Government Of Kerala

Haritha Keralam Mission

POST FLOOD PAMPA RIVER MORPHOLOGY AND THE GROUNDWATER SCENARIO OF THE SELECTED WATERSHEDS

Prepared By

Kerala State Remote Sensing And Environment Centre (KSREC)

JUNE 2020

POST FLOOD PAMPA RIVER MORPHOLOGY AND THE GROUNDWATER SCENARIO OF THE SELECTED WATERSHEDS
Study Report
Submitted to Government of Kerala
by Haritha Keralam Mission

Prepared By

Kerala State Remote Sensing and Environment Centre(KSREC)
Department of Planning and Economic Affairs
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PREFACE

Kerala experienced devastating floods resulting in unprecedented disaster during the year 2018. The situation also witnessed unparalleled and successful rescue operation with peoples' participation. State machinery mobilized all resources to contain the situation. Kerala has a well-knit stream network for its rivers. Fury of the flood waters resulted in meandering of streams and heavy silt deposits at several places. Immediately after the floods, water level in several wells near the rivers receded to a lower level. Farmers complained that fine sand particles associated with the silt deposit has damaged crops and sounded their apprehension in resuming normal farming activity.

Harithakeralam Mission works with the local bodies in ensuring additional technical support through convergence of different Government Departments/agencies in the water sector. Mission decided to commission a pilot study on the impact of floods in Pamba River, focusing on the river morphology and characteristics of the silt deposits, especially its impact on agriculture. Kerala State Remote Sensing and Environment Centre (KSREC) was entrusted with the study. It is scientific to consider the topography of the area traversed by a river in any study. Here, we have taken representative stretches in highland, midland and lowland of the river stretches for the study.

Kerala Soil Conservation and Soil survey Department did the analysis of soil samples and Gramina Padana Kendram, Karakulam conducted the profile study. 3D mapping of the Terrain by Drone mapping was done by MIT, Anna University. Ground Water Department supplied the data on Ground water in the study area. Study results were shared with experts in connected fields and their opinion taken on finalizing the inference.

We had expected to complete the study in three months time. However, unfavorable climate conditions delayed collection of field data and analysis of several parameters took more than estimated time. We would like to thank all the associated agencies and scientists for their valuable support and guidance.

Dr. T.N. Seema
Executive Vice Chairperson
Haritha Keralam Mission

FOREWORD

In the background of the flood events of 2018 and 2019 and the possibility of the further floods on the anvil, a study which can identify the response of the ecosystem of the flooded area is the need of the hour in a State like Kerala.

The project report, Post Flood Pampa River Morphology and the Groundwater Scenario of the Selected Watersheds includes information on the post flood morphology changes of the river segments, land use dynamics of the flooded area and surroundings, the soil and the groundwater dynamics in the surrounding watersheds of the flooded area. Along with other components of the study, the Drone based very high resolution remote sensing has provided useful information for benchmarking the wet land area. The report has also brought out logical conclusions and implementable recommendations.

In view of the National Green Tribunal (NGT) directions towards protecting wetlands and also the drastic response of Kerala terrain to monsoons, the need for benchmarking of the wetlands has gained utmost importance. Kerala should take a co-ordinated effort for benchmarking all the rivers and water bodies with the help of drone based very high resolution surveys integrating with cadastral information for protecting the wet lands from future depletion.

KSREC is thankful to Haritha Keralam Mission (HKM) for providing an opportunity to associate in the project, constant encouragement and support for the preparation of this report

I hope this report will be useful for various agencies involved in the field of natural resources management.

Sri. Nizamudeen A.
Director
Kerala State Remote Sensing and
Environment Centre (KSREC)
Vikas Bhavan, Thiruvananthapuram-33

ACKNOWLEDGEMENT

This work is the result of a collaborative effort by many departments/ institutes/ agencies carried out by KSREC. KSREC expresses our gratitude and feel of warmth for all who had been part of this project.

Haritha Keralam Mission, under the inspiring leadership of Smt. T.N. Seema, Ex. Vice Chairperson, along with KSREC, found the need for the study as the requirement, Kerala should address. Thus came forward to fund the project and also to coordinate the departments for KSREC to implement. Smt. T.N.Seema's far sightedness and keen interest towards the work, spells out in volumes, about her commitment towards the wellbeing of the society. Sri. Abraham Koshi, Consultant, Water Resources, requires special mention as he had been in charge for streamlining and coordinating the project from Haritha Keralam Mission. Sri. R.V. Satheesh, Technical Assistant, Water Resource also had a commendable roll in project coordination.

Kerala State Remote Sensing and Environment Centre (KSREC) under the able leadership of Sri. Nizamudeen A., Director, worked in tandem with Haritha Keralam Mission for the successful completion of the work. He was the driving force and his constant encouragement towards the completion of the work had been inspirational. Ex Director, KSREC, Sri. Reghunathan Menon K.P. also requires accolades for his enthusiasm, involvement and encouragement in the initiation and for taking ahead the project to meaningful stage before his departure. The project staff of KSREC had placed their utmost efforts for the successful completion and earns special congratulation from team KSREC.

Soil Survey Department under the gracious leadership of Smt. Ambika S., Director i/c, had been working off the routine for the soil survey and quality analysis of the project. The Pathanamthitta District Soil Survey officer Smt. Srreekala N.V. and her team were working with out of the box ideas for completing the survey. Similarly the staff in the Soil testing labs also requires special mention for their efforts.

Madras Institute of Technology (MIT), Anna University, Chennai had been on the dot in completing the Drone based Remote Sensing assigned to them. They under the charismatic leadership of Dr. Thamarai Selvi, Professor, and Sri. Hari, Consultant had completed the survey and the products delivered with dedication and sinciere efforts.

Grameena Padana Kendram, Thiruvananthapuram under the empowering leadership of Sri. V.N. Jithendran IAS (Retd.), Chairman had undertaken the river profiling part of the study. Sri.V.Sreekandan, Executive Coordinator had been the focal point and requires specific mention for his efforts along with his project team.

Groundwater Department under the decisive leadership of Smt. Joshi Mrunmai Shashank IAS, had supplied the groundwater data of the monitoring wells in and around the study area. The effort of the Hydrogeology team in supplying the same in time needs special mention.

