of the most important index in order to know whether the area is tectonically or lithological controlled. This parameter is measured by using digital elevation map as well as contour map of the area and measuring the length of the river. By means of SL index we can quantify the characteristics of stream gradient behaviour and its relationship with physiographical conditions, lithological control, topography and associated drainage parameters (Hack 1973; Cox 1994; Keller and Pinter 2002; Dehbozorgi et al. 2010; Giaconia et al. 2012; Vijith et al. 2015). The stream length- gradient index was first defined by Hack (1973) and computed by equation:

$$SL=(\Delta H/\Delta L)L \quad \text{(III)}$$

Where $\Delta H/\Delta L$ is the local slope of the channel segment being evaluated and L is the channel length from the divide to the midpoint of the channel reach for which index is calculated. The stream length-gradient index can be used to evaluate relative tectonic activity. The SL index is used to infer stream power and rock erodibility owing to its sensitivity to the disequilibrium state of channels due to tectonic and climatic perturbation in the channel slope (Keller and Pinter 2002). The SL index, (Table 2) calculated for 34 segments along the total length of the river, varies from 6 to 86 m (Fig. 7). A sudden increase in the SL index values indicates differential uplift of the region due to the neotectonic activity. The study is made in order to generate a comprehensive data about the variation and pattern of neotectonic influence in the Kayadhu river basin.

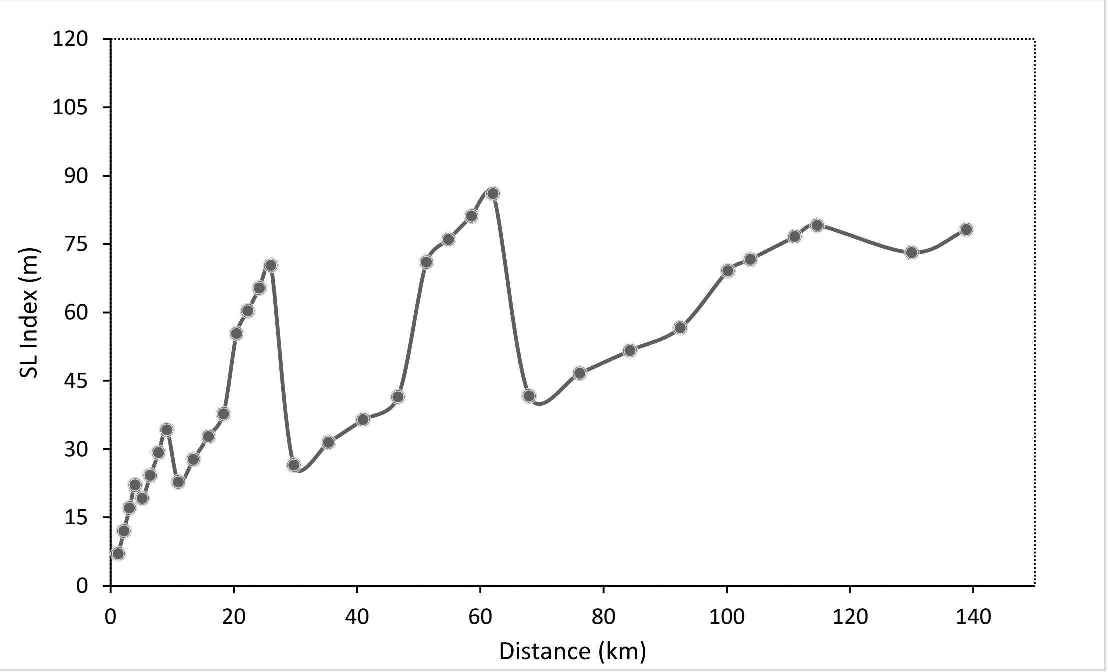

Fig. 7: SL index of the Kayadhu river

4.3.5 Longitudinal Profile

Longitudinal profile of a river is an important geomorphic tool it provides clues to interpret the geometry of geotectonic disturbances and geomorphic evolution as well as underlying material of the area (Schumm 1986; Schumm 1993; Jain et al. 2006; Ambili and Narayana 2014; Vijith et al. 2015; Kumar et al. 2018). Longitudinal profile is a plot of river distance against elevation. It represents channel gradient of the river origin to its mouth and based on the shape of the curves it can be interpreted (Ferraris et al. 2012). The concave nature of profile represents long term equilibrium between uplift and erosion rates i.e. progressive increase in river discharge in the downstream direction (Bull and Knuepfer 1987), while convex profile indicates the upliftment is dominant in the areas. The irregularity in the profile is a result of neotectonic and tributary confluences (Schumm 1986). The longitudinal profile plot indicates a number of knick points (Fig. 8) caused by change in lithology (hard or soft) or by structural disturbances in the area therefore stream is trying to adjust with terrain characteristics (Crosby and Whipple 2006).

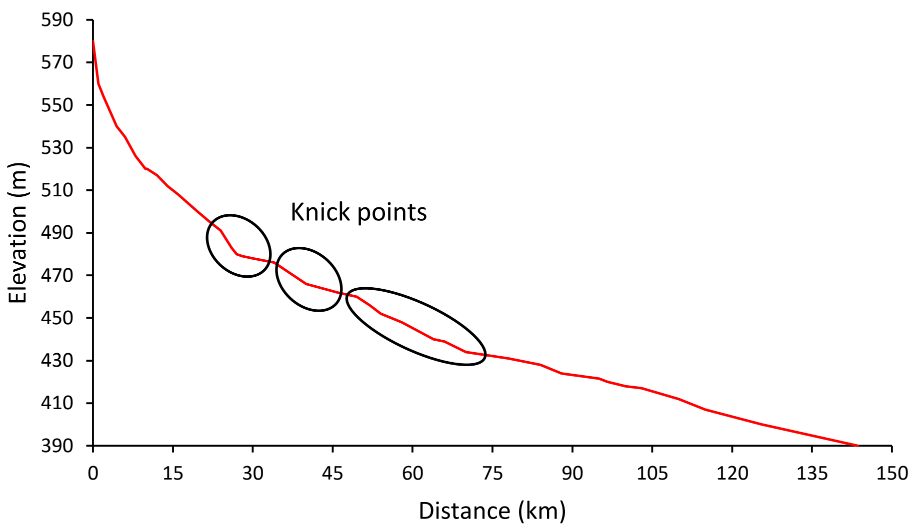

Fig. 8: Longitudinal profile of the Kayadhu river showing knick points

4.3.6 Hypsometric analysis

The hypsometric analysis provides distribution of elevation in a given area of a basin and gives an idea to evaluate the geomorphic form of catchment and landforms (Strahler 1952; Dowling et al. 1998; Singh et al. 2008; Vijith et al. 2015). The hypsometric curve is related to the volume of rock in the basin that has not been eroded (Awasthi et al. 2002; Crosby and

Whipple 2006). Hypsometric curves convex upward are interpreted as youthful, S shaped curves as mature and concave upwards are old age stages of landscape evolution. In the present study percentage hypsometric integral method used (Fig. 9) by computing two ratios from contour map measurements Table 2. The first one a/A, where a is the area enclosed between a given contour within basin and basin boundary of the basin, and A is total area of the basin. The second ratio (Keller and Pinter 2002) is h/H , where h is the height of the contour above the base level of the stream mouth and H is the total height of the basin from basin mouth. To characterise the hypsometric curve the HI can be calculated as HI= (elevation mean- elevation minimum)/ (elevation maximum-elevation minimum). High values of HI generally mean that the upper part of the basin have not been eroded much and indicate a younger landscape (Vijith et al. 2015).

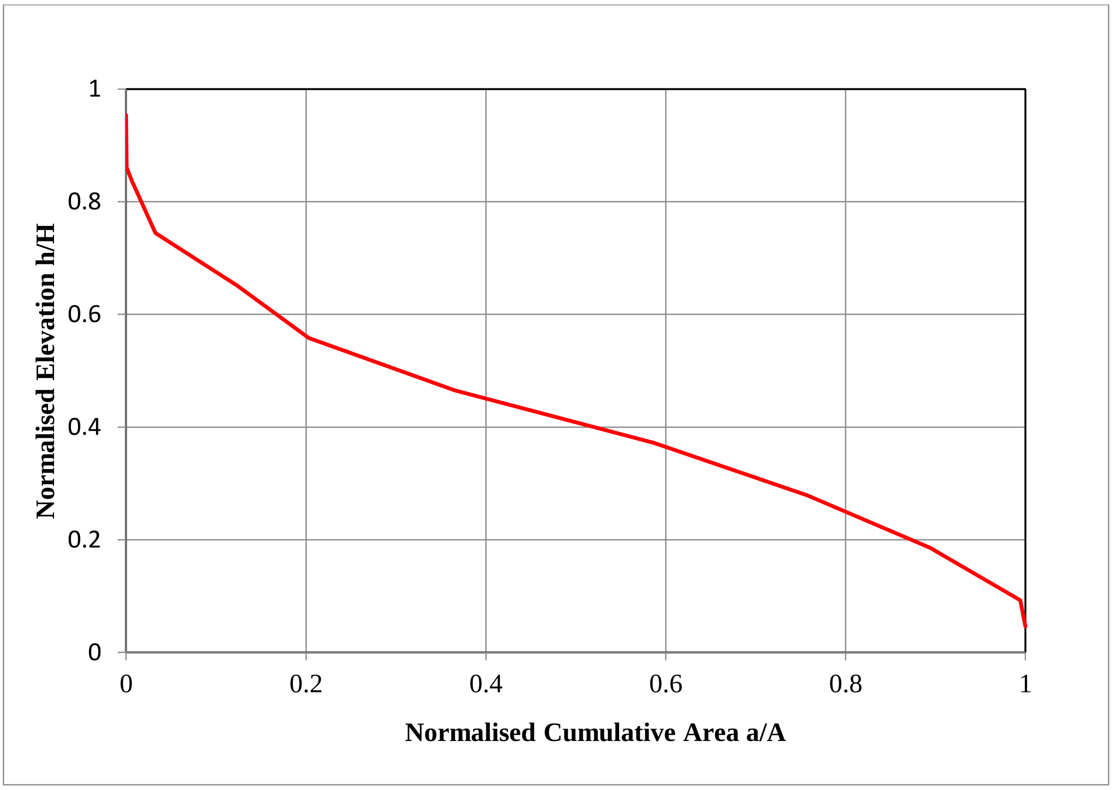

Fig. 9: Hypsometric curves with integrals for Kayadhu river basin

4.3.7 Lineaments and microseismicity

Lineaments are defined as mappable linear to slightly curvilinear subsurface features, which are differ distinctly from the adjacent feature and pattern, reflect subsurface information (O' Leary et al.1976). The structural features usually related with joints, faults and lineaments may produce essentially straight rivers with minimum meandering (Twidale 2004) Orientation and extent of individual linear structure was calculated in Arc GIS 10.3 software. The orientation of various linear elements observed on the basis of ASTER, IRS P6 LISS -IV 2016 satellite data and further validated by field studies (Cantamore, et al. 1996), the preferred stream orientations are used to reconstruct neotectonics through anomalous behaviour of the streams. Lineaments are important components of the earth surface morphology and the lineament density is related to the intensity of deformation (Nur 1982). It is interesting to note that the maximum lineament frequency is found in the central part of the basin and the length of lineaments varies from 3 to 19 km (Fig. 7). Most of the drainage of the Kayadhu river follow the NW-SE and SW-NE trend. The deformation is not observed along the lineaments, these are covered by black cotton soil therefore detailed geophysical surveys along these lineaments are essential.

Chapter 5

DISCUSSION

The morphotectonics and morphometric parameters acts as a source for studying the activeness of a region in depth. Morphotectonic evaluation of the present study area involves the study of the Kayadhu River basin with respect to its tilting pattern, tilting direction, gradient change and presence of linear features. Studying drainage system provides information on the long-term evolution of the landscape. The slope is the function of tilting hence the basin asymmetry can be used to decipher the tilting of the area, thereby helping in neotectonic studies. The data provided by asymmetric factor and transverse topographic symmetry factor helps to quantify the distinctive stream patterns and geometries. The asymmetry factor has been calculated for the Kayadhu River is found to be 47 indicating a slightly asymmetrical basin. The T index Table 5 for the Kayadhu river (Fig. 6) shows strong asymmetry (average is 0.315). From the values of T index (Table 3), we can interpret the cause of asymmetry depends on tectonic disturbances or neotectonic structural features.

The SL index (Fig. 9) is applied to identify recent tectonic activity by recognizing high index values variations on a particular rock type. In the present study SL index values are calculated in different segments for the same basin. The high and low anomalous SL points marked in the plots for each basin are shown in the map along with the lineaments. The anomalous points are lying parallel, across or even lying upon the major lineament trends of the region. The high anomalous points are controlled by the major lineaments of the area which is also same as regional tectonic setting.

The longitudinal profile plot indicates a number of knick points (Fig. 8) caused by change in lithology (hard or soft) or by structural disturbances in the area therefore stream is trying to adjust with terrain characteristics.

High values of Hypsometric analysis (HI) generally mean that the upper part of the basin have not been eroded much and indicate a younger landscape (Fig. 9).

In addition to morphometric parameters, seismicity data was also integrated in order to incorporate the effect of tectonic activity in recent times. The geomorphic indices and seismic activity classes in the study area were used to evaluate the distribution of relative tectonic activity in the study area.

Chapter 6

CONCLUSION

The morphotectonics of the Kayadhu river basin, Maharashtra, India, was studied through the various geomorphic indices, using Arc GIS10.3 software with 30m resolution ASTER GDEM and LISS IV, IRS FCC data.

- Transverse topographic symmetry (T) calculated from transverse topographic profiles of 143.58 km drainage basin segments, it implicates ground tilting as the driving mechanism of preferred migration.
- Longitudinal profile of the river indicates a number of knick points at a steep reaches in the profile caused by structural disturbance (uplift or lineaments), therefore these disturbances caused due to tectonic activities in the region over the development of river, which might have reflected as change in the gradient of along the longitudinal profile of Kayadhu river.
- The asymmetric integral value for the right bank of the basin. The absolute difference is 2.56 indicate that the basin has slight influence tectonic activity.
- The calculated hypsometric integral for the Kayadhu River is 0.38 shows basin is still under mature stage of erosion.
- The lineament ranges from 03 to 19 km long and show a dominant NW-SE and NE-SE trend, consisting with geological structure, and hence there is possibility of recent crustal movement in this area.
- The drainage density value varies from 1 to 4 Km/Km^2 and stream frequency is 2.37 streams/km2 in the Kayadhu River. It is well known that the denser the drainage network, the less recharge rate and vice versa. The percolation rate is also depending upon geology.
- The whole analysis of the basin indicates, the path of the river is tectonically influenced at some location, but most part of the basin not experienced any major disturbances.

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Acceptance of article

Dear Dr. Ghute,

We are pleased to inform you that your article has been accepted for publication in **Indian Journal of Agricultural Research.** Your submission is a well-thought out piece of writing and follows many of journal guidelines. The editors agreed that your submission showed great writing skills.

Article Title : **An approach to mapping groundwater recharge potential zones using geospatial techniques in Kayadhu river basin, Maharashtra**

Author(s) : **Bhagwan B. Ghute and Shaikh Md. Babar**

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RESEARCH ARTICLE

Indian Journal of Agricultural Research, Volume Issue : ()

An Approach to Mapping Groundwater Recharge Potential Zones using Geospatial Techniques in Kayadhu River Basin, Maharashtra

Bhagwan B. Ghute[1], Shaikh Md. Babar[2]

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ABSTRACT

Rapid increase in population, agricultural expansion and ongoing development projects in the region. However, the region is facing water scarcity because of seasonal precipitation and inadequate surface water resources. Therefore, groundwater resources are gaining much more attention mainly in Kayadhu river basin to fulfil drinkable water requirements in the area. To maintain the long-term sustainability of water resources artificial recharge is expected to become frequently necessary in future as the growing population requires more water and consequently, more storage is required to conserve water for use in the times of shortage. Geospatial techniques are used in the field of hydrology and water resources management. One of the chief advantages of this techniques for hydrological investigation and observe its ability to generate data in spatial and temporal fields, which plays vital role for fruitful analysis, estimation and authentication. The suitable zones for artificial recharge were identified by overlaying thematic layers such as land use/land cover, lineament density, slope, drainage density, lithology, geomorphology, rainfall and soil characteristics are integrated with recharge potential factors. The result reveals that 79% area of Kayadhu river basin is most effective for high to moderate artificial recharge potential zone.

Key words: Geographic information system, Groundwater recharge, Kayadhu River, Weighted overlay.

INTRODUCTION

According to Freeze and Cherry (1979) groundwater is defined as subsurface water that fills all the openings in the soil and rock formations below the water table. Groundwater flows through the aquifer towards the point of discharge such as springs, wells, rivers, lakes and the ocean. Ground water conditions are largely controlled by the prevalence and orientation of primary and secondary porosity. The depletion of groundwater levels is not a new account in Maharashtra, India, however, it has continued for last two decades, while annual water demand increased for agricultural, industrial activities and semi-arid situations in the Kayadhu river basin of Deccan Basaltic Province (DBP). The state is facing severe shortage of groundwater in spite of receiving a high annual rainfall (Raju, 1998). There are many influencing parameters that affects groundwater recharge potential in the area such as land use/land cover, lineament density, slope, drainage density, geology, geomorphology, rainfall and soil characteristics. Modern remote sensing techniques enable demarcation of suitable areas for groundwater renewal by taking into account the diversity of factors that control groundwater recharge. Satellite remote sensing has emerged as a useful tool for watershed characterization, conservation, planning and management in recent times (Aher and Sharma, 2014). Various studies have been carried out throughout the world to identify the groundwater recharge potential zones by employing remote sensing and GIS techniques were frequently employed in these studies for the preparation of required thematic layers. Moreover, existing maps, aerial photographs and ûeld data inputs have been commonly used (Krishnamurthy and Srinivas 1995; Krishnamurthy *et al*. 1996; Saraf and Choudhury 1997; Saraf and Choudhury 1998; Murthy 2000; Shahid *et al*. 2000, Krishnamurthy *et al*. 1996; Sener *et al*. 2005; Sree Devi 2003; Shaban *et al*. 2006; Solomon and Quiel, 2006; Tweed *et al*. 2007; Jasrotia and Kumar 2007; Ghayoumian *et al*. 2007; Yeh *et al*. 2009; Nagarajan and Singh 2009; Chenini *et al*. 2010, Subagunasekar and Sashikkumar 2012; Senanayake *et al*. 2016). 2009; Riad *et al*., 2011b). Most of these studies were built on knowledge-based approach and integrating diverse thematic layers such as land use/land cover, geology, geomorphology, lineament density, drainage density, slope, soil etc. with GIS techniques. Artificial recharge is a controlled recharge where surface water is put on or in the ground for infiltration and consequently

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moves towards the aquifer to enhance the groundwater resources (Ta'any, 2011). It can be defined as the practice of increasing the amount of water entering to the subsurface reservoirs by artificial means (Bouwer 2002; Bhattacharya 2010). With Geographical Information System and satellite data, attempts were made to develop a suitable GIS based model, for mapping groundwater recharge potential zones by integrating different thematic layers which have direct control on ground water recharge in Kayadhu river basin, Maharashtra, India.

MATERIALS AND METHODS

The study area (Kayadhu river basin) is located in the eastern part of Deccan Basaltic Province (DBP), Maharashtra, India. The basin is confined between N19° 22", E77° 40" in the South East and N 20° 00'' E76° 40'' North West and total area of the basin is 2158.38 km^2. Out of the total area, around 1639.57 km^2 is covered with agriculture, 435.57 km^2 with waste land, 38.52 km^2 with settlements, 38.79 km^2 with forest and 5.92km^2 with water bodies. The Kayadhu river is seventh order and the major water source of this area and it originates from the Angarwadi village in Risod tauka of Washim district in Ajanta hill ranges with an elevation of 580 m. The drainage pattern in the study area is mostly dendritic as well as semi-dendritic. Climatologically, this area experiences semi-arid, sub-tropical condition characteristically hot summer with an annual rainfall ranging from 750 to 1244 mm and the temperature ranges between 12.7 and 41.7°C. The southwest monsoon is a major source of rainfall in the study area and it occurs during June to September (CGWB 2013). The population in the study area is around 5,00,000 and are distributed over 270 Panchayat villages and 4 townships (Fig 1).

For the present study, the methodology used is shown in the flow chart (Fig 2). In this study the spatial data base has been created using the topographic maps obtained from the Survey of India (SOI) 1:50000 scale, IRS P6 LISS IV MX satellite data, ASTER GDEM and field verification. Various thematic maps such as geology, drainage density, lineament density, rainfall data, soil, land-use/land cover, slope and geomorphology are prepared by using GIS and remote sensing. All of the map themes were presented in UTM Projection Zone 43 N, Datum WGS84 with 30 m resolution and converted to raster format.

Preparation of thematic layers

Geology

The type of rock exposed on the surface significantly affects the groundwater recharge (Shaban *et al*. 2006). According to El-Baz and Himida (1995) geology affects the groundwater

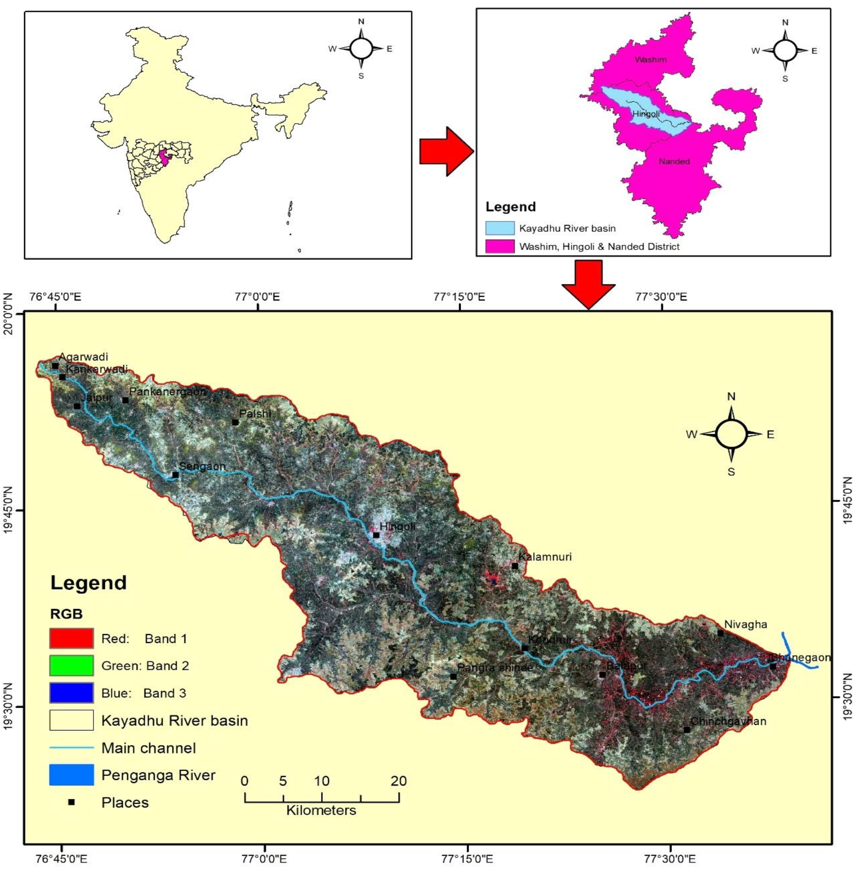

Fig 1: Location map of the study area.