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CHAPTER 1

INTRODUCTION

Kerala with its fast pace horizontal model of urbanization has developed structures beyond the carrying capacity of the urbanized locations and had extended the growth to the wetlands and paddy lands of the State. This has impacted the surface and groundwater dynamics thereof recharge and runoff. The depleted recharge and increased runoff resulted in the seasonal drought even after 3000 mm of annual rainfall. On the other hand the paddy lands which were the temporary reservoirs at the time of excess rainfall are now filled up and have structures which resulted in water entering buildings/structures during floods.

Kerala has a good socio-economic status, as the state has got rich cultural heritage and progressive social development even comparable to developed countries. The developmental history of Kerala has received global attention, as the state was able to achieve developmental goals comparable to its economic growth with moderately low per capita income and low investment. In recent years, socio-economic development in the state explains its qualitative changes in the structure and framework of society that help to better know its objectives and responsibilities. Kerala had experienced a low level of urbanization till 2001 showed a rapid increase in its urban share in 2011, which is about 48 % in a decade, and has the highest growth rate of urban population, comparing to the major states of India.

As part of urban development, several infrastructure facilities have to be developed, along with adequate backup area and other land resources have been acquired in the vicinity of the development areas. As part of infrastructure development, numerous benefits such as development of new and advanced transportation facilities were implemented. Most of these benefits impact environment, such as development of road-rail connectivity may result in land and sea-side environmental changes through increased traffic and development. Therefore, adequate environmental mitigation and management measures are essential in the State. Diverse concerns have been expressed about the environmental effects of road network, and such effects can be local or extensive, which include spatial and temporal dimensions and biotic and abiotic components. Roads that intersect drainage basins generally modify the natural flow of surface water by concentrating flows at certain points and in many cases, increasing the speed of flow. Road drainage and excavation can contribute to flooding and soil erosion, and also lower the water table in surrounding areas. Quality degradation of surface water and groundwater, sedimentation, changes in biological activity in streams and on their banks, uncontrolled construction activities, and spills of chemicals and pollutants can all have adverse effects on roadside water quality.

A Groundwater system is of foremost importance in which it provides essential water supply, and is intensively exploited for private, domestic, and industrial use in many urban centers of the developing world. There are significant impacts on groundwater systems by the development of urban areas, and these impacts can have important values for human activities and the environment.

Soil is the other important natural resource which supports productivity of any region. The knowledge of the impact of floods on the soil characteristics is highly essential to maintain sustainable ecosystem balance. Soil erosion due to excessive runoff and silt deposition during floods will result in the change of qualitative and quantitative characteristics of the soil.

Morphology studies of any wetland system are essential to identify the impact of flood or the impact of similar human life disruptors. The environmental imbalance caused by the human interventions will surely have its marks embedded in the morphologic features of the earth.

Nowadays, applications of Geospatial Technology, which comprise Remote Sensing, Geographical Information System (GIS) and Global Positioning System (GPS) has a vital role, as it is used as an effective tool for planning and better decision making. GIS can integrate and relate any data with a spatial component regardless of the source of data. Researchers and managers can view information from new and varying perspectives using GIS and Remote Sensing, and GPS receivers allow the researcher to identify the exact location of interest. GIS had got more attention among groundwater assessment and in geotechnical studies. The spatial technology can be combined with ground-water quality and flow models in order to identify and rank the areas susceptible to effluence potential for different scenarios and land use practices. Various GIS software's also proved its significant role in geotechnical engineering aspects which includes preliminary site investigations, identification of potential project barriers, interpolation for obtaining data at inaccessible locations, data visualization, data processing etc.

1.2. Importance of the study

On 16 August 2018, severe floods affected Kerala, due to unusually high rainfall during the monsoon season.It was the worst flood in Kerala in nearly a century.Over 483 people died, and 140 are missing.About a million people were evacuated, mainly from Chengannur,Pandanad,Edanad, Aranmula, Kozhencherry, Ayiroor, Ranni, Pandalam, Kuttanad, Malappuram, Aluva, Chalakudy, Thrissur, Thiruvalla, Eraviperoor, Vallamkulam, North Paravur, Chellanam, Vypin Island and Palakkad. All 14 districts of the state were placed on red alert and around one-sixth of the total population of Kerala had been directly affected by the floods and related incidents.The Indian government had declared it a Level 3 Calamity or "calamity of a severe nature".It is the worst flood in Kerala after the great flood of 99 that took place in 1924.

The impact of flood increased due to the rapid urbanization and spread of settlements in the valley fills. The urbanization and the problems aroused are intractable to conventional, single sector approaches. Some possible examples are drought, flooding, groundwater overdraft, water borne diseases, land and water degradation, and ongoing damage to ecosystem. The solution to such problems may fall outside of the normal purview of the agencies involved and usually requires cooperation from multiple sectors. In such cases Integrated Resource management approach helps solving problems.

Field evidence suggests that on relatively small timescales (of the order of years or decades) and in the absence of major anthropogenic effects, the average bed profile of rivers may be in quasi equilibrium, ie. the mean elevation of the active bed and a function of the longitudinal coordinate does not experience significant temporal variations. Natural rivers display spatial variations and temporal fluctuations of flow properties and bed topography acting on a variety of scales. Larger-scale fluctuations are associated with variations of the driving forces namely water discharge and sediment flux forced by a variety of possible events: floods, natural seasonal oscillations etc. And hence any notion of morpho-dynamic equilibrium can only approximate and must refer to the cross-sectionally averaged bed elevation (BollaPittaluga et. al. 2014)

Whether groundwater reaches soil surface or not, the evolution of soil structure after flooding mainly depends on the quality of flooding water (salinity, type of sodium salt etc) it is important to determine the origin of flooding water which in about 90% of cases comes from groundwater. Whether the soil will be ponded by fresh or salty water, it will depend on soil profile characteristics(C. Brouwer et. al. 1985).

1.3. Groundwater Scenario of the State

Exploitation of groundwater has increased greatly in the last two to three decades in Kerala, particularly for agricultural purposes, because large parts of the country have little access to surface water sources. Groundwater scenario of the state has been subject to change over the years and has necessitated proper groundwater management. The groundwater potential of Kerala is limited because 88 per cent of the total geographical area of the state is underlain by crystalline rocks devoid of any primary porosity. Rainfall pattern of the state plays an important role on the water levels, as it is the major source of groundwater recharge.