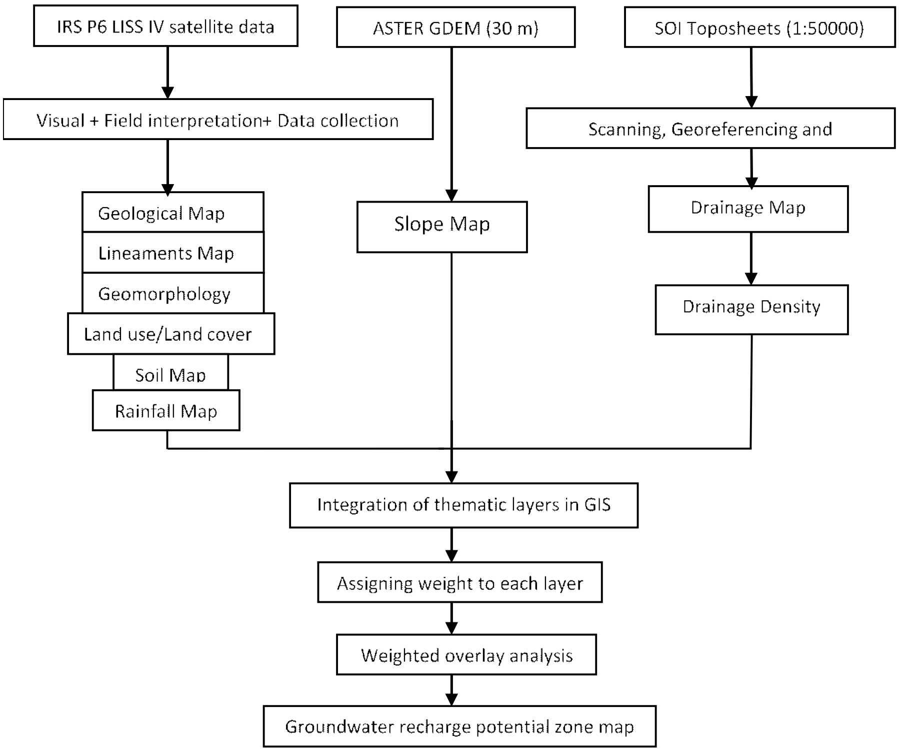

Fig 2: Flow chart showing methodology adopted in the study area to mapping groundwater recharge potential zone.

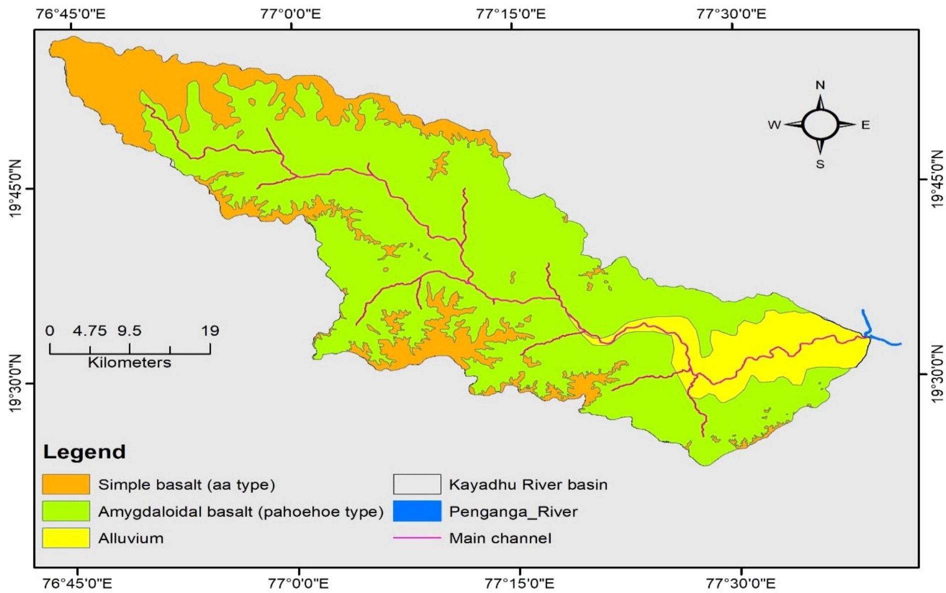

Fig 3: Geological map of Kayadhu river basin.

recharge by controlling the percolation of water flow. While, some researches have ignored this factor by regarding the lineaments and drainage features as a function of primary and secondary porosity, this study includes lithology to minimize uncertainty in determining lineaments and drainage.

Land use/cover

Land use /cover is an important indicator of the extent of groundwater requirements and groundwater utilization as well as important for selection of groundwater recharge. Satellite data LISS IV, topographic maps and field evidences were used as reference data. The different classes of land use /cover are identified on the basis of different tone in the satellite image such as barren land, water bodies, settlements, agriculture land and forest area.

Slope map

The study related with groundwater flow and storage the

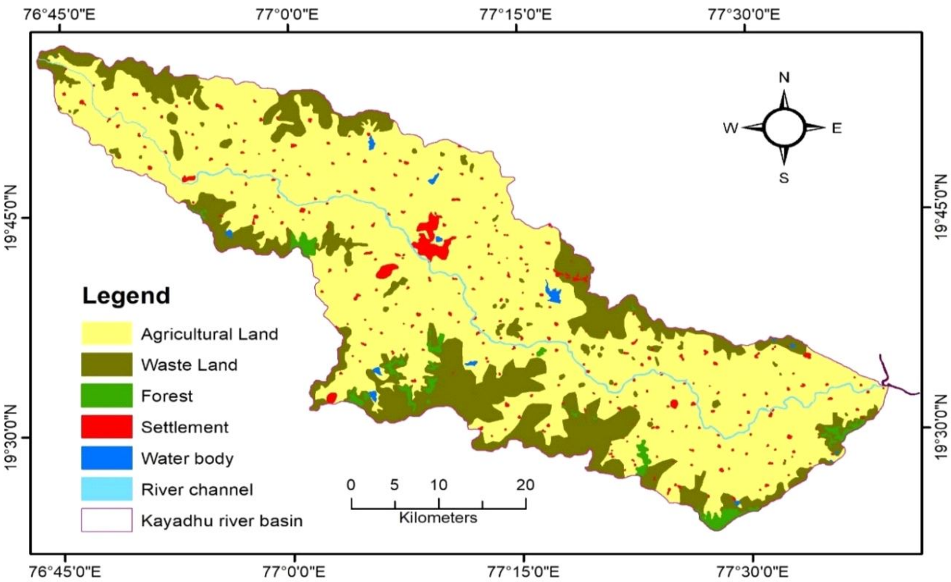

Fig 4: Land use land cover map of Kayadhu river basin.

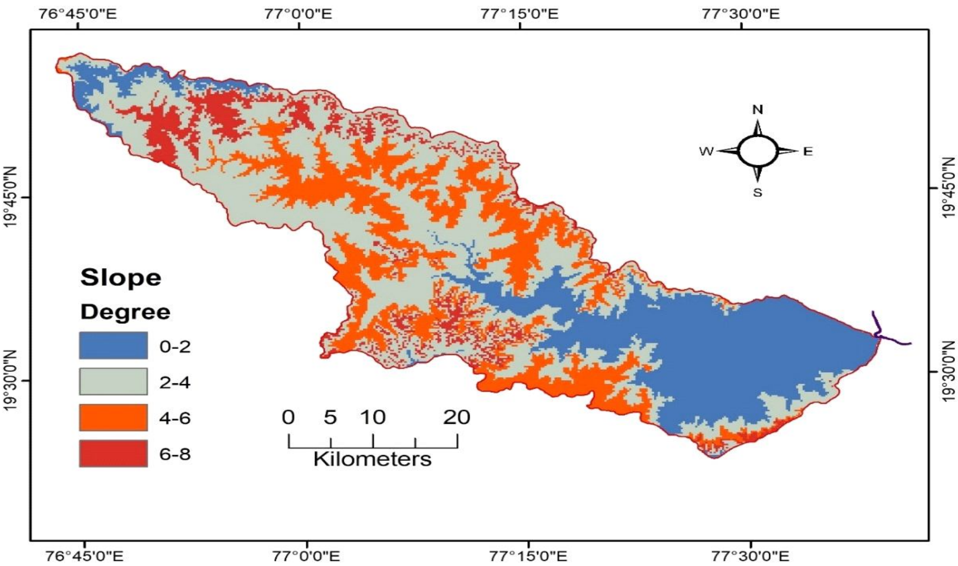

Fig 5: Slope map of Kayadhu river basin.

slope is often neglected; mainly in the plain areas (Al Saud, 2010). The slope gradient is directly affecting the infiltration of surface runoff. High slope gradient produces small recharge and the area where slope is minimum it tends to water longer had a greater chance of infiltration and recharge during rainfall (Jasrotia *et al*. 2007; Yeh *et al*. 2016). The slope map was prepared from the ASTER GDEM in the GIS by using slope analysis function to assess the variation of the slope in the Kayadhu basin.

Lineaments

The term *lineament* is a commonly used in remote sensing studies in connection with fractures or weak zone. Lineaments are defined as mappable linear to slightly curvilinear subsurface features, which are differ distinctly from the adjacent feature and pattern, reflect subsurface information (O' Leary *et al*. 1976). The structural features usually related with joints, faults and lineaments may produce essentially straight rivers with minimum meandering (Twidale 2004). Lineaments are extracted from drainage pattern and vegetation shows prominent trends of feature observation on IRS P6 LISS IV satellite image. Lineaments in Kayadhu basin area were extracted through manual lineament extraction techniques (Weerasekara *et al*. 2014). Many non-geological structures, such as roads and channels, cause errors in the analysis of lineaments. These features are eliminated from the resultant layer.