The latest Census shows that 65% of rural and 59% of urban households have wells and the density of wells is higher in the coastal regions. In addition, 50% of irrigation needs are met through groundwater as per the Economic Review 2012. The net groundwater availability of the State is 6229.04 MCM as per the estimation of the Central Groundwater Resource Board. According to Central Groundwater Board, only 48% of the groundwater sources in Kerala have been exploited. Open wells are major as well as the traditional source of drinking water in Kerala; in fact, the whole concept of drinking water is still attached to open wells. The density of open wells is also very high in Kerala, with density around 250 well/Sq.km in the coastal belt; 150 in the midlands and 25 in the highlands. Groundwater is the prominent source for meeting the domestic needs of more than 80 percent of rural and 50% of urban population besides fulfilling the irrigation needs of around 50% of irrigated agriculture. The problems of decline in water table, contamination of groundwater, seawater intrusion etc. are being reported at many places.

Annual Groundwater Recharge from rain fall and other sources during both monsoon season and non-monsoon season is higher in Palakkad and lower in Idukki. The district which receive highest amount of recharge from rainfall during monsoon is Thrissur (418.46 MCM) and lowest is Pathanamthitta (151.41 MCM). Pathanamthitta is the only district with recharge from other sources during monsoon season. Total Annual Groundwater Recharge of Kerala is 6841.33 MCM. Natural discharge during non-monsoon season in Kerala is 611.75 MCM. The district with highest natural discharge during non-monsoon season is Palakkad (73.55). (Source: Dynamic Groundwater Resources of Kerala, Groundwater Department & Central Groundwater Board)

Remote sensing provides important data and tools for groundwater exploration. Remote sensing data provide accurate spatial information and are cost-effective compared with conventional methods ofhydro geological surveys. It is a rapid and cost-effective tool in producing valuable data on geology, geomorphology, lineaments, slope, etc., that helps in interpreting groundwater potential zones, as maps of the same can be extracted from satellite data. A systematic integration of these data with follow up of hydro-geological investigation provides effective delineation of groundwater potential zones.

Pathanamthitta district is situated on the southeastern part of Kerala andextends over an area of 2,65,277 ha. The district lies between 9^{o} 4' and 9^{0} 28' north latitude and 76^{o} 28' and 77^{o} 17' east longitude. Major physiographic divisionsof the district are Lowland, Midland, Mid upland, Upland and Highland. The districtis mainly drained by Pamba,Achenkovil,Manimala, Kallada and Pallikkathodu rivers.

CHAPTER II
STUDY AREA AND METHODS

2.1. Study Area

Pampa River flowing through Pathanamthitta district witnessed an unprecedented flood in the 2018 South West Monsoon. Post the flood, Pampa River morphology has been modified as the river system is a dynamic entity. It flows forked from the Pampa Triveni, where it confluences with the Kakki and the Kullar river. The portion of the river bank that once used is now an island. Pampa River encompasses a basin area of approximately 2235 km^2 spread over four districts of the state viz, Idukki, Pathanamthitta, Kottayam and Alappuzha. The study area identified as per the discussions with Haritha Keralam Mission falls in three stretches of 10km each in the Lowland, Midland and Highland area of Pamba River as shown in figure1.

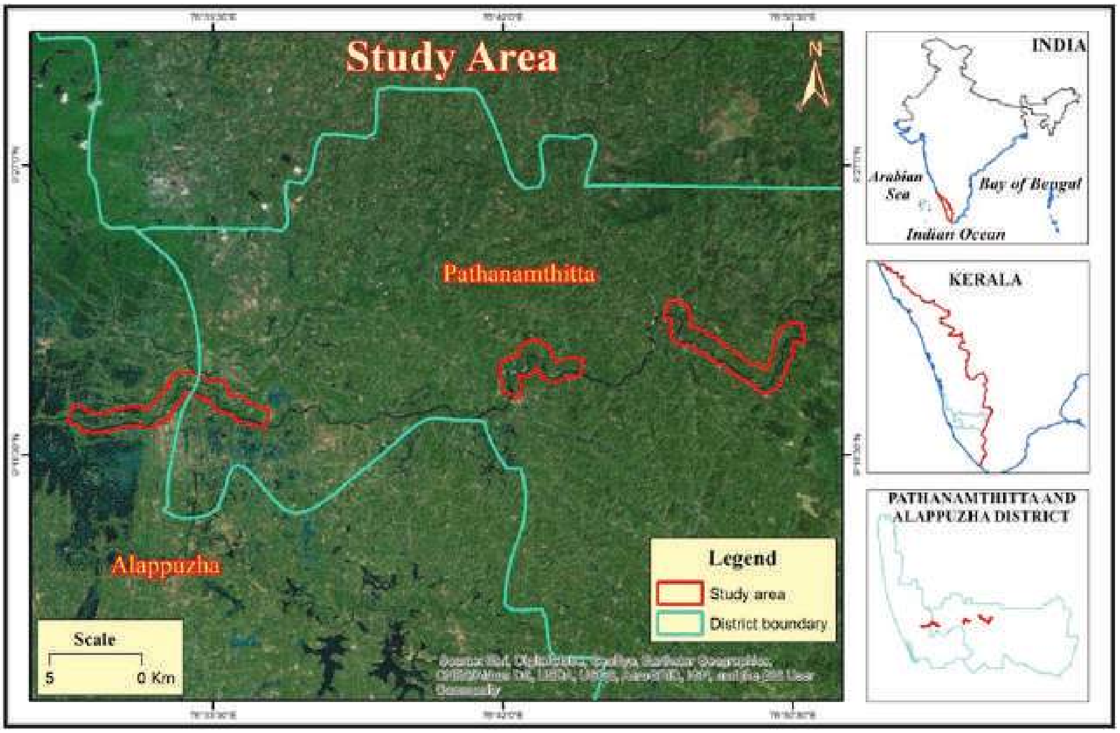


Fig.2.1. Pamba Basin -Study Area

The river profiling study is planned in the three stretches and the Soil sample collection and analysis is envisaged from the Micro-watershed area around the three stretches as shown in the figure 2&3. The study area is geographically located in between 9^o 19' 00.35" N to 9^o 23' 37.22" N and 76^o 29' 10.57" E to 76^o 50'51.46" E.