Drainage density

The drainage density map of Kayadhu river (Fig 6) is the

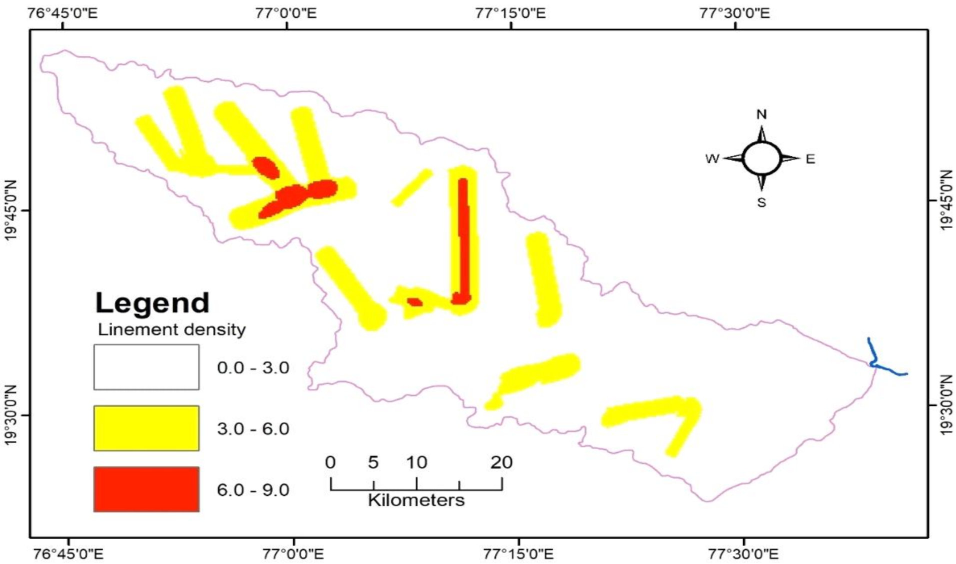

Fig 6: Lineament density map of Kayadhu river basin.

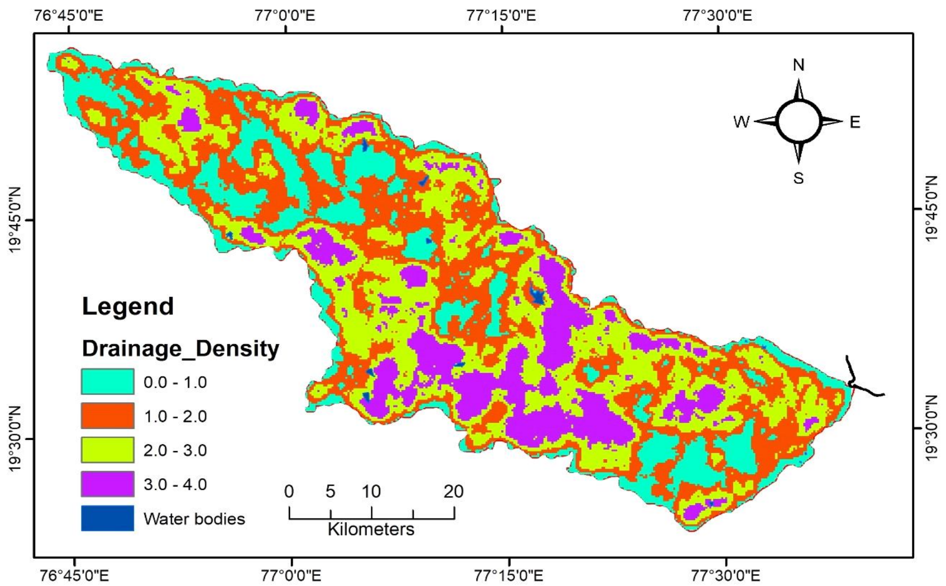

Fig 7: Drainage density map of Kayadhu river basin.

total length of all the streams in a drainage basin divided by the total area of the drainage basin. The structural analysis of a drainage network access the characteristics of a groundwater recharge zone. It is well known that the denser the denser the drainage network, the less recharge rate and vice versa. The percolation rate is also depending upon geology. According to Greenbaum (1985) is determined by an equation (1):

$$D_d = \frac{\sum_{i=1}^{i=n}}{A} Si \qquad (1)$$

Where, $\sum_{i=1}^{i=n} Si$ denotes the total length of the drainage

On the basis of topographic maps drainage network is digitised and using density function in GIS, drainage density is calculated.

Soil types

The soil map of study area obtained from the National Atlas and Thematic Mapping Organization (2005) and subsequently georeferenced and digitized. Thickness of soil cover is less towards NW part of the basin where ground elevations are higher. Soil in central, southern and eastern regions of the basin near the banks of rivers are thicker. Here soil, ranging in depth from 1 to 2 m, are black and rich in plant nutrients (CGWB 2013). When assigning weights to each soil class, permeability of each soil type has been considered in this study, since inûltration and percolation rates is directly related to permeability Senanayak *et al.,* (2016).

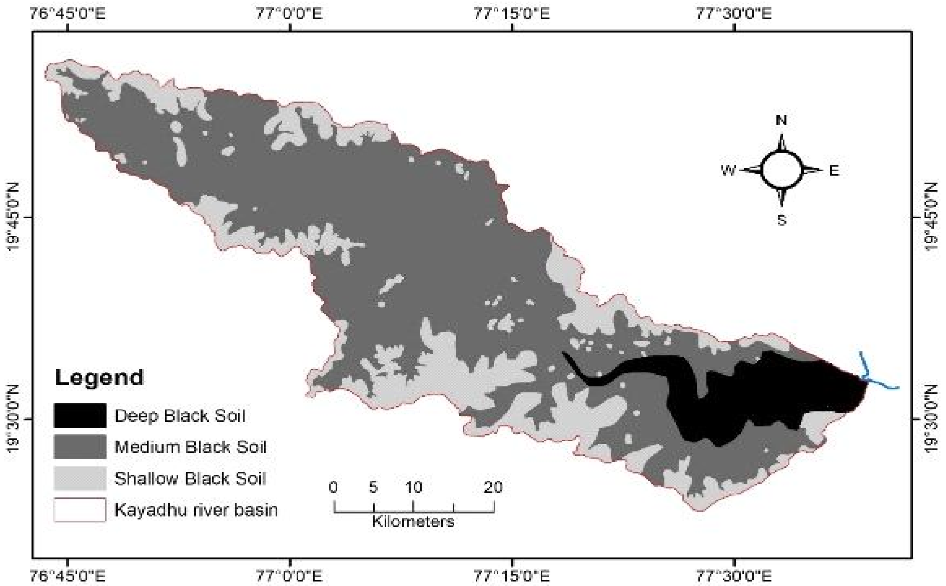

Fig 8: Soil map of Kayadhu river basin.

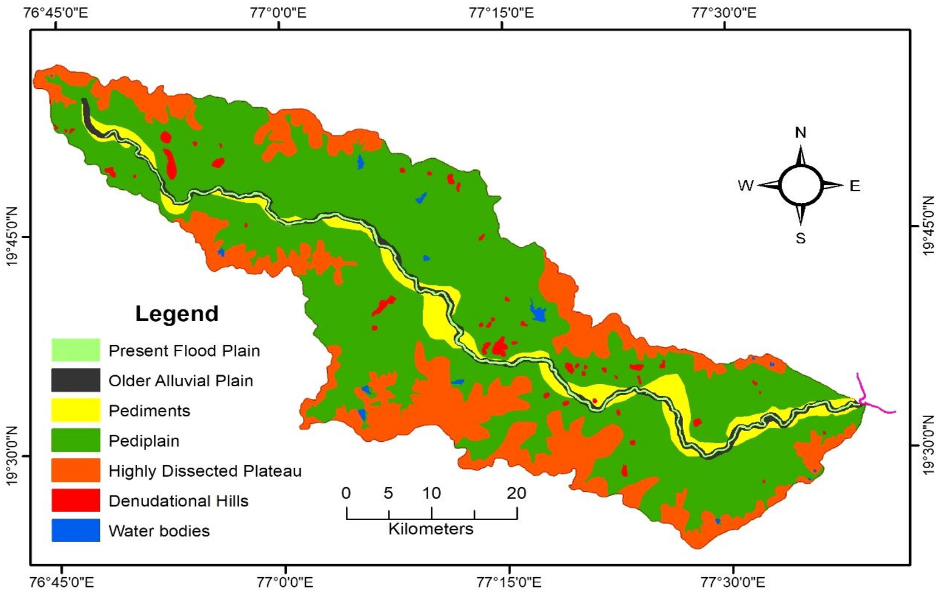

Fig 9: Geomorphological map of Kayadhu river basin.

Geomorphology

Geomorphologically, the study area is identified by various landforms such as older alluvial plain, present flood plain, pediments, pediplains, highly dissected plateau and denudational hills. Among these landforms older alluvial plain, present flood plain and pediplains have more potential for groundwater recharge, but the highly dissected plateau and denudational hills are not suitable for water augmentation because of the steep slope.

Rainfall

Rainfall is main source for groundwater recharge (Musa *et al*., 2000) and similarly for all hydrological process. The annual rainfall data collected from the Indian Meteorological

Table 1: Ranks assigned to themes (Modified after Shahid *et al*. 2000; Jaiswal *et al*. 2003; Basavaraj and Nijagunappa 2011; Magesh *et al*. 2012; Sarup *et al*. 2011; Yeh *et al.,* 2016; Senanayak *et al.,* 2016).

Theme	Rank Assigned
Geology (GLr)	15
Geomorphology (GGr)	12
Land cover/ land use (LCr)	10
Lineament density (LDr)	13
Drainage density (DDr)	10
Rainfall (RFr)	15
Soil (SCr)	14
Slope (SGr)	11

Department (IMD) for annual rainfall measurements from rain gauge stations in the study region. The rainfall map has been categorized into three categories of rainfall zones each of 100 mm interval.

Subsequently, the thematic maps are used to analyse in overlay and ranks and weights are assigned for each thematic layer to evaluate the groundwater recharge potential zone as shown in Table 1 and Table 2. For identifying ground water recharge potential zones for an area following equation (2):

$$Pr=GL_wGL_r + DD_wDD_r + LC_wLC_r + LD_wLD_r + RF_wRF_r + GG_wGG_r + SG_wSG_r + SC_wSC_r \quad (2)$$

Where,

Pr is the groundwater recharge potential index, GL is the geology index DD drainage density index, LC land use land cover index, LD is lineament density, RF is rainfall index, GG is geomorphology, SG is slope gradient and SC is soil cover index. The subscript w and r represent the weight of a theme and the ranking of individual class of the theme respectively.

RESULTS AND DISCUSSION

The geological map of area having three geological units such as Simple (aa type) basalt, compound (pahoehoe type) basalt and alluvial deposits in the study area (Fig 3). Simple aa type basalt covers 420.16 km^2 area having low porosity and permeability compared with compound pahoehoe type basalt 1531.73 km^2. Alluvium occupied 206.42 km^2 area of the study area. Land use /Land cover is one of the major governing factors in groundwater recharge processes. The different types of land use pattern identified in the study area, which includes agricultural land, waste land, settlements, forest and water bodies. Water bodies and agriculture land are good zones for groundwater recharge. Settlements and forest are moderate for groundwater

Table 2: Weight assigned to each class of the theme (Modified after Shahid *et al.* 2000; Jaiswal *et al.* 2003; Basavaraj and Nijagunappa 2011; Magesh *et al.* 2012; Sarup *et al.* 2011; Yeh *et al.,* 2016; Senanayak *et al.,* 2016).

Theme	Classes	Weight assigned
Geomorphology	Present flood plain	3
	Older alluvial plain	4
	Pediments	6
	Pediplain	7
	Highly dissected plateau	2
	Denudational hill	1
Land use/Land cover	Agricultural land	6
	Waste land	2
	Forest	5
	Settlement	3
	Waterbody	8
Soil	Shallow black soil	2
	Medium Black soil	5
	Deep black soil	8
Geology	Simple Basalt	1
	Amygdaloidal basalt	4
	Alluvium	7
Slope (Degre)	0^0-2^0	10
	2^0-4^0	8
	4^0-6^0	4
	6^0-8^0	1
Drainage density (km/km2)	0.0-1.0	1
	1.0-2.0	2
	2.0-3.0	4
	3.0-4.0	6
Rainfall (mm)	<750	4
	750-850	5
	>850	6
Lineament density (km/km2)	0.0-3.0	1
	3.0-6.0	4
	6.0-9.0	6

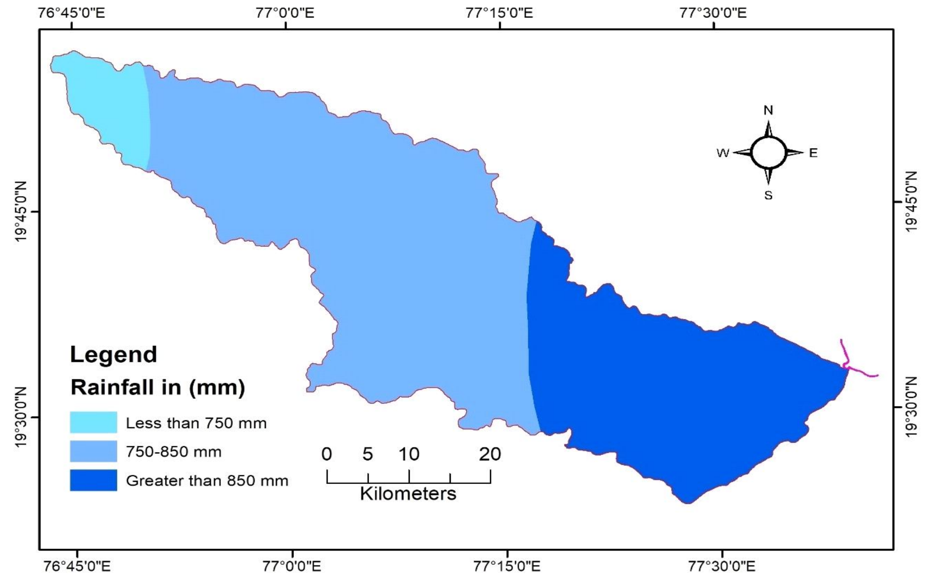

Fig 10: Rainfall map of Kayadhu river basin.

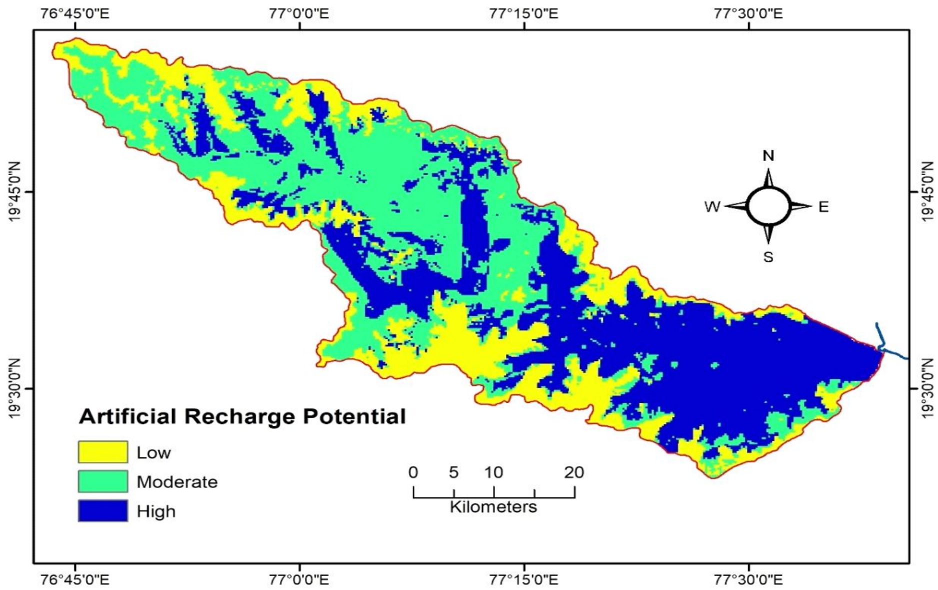

Fig 11: Groundwater recharge potential zone map of Kayadhu river basin.

recharge, whereas waste land having steep slope therefore low potential for groundwater recharge. The ranking potential distribution of land use and land cover (Fig 4) of the study area. The slope gradient has its own importance in affecting the runoff, recharge and movement of surface water. These are classified into four classes: (1) 0^o–2^o, (2) 2^o–4^o, (3) 4^o–6^o and (4) 6^o-8^o. It can be seen that the lowest slope (0^o–2^o). Slope is inversely proportional to recharge (Fig 5).

Lineaments density (Fig 6) and drainage density (Fig 7) are also important, more the density more will be the recharge. Soil map of the study area reveals three main soil categories (Fig 8). The study area is dominated by medium black soil (1479.64km^2) and shallow black soil (476.70km^2) with deep black soil present in relatively small areas (202.03 km^2) (NATMO 2005). Black soil is highly resistant for recharge because it having low permeability. Geomorphologically, the study area is identified by various geomorphic units such as older alluvial plain, present flood plain (17.75km^2), pediments (156.11 km^2), pediplains (1455.39 km^2), highly dissected plateau (457.55 km^2) and denudational hills (21.48 km^2) (Fig 9). A large part of the study area is covered with pediplain formation. A pediment is a gently sloping and transport and erode rock and connects eroding slopes to the areas of sediment deposition at lower levels (Oberlander, 1989). Among these geomorphic units alluvial plain, present flood plain and pediplains have more potential for groundwater recharge, but the highly dissected plateau and denudational hills are not suitable for effective groundwater recharge. Rainfall map of study area (Fig10) shows a variation in the rainfall pattern in the Kayadhu river basin.

CONCLUSION

In order to demarcate the ground water recharge potential zones, different thematic layers have been prepared by utilizing GIS techniques, thus it provides an effective practice for saving extensive time, labour and cost. Thematic layers such as rainfall, lineament density, slope, drainage Density, land use/land cover, geology, geomorphology and soil cover map layers were integrated on a GIS platform using the raster calculator in overlay analysis method for classifying ideal artificial recharge zone (Fig 11) in Kayadhu river basin. Around 79% area was found to have high to moderate groundwater recharge potential zone, whereas only 21% area have a low artificial groundwater recharge potential. Moreover, the most effective recharge potential is found on regions of alluvium deposit. Whereas, the least effective recharge potential is in simple basalt formations. The resultant artificial recharge potential map and the technique used in this study will help as for sustainable use of groundwater resource for enhancing groundwater recharge by proper management and recommendation for artificial recharge structures such as percolation tanks, recharge basins, recharge wells, ridges and furrows, check dams, gully control/ stone wall structures, contour bunding, trenching, land fooding etc. This technique evaluates best qualitative approach for artificial recharge.

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Morphotectonics of Kayadhu river basin in Washim-Hingoli -Nanded districts, Maharashtra: A spatial analysis

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Abstract

The morpho-tectonic and morphometric analysis of Kayadhu river basin is carried out to interpret the landscape development and stream features of the river basin with the help of quantitative analysis of geomorphic indices and field observations. This analysis is based on relief and tectonic aspects such as elongation ratio (Re), hypsometric integral (HI), basin asymmetry factor (AF), transverse topographic symmetric factor (T), stream length gradient (SL) index, longitudinal profile and lineament and microseismicity in the area. The spatial analysis has been completed with the help of remote sensing and GIS techniques. The Kayadhu river is one of the major tributaries of the Penganga river in the deccan trap area of Maharashtra. The calculated geomorphic indices of the river, which shows positive marker of tectonic inscription on drainage network. A moderate hypsometric integral value indicate that the basin is still under mature stage of erosion. Longitudinal profile of the stream also shows the presence of Knick points. The analysis points out south westward tilting of the drainage basins with asymmetry and lineament control on smaller tributaries of the Kayadhu drainage is observed. Overall assessment of morphotectonic analysis revealed that the area is influenced by tectonics.

Keywords: Morphotectonics, Kayadhu river, Geomorphic indices, Neotectonics

1 Introduction

The study area belongs to the eastern part of Deccan Basaltic Province of Maharashtra, India. The tectonics plays a very important role in the evolution of the drainage basin and it reflect on structural, fluvial and morphotectonic features of the basin. Evaluation of neotectonics depends upon the geomorphic indices, which marks on rock resistance, climatic changes and tectonic processes results into landscape evolution. The information about tectonic history of an area can be recovered by quantification of different morphotectonic indices, by using the techniques of remote sensing and GIS in different drainage basins by many workers including (Keller 1986; Krishnamurthy et al. 1996; Singh and Singh 1997; Obi Reddy et al. 2002; Nag and Chakraborty 2003; Narendra and Rao 2006; Pankaj and Kumar 2009; Javed et al. 2009; Babar et al. 2012; Vijith et al. 2015). It provides quantitative analysis of the river basin to understand initial ladders and the basin dynamics. Fluvial systems in the upland areas of the Deccan Trap have been studied by Rajguru and Kale (1985). The microseismicity in Nanded and Parbhani region studied (Babar et al. 2011; Kaplay et al. 2016). Tectonic evolution and neotectonic activity of an area can be studied by analysing the consequences of neotectonic activities over the drainage networks and basins which reflect minor and major changes in terrain morphology (Potter 1978; Salvany 2004; Garrote et al. 2008; Kothyari and Rastogi 2013; Ambili and Narayana 2014). Geomorphic indices are useful tools in evaluating tectonic activity in the area. Tectonic activities play a very important role in the morphological development of drainage basin and well reflected by structural, fluvial and morphotectonic parameters. The south eastern part of the Hingoli district of Deccan volcanic province has been experiencing micro- earthquake activity since 2016, approximately at a junction of Sirli Ghat Lineament and Wapti Lineament. In the present study the remote sensing and GIS approach have been used to enlighten the morphotectonics of a Kayadhu river basin.

2 Geology of the area

Geologically the river basin comprises simple (aa type) and compound (pahoehoe type) basalt flows (Fig. 7) of nearly horizontal lava formations. These flows have been formed due to fissured type of lava eruption during late Cretaceous to early Eocene period (Muley et al. 2012). These basalt flows belonging to the Ajanta Formation, that are stratigraphic equivalent of upper Ratangad Formation of the Wai sub-group of west Maharashtra comprising compound flows (Godbole et al. 1996; Kaplay et al. 2016;).

Simple basalt flows are thick and extensive. The general characteristics of these flows are observed based on its variation from top to the bottom and degree of compaction and jointing pattern. The top surface of the basalt flows is rather undulating or weathered up to some thickness due to hydrothermal alteration, purple or greyish coloured and vesicular in nature. The middle and lower portions of the flows are free from vesicles and amygdules and they occurs as thick and compact. Joints, which are contractions cracks, developed during cooling and solidification of lava always occurs in the middle and lower portion of the flow (Muley et al. 2010). The red bole bed or Tachylitic bands or paleo sole or marker bed occurs between consecutive flows (Babar et al. 2010).

The outpouring of low viscous lava through a large number of outlets result in to the compound flows (Bondre et al. 2000; Bondre et al. 2004; Duraiswami et al. 2003; Duraiswami et al. 2008). These lava flows are large, irregular and having a huge lateral extent (Duraiswami et al. 2002; Duraiswami et al. 2008). The flows are marked by the presence of vesicles and amygdules. The vesicles are filled with secondary minerals like Zeolites, calcite, silica chlorophaeite etc to form the amygdules (Babar et al. 2010).