Fig.2.2. Low land study area

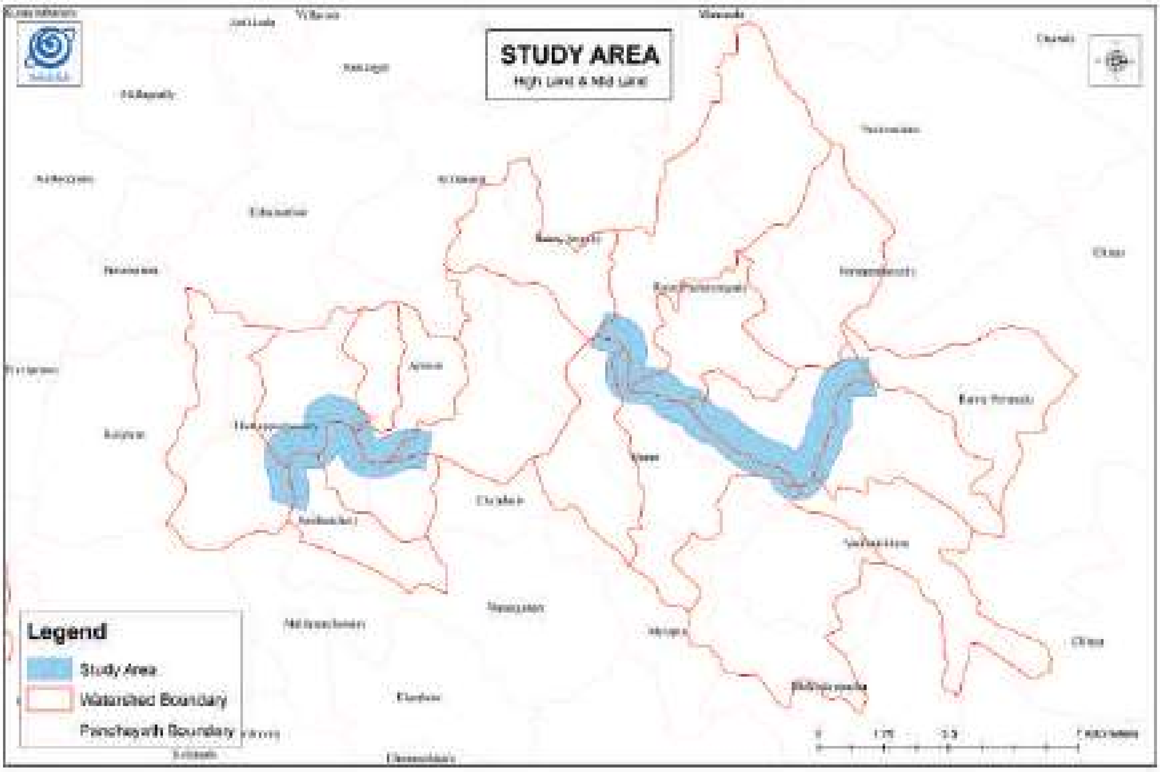


Fig.2.3. Mid land & High land study area

The study area including the watersheds covered falls in the following local self governments as given in Table 1. The lowland is having 8 watersheds with one Municipality and 18 Panchayaths, the midland is having 7 watersheds and 13 panchayaths and the high land is having 11 watersheds and 12 panchayaths.

Low Land	**Mid Land**	**High Land**
No. of Watersheds : 8	No. of Watersheds : 7	No. of Watersheds : 11
Municipality - Chengannur	**Panchayaths**	**Panchayaths**
Panchayaths	1. Kottanadu	1. Chittar
1.Kadapra	2. Ranny Angady	2. Vechoochira
2.Niranam	3. Ezhumattoor	3. Kottanadu
3.Edathua	4. Puramattam	4. Ranny Angady
4.Thalavady	5. Ayiroor	5. Ranni Pazhavangady
5.Thiruvanvandoor	6. Thottappuzhassery	6. Naranammoozhy
6.Pandanadu	7. Koipram	7. Ranny Perunadu
7.Veeyapuram	8. Ranni	8. Ayiroor
8.Mannar	9. Cherukole	9. Ranni
9.Bhudhanoor	10.Kozhanchery	10. Vadaserikkara
10.Mulakkuzha	11. Naranganam	11. Cherukole
11.Puliyoor	12. Aranmula	12. Mylapra
12.Harippad	13. Mallappuzhassery	
13.Chennithala		
14.Thripperunth		
15.Ala		
16.Pallippadu		
17.Cheriyanadu		
18.Chettikulangara		

Table:1.1. Detailed list of Panchayats and Muncipality in the study area

2.2. Rainfall Pattern during the Flood Period

From the rainfall pattern shown in the graph (Fig. 4), it can be inferred that the district received 27% more rainfall than the normal during the southwest monsoon period of 2018. The torrential rains received from 5th August to 25th August aggravated the flood situation in the district. The graph adopted from the Soil Survey report 2018.