3 Study area

The Kayadhu river is a tributary of the Penganga river originates from Angarwadi village south west part of the Washim district in Ajanta hill ranges (at an elevation 580 m), and flowing over the Deccan traps. The river flows from NW- SE direction and confluences to Penganga river near Chincholi Sangam village in Nanded district. The basin is confined between N19^{o}22”, E77^{o}40” in the south east and N 20^{o}00”, E76^{o}40” North west (Fig. 1). The river having maximum flow length is 143.58 km and total area of 2158.38 km^2. The maximum and minimum elevations are 605 and 390 m above mean sea level. The Kayadhu river is of seventh order with a dominant dendritic drainage pattern. The basin is located in low seismic intensity zone, the study area had microseismicity in last two years, some of them ≤3 with epicentre falling inside the river basin (Table 1).

Table 1 Details of micro seismic events (IMD 2017; 2018; 2020)

Sr. No.	YYYYMMDD	HHMMSS	Latitude	Longitude	Depth	Magnitude
1	20181104	185214	19.6 N	76.9E	15	2.5
2	20180913	034902	19.7 N	76.9E	10	2.5
3	20170816	063523	19.5 N	77.2E	10	3.0
4	20200602	070900	19.5 N	77.1E	10	3.4

4 Methodology

For the present study the analysis is based on the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Digital Elevation Model (DEM), derived from ASTER data collected from the website of

Global Digital Elevation Model (GDEM). Along with the DEM, the satellite data collected from Indian Remote Sensing (IRS P6) LISS IV was also used to delineate and map the active channels and floodplain features. The digital data from IRS- P6 LISS -IV (70 km X 70 km) collected in 2016 in FCC format with high resolution (Fig. 2) and SOI toposheet map Nos. 56A/9, 56A/13, 56A/14, 56E/1, 56E/2, 56E/3, 56E/5, 56E/6, 56E/7, 56E/10, 56E/11 were used to meet the requirement of area under study. Digital satellite data were geometrically rectified and georeferenced by using Arc GIS 10.3 software for the preparation of various maps, landforms and processes of basin information is extracted from the satellite imagery, survey of India toposheet maps and extensive field visits are carried out.

Table 2 Formulae and References for morphotectonic parameters

Parameters	Formulae and References
Elongation Ratio	$Re=2\sqrt{Ff/\pi}$, (Schumm 1956)
Drainage basin asymmetry (AF)	AF=100(Ar/At), (Hare and Gardner 1985)
Transverse topographic symmetry (T)	T=Da/Dd, (Cox et al. 2001)
Hypsometric Analysis	HI= (elevation mean- elevation minimum)/ (elevation maximum-elevation minimum) Keller and Pinter 1996
Longitudinal Profile	(Schumm 1986)
Stream length gradient (SL) index	$SL=(\Delta H/\Delta L)L$ (Hack 1973)

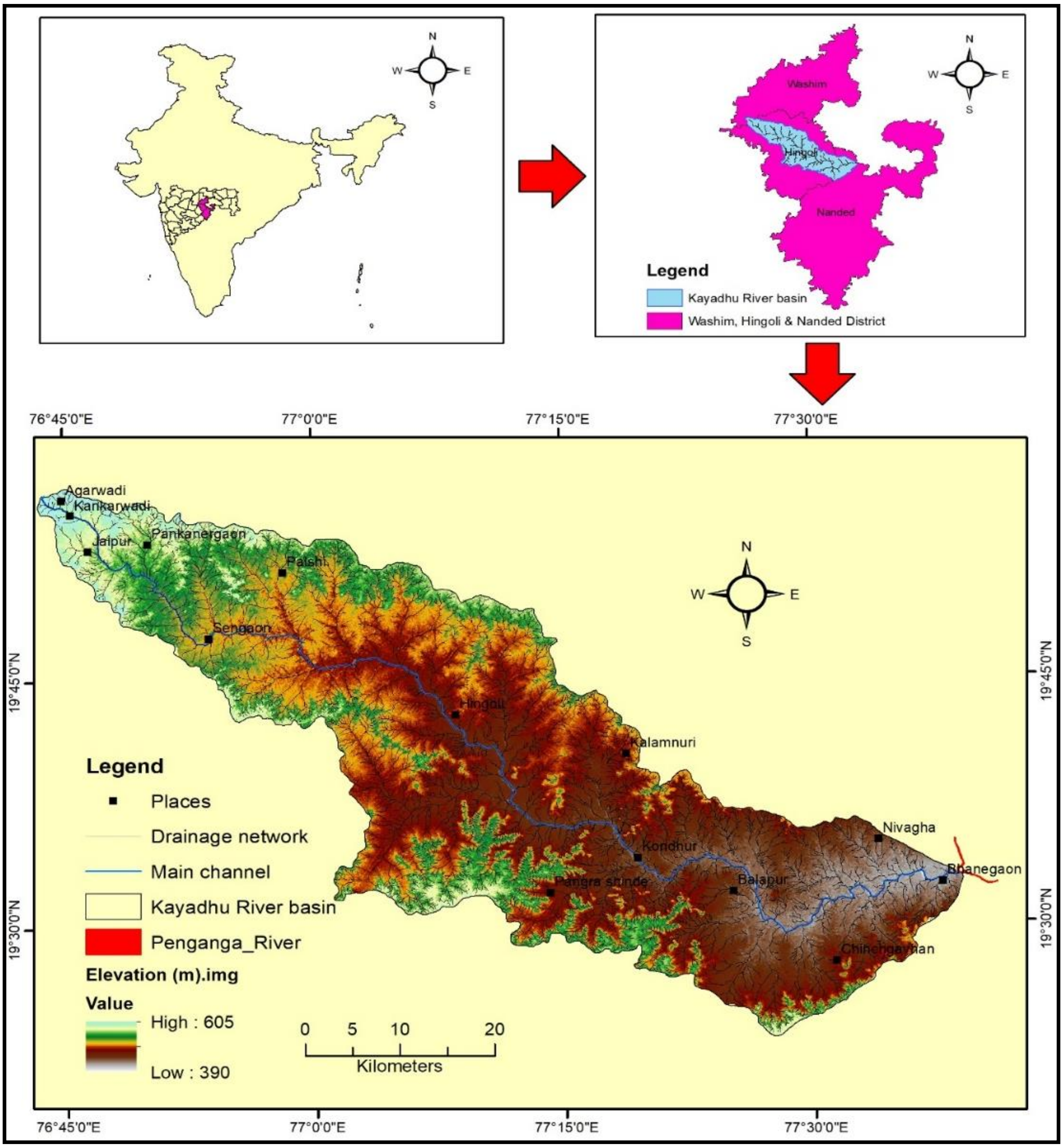

Fig. 1 Location map of study area**.**

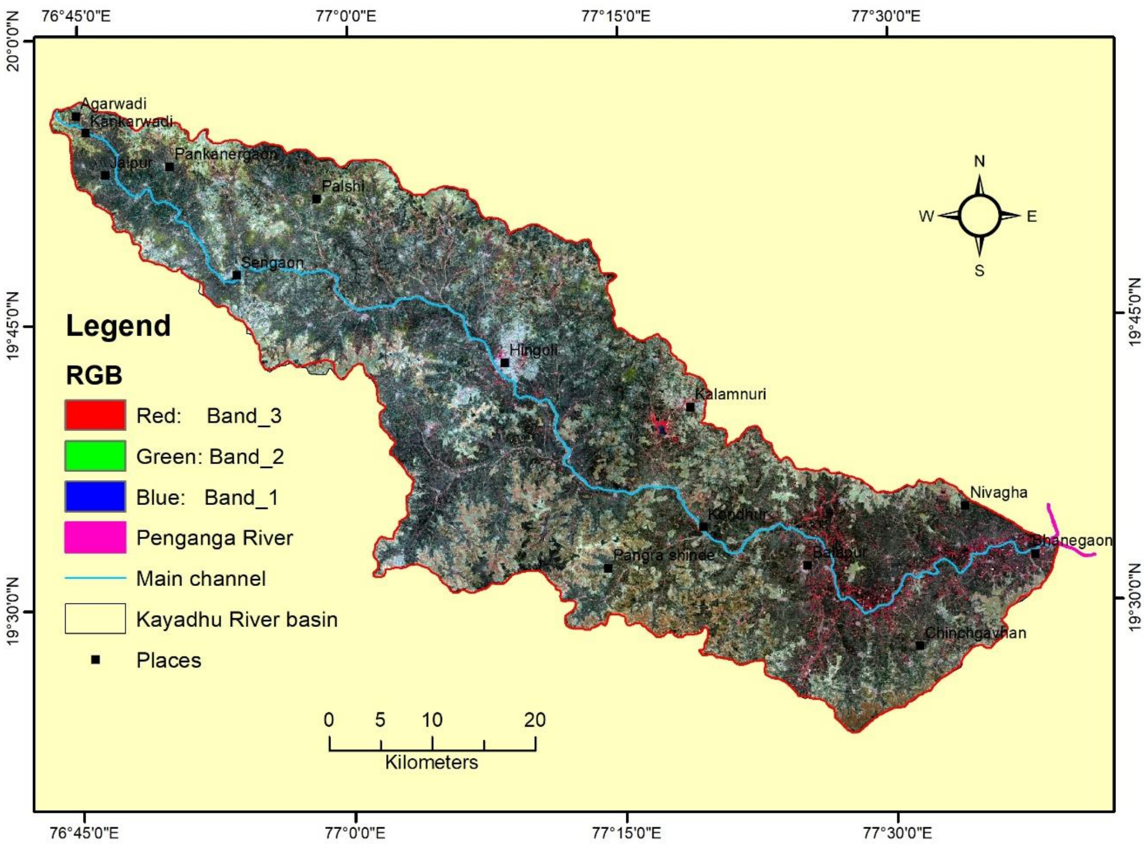

Fig. 2 LISS IV (FCC) image of Kayadhu river basin

5 Results and Discussion

5.1 Elongation ratio (Re)

According to Schumm (1956) elongation ratio Re, is the ratio of diameter of a circle of the same area as the basin to the maximum basin length Table 2. The ratio ranges between 0.60 and 1.0 over a wide diversity of climate and geology. The varying slopes of the basin can be classified with the help of elongation ratio, i.e. circular (0.9-1.0), oval (0.8-0.9), less elongated (0.7-0.8), elongated (0.5-0.7) and more elongated >0.5 (Kale and Shejwalkar 2008). The elongation ratio of Kayadhu river is 0.48, which represents that the basin is more elongated in shape with low relief.

5.2 Drainage basin asymmetry (Af)

Drainage basin asymmetry, used to evaluate local and regional scale tectonic tilting produced asymmetry of the drainage networks and the basin, corresponds to the orientation of the basin axis (Hare and Gardner 1985; Cox 1994; Keller and Pinter 2002; Garrote et al. 2008; Giaconia et al. 2012; Özkaymak and Sözbilir 2012; Vijith et al. 2015). The asymmetry factor can be represented as the percent of the area of the basin that is found on the right bank side of the main stream (while looking downstream) to the whole area of the basin and is defined as:

$$AF=100(Ar/At) \qquad (I)$$

Table 3 Topographic transverse symmetric (T) factor calculated for the selected segments in the main stream

Segments	1	2	3	4	5	6	7	8
T	0.267	0.157	0.363	0.170	0.148	0.348	0.667	0.395
Direction of Shift	WNW	WNW	ENE	ENE	NE	WSW	WSW	WSW

Where Ar is the area of the basin to the right of the trunk stream and At is the total area of the drainage basin (Hare and Gardner 1985). This index identifies tectonic tilting of a drainage basin and characterizes its asymmetry or symmetry, as it is sensitive to rotations normal to the axis of main stream (Tsodoulos et al. 2008; Özkaymak and Sözbilir 2012). Under stable settings of a drainage network formation, the index will be equal to 50%, AF close to 50% shows little or no tilting perpendicular to the direction of the trunk channel. AF, which is significantly above or below 50%, results from drainage basin tilting (tilting left downstream for >50% and tilting right downstream for <50%), either due to active tectonics or lithologic control. The asymmetry factor has been calculated for Kayadhu river is found to be 47 indicating a slightly asymmetrical basin (Fig. 3).

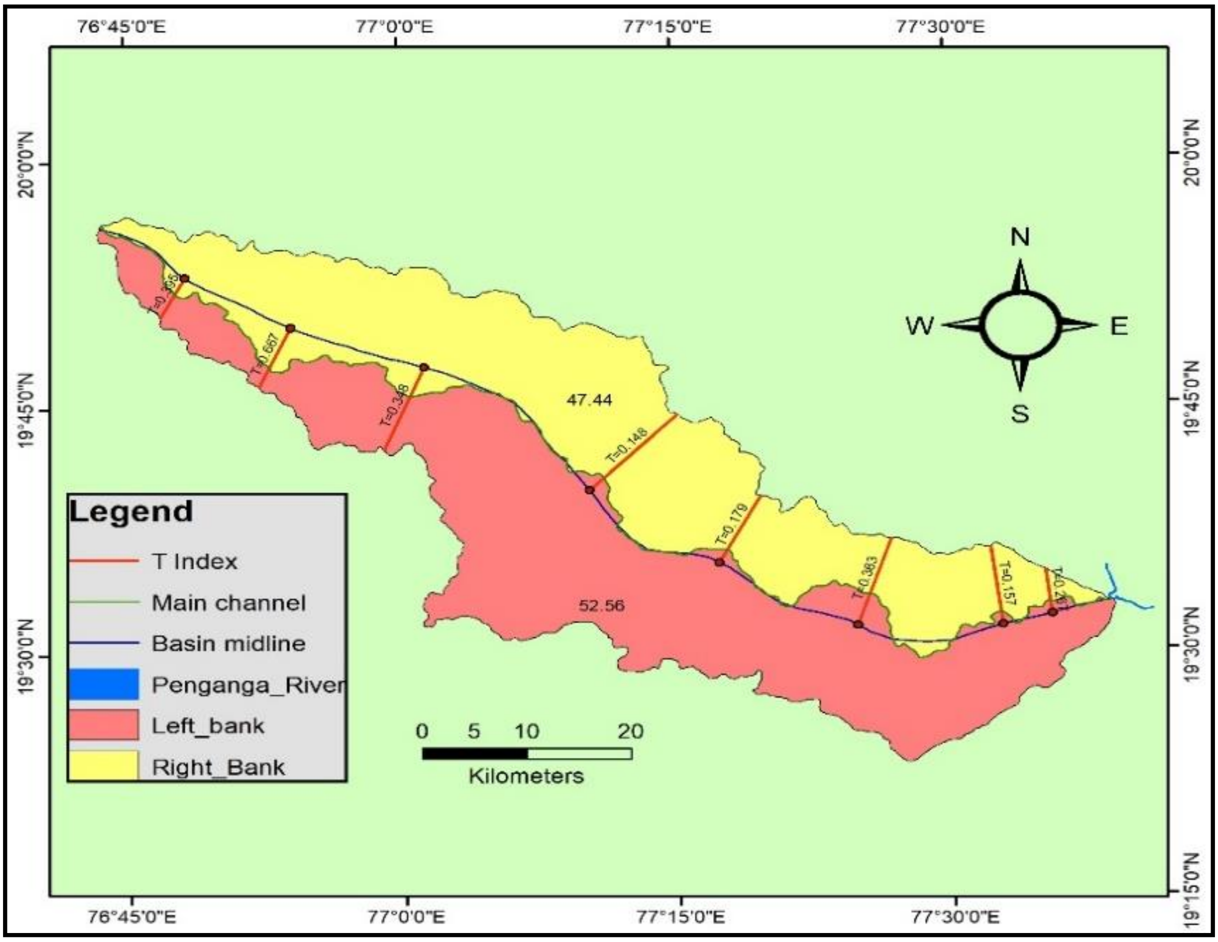

Fig. 3 Map showing transverse tographic symmetric factor (T) and drainage basin asymmetry (Af)

5.3 Transverse topographic symmetry factor (T)

The transverse topographic symmetry factor is used to determine possible lateral tilting and preferred stream migration in the basin (Cox et al. 2001). This index is used to provide important asymmetry information in larger drainage system and rapid uplift in the regions. The basin midline would be the location of a river that is symmetrically placed with respect to the basin divide. It also indicates the migration of the drainage system perpendicular to the principal axis of the basin due to internal fluvial processes or external forces (Keller and Pinter 2002; Salvany 2004). The T factor Table 2 can be calculated by using equation:

$T=Da/Dd$ (II)

Where, Da is distance from midline of the drainage basin to the midline of the active meander belt. Dd is the distance from the basin midline to basin divide. In general, the T values ranges from 0 to 1 and T values close to 0 signifying symmetrical basin and stream is in the middle of the drainage basin, while values close to 1 indicate highly asymmetric basin and stream migrates laterally away from the centre of the basin margin. The T index Table 2 for the Kayadhu river (Fig. 3) shows strong asymmetry (average is 0.315). From the values of T index (Table 3), we can interpret the cause of asymmetry depends on tectonic disturbances or neotectonic structural features.

5.4 Stream length gradient Index (SL)

It is one of the most important index in order to know whether the area is tectonically or lithological controlled. This parameter is measured by using digital elevation map as well as contour map of the area and measuring the length of the river. By means of SL index we can quantify the characteristics of stream gradient behaviour and its relationship with physiographical conditions, lithological control, topography and associated drainage parameters (Hack 1973; Cox 1994; Keller and Pinter 2002; Dehbozorgi et al. 2010; Giaconia et al. 2012; Vijith et al. 2015). The stream length- gradient index was first defined by Hack (1973) and computed by equation:

$$SL=(\Delta H/\Delta L)L \qquad \text{(III)}$$

Where $\Delta H/\Delta L$ is the local slope of the channel segment being evaluated and L is the channel length from the divide to the midpoint of the channel reach for which index is calculated. The stream length-gradient index can be used to evaluate relative tectonic activity. The SL index is used to infer stream power and rock erodibility owing to its sensitivity to the disequilibrium state of channels due to tectonic and climatic perturbation in the channel slope (Keller and Pinter 2002). The SL index, Table 2 calculated for 34 segments along the total length of the river, varies from 6 to 86 m (Fig. 4). A sudden increase in the SL index values indicates differential uplift of the region due to the neotectonic activity. The study is made in order to generate a comprehensive data about the variation and pattern of neotectonic influence in the Kayadhu river basin.

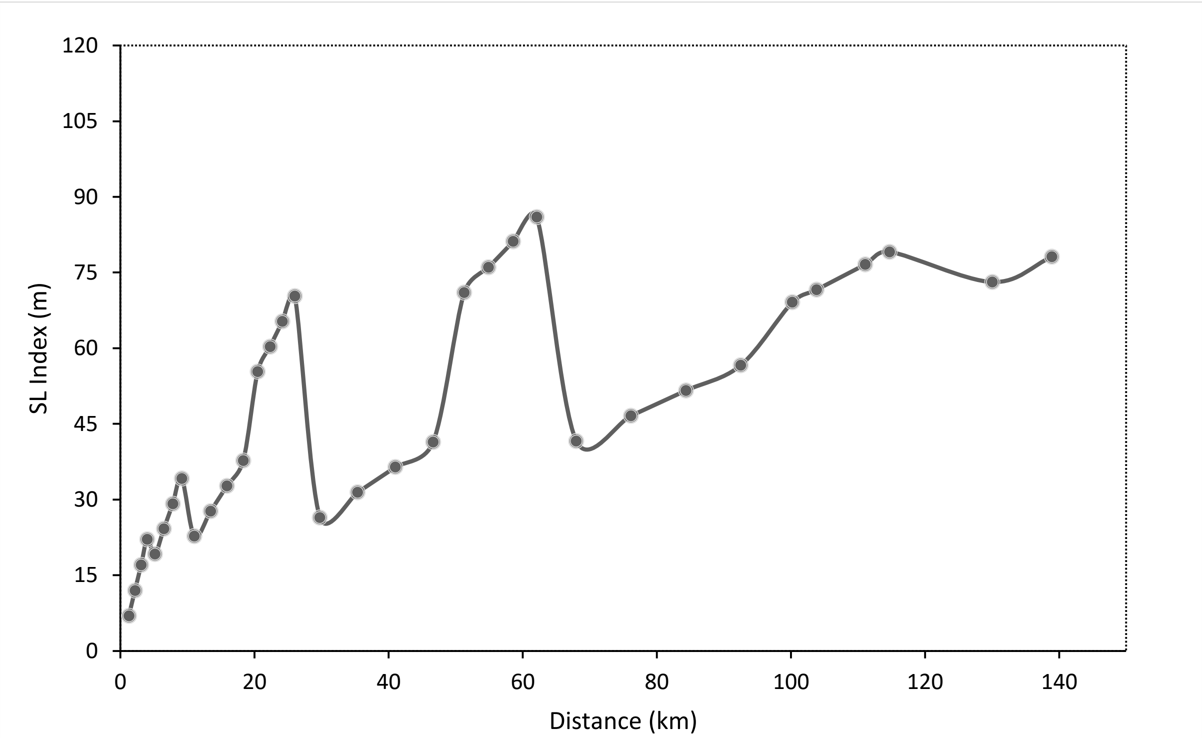

Fig. 4 SL index of the Kayadhu river

5.5 Longitudinal Profile

Longitudinal profile of a river is an important geomorphic tool it provides clues to interpret the geometry of geotectonic disturbances and geomorphic evolution as well as underlying material of the area (Schumm 1986; Schumm 1993; Jain et al. 2006; Ambili and Narayana 2014; Vijith et al. 2015; Kumar et al. 2018). Longitudinal profile is a plot of river distance against elevation. It represents channel gradient of the river origin to its mouth and based on the shape of the curves it can be interpreted (Ferraris et al. 2012). The concave nature of profile represents long term equilibrium between uplift and erosion rates i.e. progressive increase in river discharge in the downstream direction (Bull and Knuepfer 1987), while convex profile indicates the upliftment is dominant in the areas. The irregularity in the profile is a result of neotectonic and tributary confluences (Schumm 1986). The longitudinal profile plot indicates a number of knick points (Fig. 5) caused by change in lithology (hard or soft) or by structural disturbances in the area therefore stream is trying to adjust with terrain characteristics (Crosby and Whipple 2006).