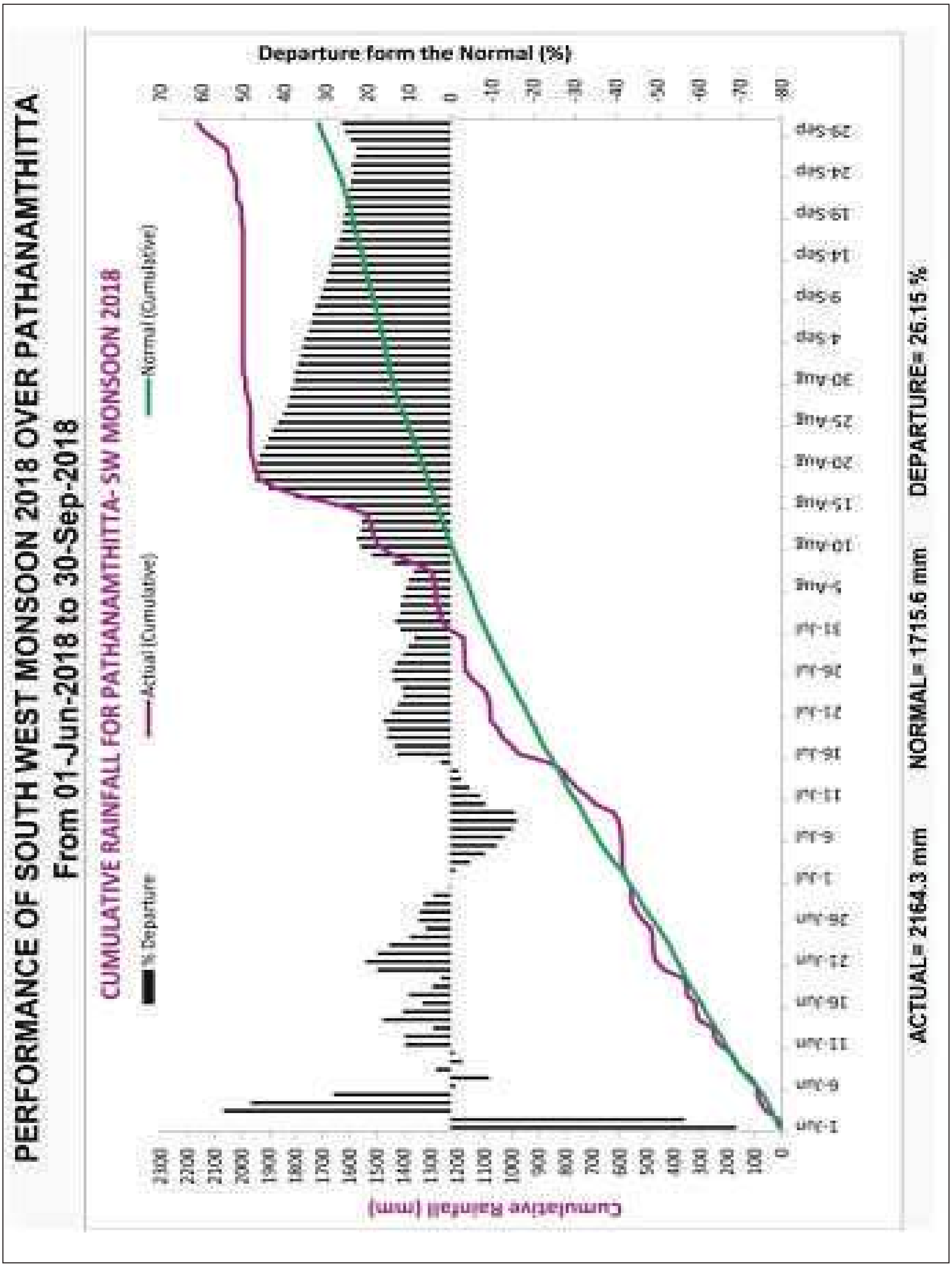


Fig:2.4.Graph showing Performance of South West Monsoon

2.3.Impact of Distress in the District

Pathanamthitta district was severely affected by the flood and landslide which occurred in August, 2018. Out of 53 panchayaths, 18 panchayaths were totally affected and 27 panchayaths were partially affected. The total estimated loss is Rs. 1810/-crores, of which 66.03 crore is in agriculture sector and 16.89 Crore inAnimal Husbandary sector. Three persons were killed in the natural calamity and, 15,519 people had to be evacuated to relief camps.The unprecedented rainfall which occurred in the district 12th to 17th August forced the opening of Kakki, Kochupampa and Anathode dam to let out raging waters of Pampa and Manimalariver which increased the water level up to 15 feet high in Ranni and Vadasserikkara and upto 10 to 13 feet high in Aranmula and Kozhenchery area situated on the banks of Pampa river. Water stagnation continued for 5-6 days inthe entire flooded area with thick deposition of silt in Aranmula and villages of Thiruvalla Taluk. Deposition of sand up to 6-8 feet was observed along PampaRiver bank in RanniTaluk.Theworst affected area's in the district are Ranni, Vadasserikkara, Ranni, Angadi, Pazhavangadi,Ayroor,Thottappuzhassery,Cherukole, Kozhenchery, Mallappuzhassery and Aranmulapanchayath along the Pampa river Bank and Kadapra,Niranam, Peringara, Nedumpuram and Thiruvalla.

Muncipality area in Thiruvalla taluk which are drained by both Pamba and Manimala River,Vallikkode and Pramadam panchayaths and Pandalam Municipality were severely affected as Achankovil river overflowed due to heavy rainfall as wellas heavy water flow as a consequence of landslides.The district also experienced severe landslide in Chittar Panchayath in Meenmutty and Valiyakulangara area due to heavy rain persisting for 4-5 days resulting in loss of human life as well as Agricultural crops. These are steeplysloping areas. Human interventions disturbing the slope stability has increased the vulnerability to erosion. Gneissic soils are observed in the area.

2.4. Importance of River Bed Profile Study

Field evidence suggests that on relatively small timescales (of the order of years or decades) and in the absence of major anthropogenic effects, the average bed profile of rivers may be in quasi equilibrium, i.e. the mean elevation of the active bed and a function of the longitudinal coordinate do not experience significant temporal variations. Natural rivers display spatial variations and temporal fluctuations of flow properties and bed topography acting on a variety of scales. Larger-scale fluctuations are associated with variations of the driving forces namely water discharge and sediment flux forced by a variety of possible events: floods, natural seasonal oscillations etc. And hence any notion ofmorphodynamic equilibrium can only approximate and must refer to the cross sectionally averaged bed elevation(BollaPittalugaetal. 2014).

2.5. Importance of Soil Characteristics in Studying Groundwater Availability

It determines whether groundwater reaches soil surface or not, the evolution of soil structure after flooding mainly depends on the quality of flooding water (salinity, type of sodium salt etc). It is important to determine the origin of flooding water which in about 90% of cases comes from groundwater. Whether the soil will be ponded by fresh or salty water it will depend on soil profile characteristics.