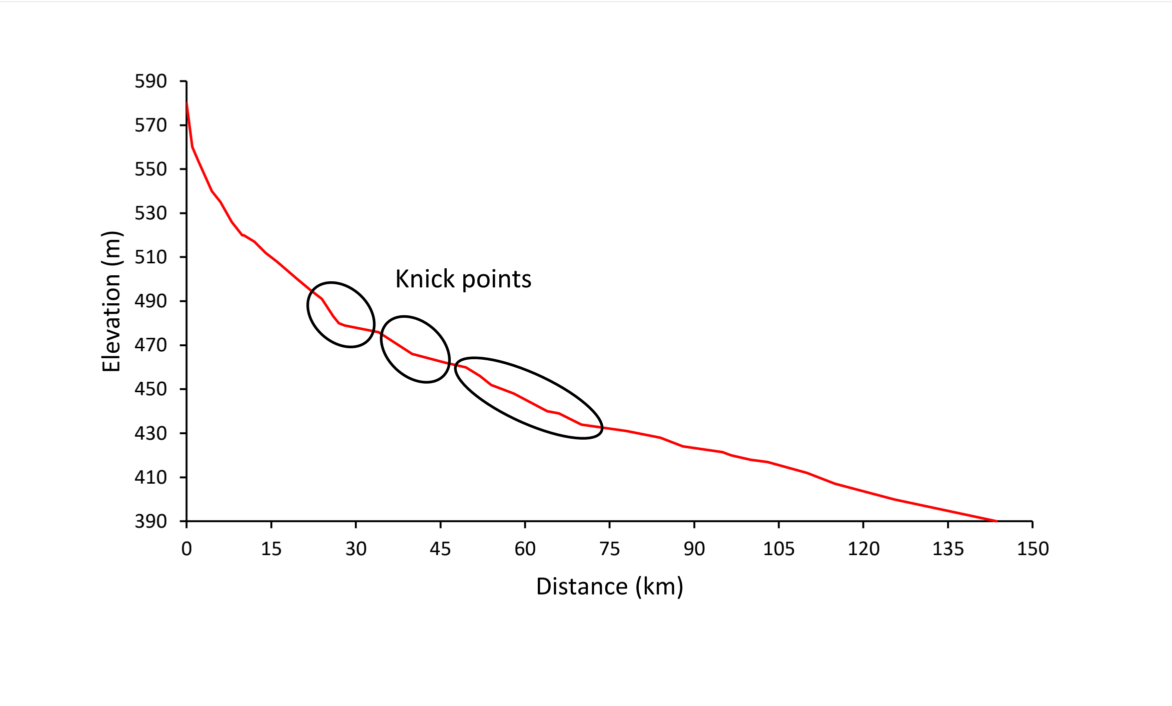

Fig. 5 Longitudinal profile of the Kayadhu river showing knick points

5.6 Hypsometric analysis

The hypsometric analysis provides distribution of elevation in a given area of a basin and gives an idea to evaluate the geomorphic form of catchment and landforms (Strahler 1952; Dowling et al. 1998; Singh et al. 2008; Vijith et al. 2015). The hypsometric curve is related to the volume of rock in the basin that has not been eroded (Awasthi et al. 2002; Crosby and Whipple 2006). Hypsometric curves convex upward are interpreted as youthful, S shaped curves as mature and concave upwards are old age stages of landscape evolution. In the present study percentage hypsometric integral method used (Fig. 6) by computing two ratios from contour map measurements Table 2. The first one a/A, where a is the area enclosed between a given contour within basin and basin boundary of the basin, and A is total area of the basin. The second ratio (Keller and Pinter 2002) is h/H , where h is the height of the contour above the base level of the stream mouth and H is the total height of the basin from basin mouth. To characterise the hypsometric curve the HI can be calculated as HI= (elevation mean- elevation minimum)/ (elevation maximum-elevation minimum). High values of HI generally mean that the upper part of the basin have not been eroded much and indicate a younger landscape (Vijith et al. 2015).

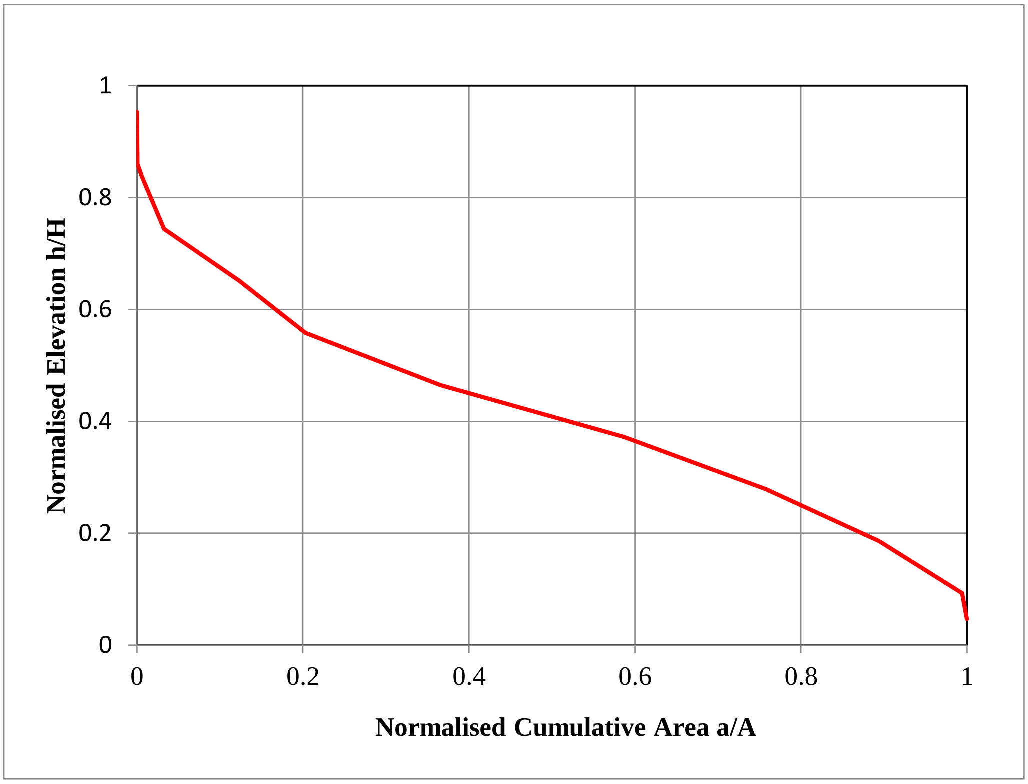

Fig. 6 Hypsometric curves with integrals for Kayadhu river basin

5.7 Lineaments and microseismicity

Lineaments are defined as mappable linear to slightly curvilinear subsurface features, which are differ distinctly from the adjacent feature and pattern, reflect subsurface information (O' Leary et al.1976). The structural features usually related with joints, faults and lineaments may produce essentially straight rivers with minimum meandering (Twidale 2004) Orientation and extent of individual linear structure was calculated in Arc GIS 10.3 software. The orientation of various linear elements observed on the basis of ASTER, IRS P6 LISS -IV 2016 satellite data and further validated by field studies (Cantamore, et al. 1996), the preferred stream orientations are used to reconstruct neotectonics through anomalous behaviour of the streams. Lineaments are important components of the earth surface morphology and the lineament density is related to the intensity of deformation (Nur 1982). It is interesting to note that the maximum lineament frequency is found in the central part of the basin and the length of lineaments varies from 3 to 19 km (Fig. 7). Most of the drainage of the Kayadhu river follow the NW-SE and SW-NE trend. The deformation is not observed along the lineaments, these are covered by black cotton soil therefore detailed geophysical surveys along these lineaments are essential.

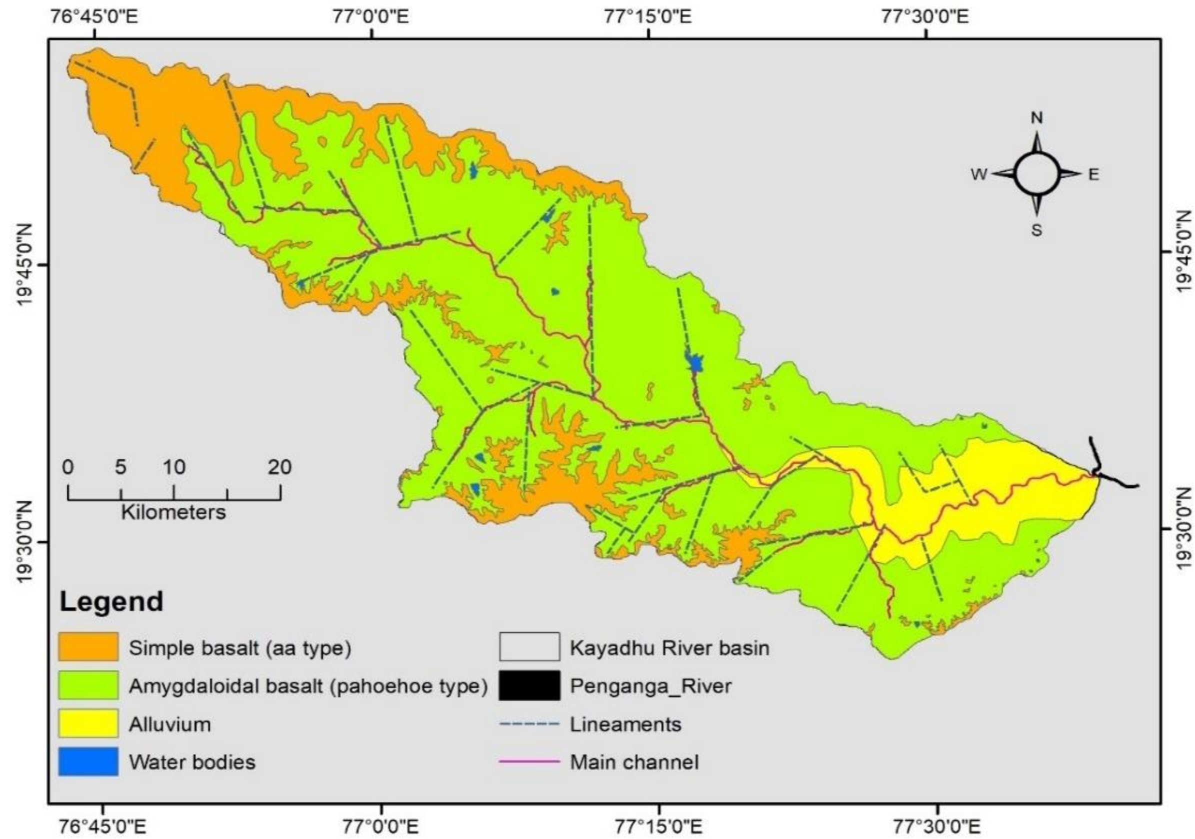

Fig. 7 Lineament and Geological map of study area

6 Conclusion

The morphotectonics of the Kayadhu river basin, Maharashtra, India, was studied through the various geomorphic indices, using Arc GIS10.3 software with 30m resolution ASTER GDEM and LISS IV, IRS FCC data. Transverse topographic symmetry (T) calculated from transverse topographic profiles of 143.58 km drainage basin segments. Northern half part of the river migrates towards WSW and southern half part migrate towards South east, thus it implicates ground tilting as the driving mechanism of preferred migration. Longitudinal profile of the river indicates a number of knick points at a steep reaches in the profile caused by structural disturbance (uplift or lineaments), therefore these disturbances caused due to tectonic activities in the region over the development of river, which might have reflected as change in the gradient of along the longitudinal profile of Kayadhu river. The asymmetric integral value for the right bank of the basin (Fig. 3). The absolute difference is 2.56 indicate that the basin has slight influence tectonic activity. The calculated hypsometric integral for the Kayadhu river is 0.31 shows basin is under the mature stage of erosional development. The lineament ranges from 03 to 19 km long and show a dominant NW-SE and NE-SE trend, consisting with geological structure, and hence there is possibility of recent crustal movement in this area. The whole analysis of the basin indicates, the path of the river is tectonically influenced at some location, but most part of the basin not experienced any major disturbances.

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