2.6. Process flow of the study

- Study of River bed profile in comparison with the river bed profile study conducted by GrameenaPadanaKendram earlier. Profiling study will be in three stretches of Highland, Midland and low land with an extent of 10 km stretches each with 1 Km distance profiles.
- Soil sampling & Soil testing will be done by collecting samples in one sq.km. grids from the surface and in the case of not flooded region and from the surface and original surface in the case of flooded region.
- Soil quality modelsdevelopment in the parameteric and nutrient aspects
- 3D Mapping of the terrain by Drone for bench marking
- DSM, DEM and ortho image development.
- Contour and profile development
- Land Use mapping of 2017 and 2018 for Change analysis
- Changes in groundwater table and periodic monitoring.
- Mobile application for geo-tagging and well survey
- Well survey for around 20,000 wells (study abandoned)

- Groundwater status evaluation.
- Recommendations

2.7. Collaborating Agencies and Their Roles

The following agencies participated in the study as shown in the table 2.1.The activities and roles by each departments/ collaborating agencies are also represented.

Sl.No	NAME OF AGENCY	ROLE DEFINED
1	KSREC	• Development of mobile application. • Training to volunteers in a Panchayath for well survey. • Data Integration and generation of Report. • Funding
2	Haritha Keralam Mission	• Procurement of Profile details from ILDM Coordination activities • Funding
3	Grameena Padana Kendram	• Profiling study • Well survey using Mobile Application (Abandoned)
4	Soil Survey and Conservation Department	• Soil sample collection and analysis
5	Ground Water Department	• Supply of Groundwater data
6	MIT, Anna University	• Mapping of terrain by drone and data processing • KSREC will coordinate the activities of MIT

Table: 2.1.Collaborating Agencies and Roles

2.8. Methodology

The study is intended to characterize the morphological changes that happened to the terrain due to flood and also to identify the impacts the flood created on the soil quality. The groundwater dynamics and the influence of flood on the groundwater dynamics is also aimed at to characterize. A detailed methodology diagram is given below in the figure 2.5.

Profile of the river and the comparison with the earlier profiles is aimed as a manual mode of assessment of the morphology change along with the Remote Sensing method of drone based study. Soil quality analysis is intended with the sample collection in one square kilometer grids within the watershed area of influence to the study river segments. Groundwater characterization is also intended with the watershed area. An integrated analysis including the Land Use change analysis is planned to identify the groundwater dynamics and the river morphological dynamics in the post flood scenario.

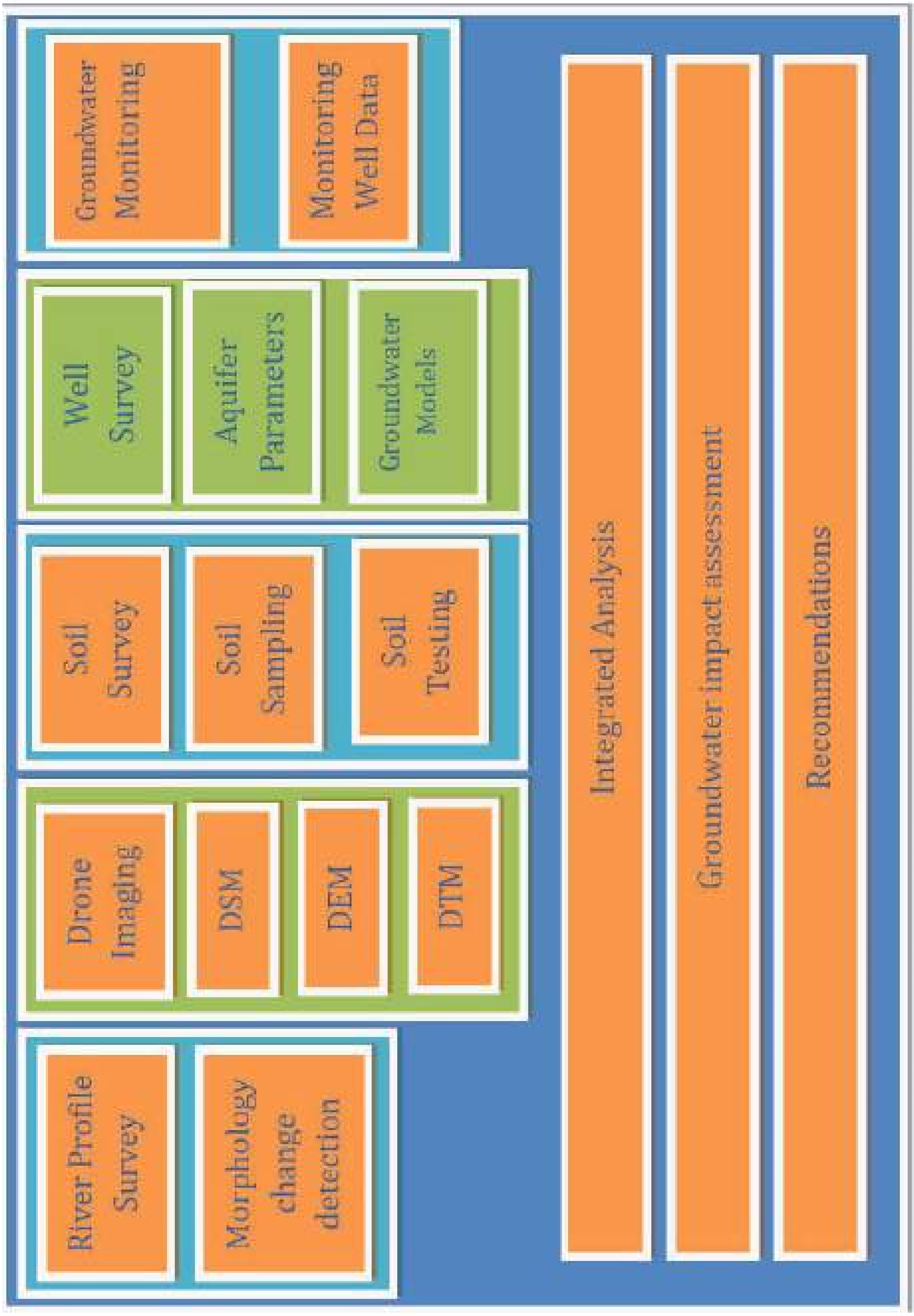


Fig. 2.5. Methodology

CHAPTER III

BENCH MARKING REMOTE SENSING SURVEY AND TERRAIN ANALYSIS USING UNMANNED AERIAL VEHICLE (UAV)

3.1.Introduction

Unmanned Aerial Vehicle (UAV) is an excellent platform for generating Very High Resolution Remote Sensing data. The resolution is high enough to map individual objects on the surface of the earth. AS the details are discernible enough it will help to bench mark the status of any terrain so that further changes from that date of mapping can be identified. As the wetland ecosystem of Kerala is highly destructed and depleted, it is essential that a bench marking survey of all the wetlands should be looked into for records of the Government for protection and maintenance of the system as in lines with the directions of National Green Tribunal.

3.2. Data Acquisition

In this project, Fixed wing UAV (DH-FX Mapper) has been used for acquiring nadir photo (90^o photo), which is shown in figure 3.1. It is flown in the direction of east – west and north – south respectively and took 12067 photographs. UAV captured with 70% of side overlap and 75% of forward overlap photographs. These photographs have been used to generate the Orthomosaic image and Digital Surface Model (DSM). Digital Terrain Model (DTM) was extracted from the DSM with the help of Photogrammetry software. The main advantages of this UAV is cost effective, flexible, flying under cloud, long endurance compared to the multi rotor UAV, safe landing mechanism and capture the high-resolution images.

Fig:3.1. Fixed Wing UAV

3.3. Ground Control Station (GCS)

Ground Control Station (GCS) act as a land based control center that provides the facilities for pilot to control UAV and payloads. GCS is used to configure, monitor and control the flight parameters of UAV in real time. The major role of the GCS in mapping is to view the flying patterns as shown in the figure 3.2.GCS provides a user interface map screen where the operator can define waypoints for the flight, camera coverage setting (overlap percentage), flying height, flying speed and control, monitor the UAV behavior and check the battery life. UAV's real time location is monitored using mobile phone with the help of location finder app and to track the location of the UAV in the event of the radio communication failure. The GCS mission planner operation for the survey pattern is shown in figure 3.2.

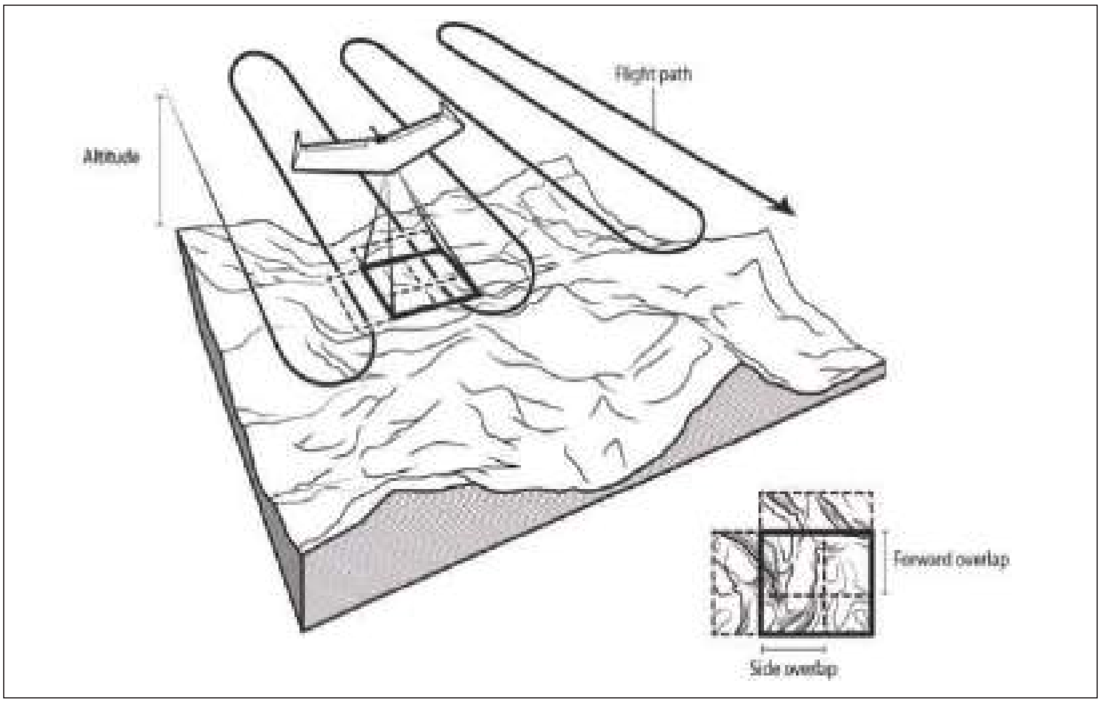


Fig:3.2. 3D View of Flight Path

3.4. Ground Control Points (GCP)

UAV acquires the high resolution aerial images along with GPS location. But the horizontal and vertical positional accuracy of the image position is depending on the pre-surveyed Ground Control Points (GCP). Images position stored using GCS can be used for image processing, but it will give only the relative horizontal and vertical position. To obtain the survey grade positional accuracy of the end product, the pre-defined GCP points were placed on the permanent structure on the ground. These locations were surveyed using Differential Global Positioning System (DGPS) instrument and accurate position details are derived in X, Y and Z format before UAV survey. Sample GCP marking on ground is shown on figure 3.3.

3.5. DGPS Instrument used for this Study

The Spectra - SP80 DGPS instrument used for GCP observation. It is a new generation GNSS receiver which uses the unique Z-Blade technology to track and process all available GNSS signals, to provide the most reliable measurements and the highest possible accuracies in the challenging environment. The physical structure of the DGPS instrumentisFig:shown in figure 3.4.

Fig: 3.3.GCP marking

DGPS points are estimated and marked based on Area of Interest (AOI) extent. During the field survey, the permanent GCP locations like road marking, road gullies, road curb were identified and surveyed using DGPS instrument. Base point was established and the continuous observation has been done. Base point DGPS errors are corrected using base line process method with the help of nearest GNSS station located in IISC Bangalore. Rover DGPS point errors are corrected using calibrated base point.

Fig:3.4.DGPS Instrument for GCP Measurement

3.6. Work Flow

Drone Survey for Bench Marking	Pre &Flying Activities	Unmanned Aerial Vehicle (UAV) Acquisition
		Ground Control Station (GCS)
		DGPS based Ground Control Points (GCP)
		Flying and Image Acquisition
	Aerial Triangulation	
	Post Flying Activities	Dense Point Cloud Generation
		Digital Surface Model (DSM) & Digital Elevation Model (DEM)
		DTM and River profiling
Soil Survey	Soil Sampling and Analysis in Watershed based approach	Field traversing and site selection for soil sampling
		Soil sample collection and analysis
		Preparation of Analysis Maps based on soil quality
		Soil Quality Model

Land Use	Change analysis (Pre &Post flood)	Low Land
		Mid Land
		High Land
Groundwater Level	Fluctuation Analysis (Pre &Post flood)	Low Land
		Mid Land
		High Land
River profile	Variation Analysis (Pre &Post flood)	Low Land
		Mid Land
		High Land
Status Evaluation and Recommendations		

Table:3.1. Work flow

3.7. UAV Data Processing Work Flow

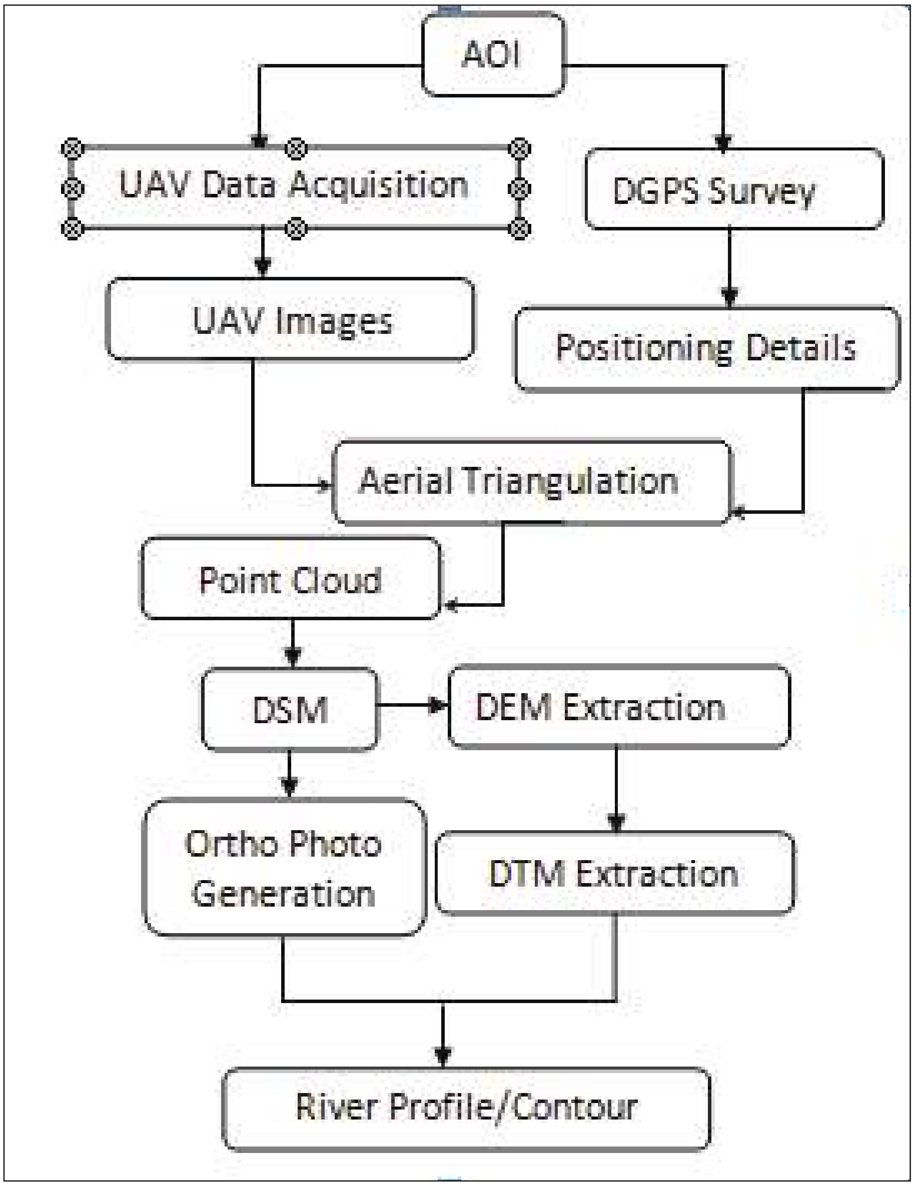


Fig:3.5. Processing Flow Chart

3.8.Photo Alignment

Aligning photo is the initial process to combine the aerial photographs. Pair selection option took the GPS/IMU data to generate the point for combining photographs. This option significantly speedup the processing time. High accuracy setting helps to obtain more accurate camera positions estimates, but it requires huge utilization of full computational power of the system. Lower accuracy setting can be used to get rough camera positions in a shorter period of time. The tie point generated outputs are shown in figure 3.6.

Fig:3.6.Generation of Tie Point

3.9. Ground Control Point Measurement (or) Aerial Triangulation

UAV image positions are realigned based on GCP and camera position. Marking the GCP in relevant picture based on the GCP marker and optimized control points update the existing orientation of camera, to compute new orientation which allows the better dense cloud generation. After GCP calibration part of Pamba River is indicated in the figure 3.7.

Fig:3.7. GCP Calibration Output

3.10. Dense Point Cloud Generation

Build Dense Point Cloud is a computationally intensive operation this will take long time, depending on the quantity and resolution of loaded photo. Structure from Motion (SfM) algorithm is used in this stage; these points can meshed later based on triangulated irregular network connection of generated points. The dense point cloud generated are shown in figure 3.8.

Fig: 3.8. Dense Point Cloud

3.11. Drone Survey for Bench Marking and 3d models

Drone based survey was conducted for imaging and 3D models generation to identify the post flood status of the terrain.

3.12. Digital Surface Model (DSM)

A Digital Surface Model (DSM) contains elevations at regularly spaced intervals; however, the elevations represent the first reflected surface detected by Structure from Motion (SfM) algorithm. These first returns may be reflected by bare ground or by surface features such as trees and structures. It is useful for 3D modeling for line of site analysis, telecommunications, urban planning and aviation. The sample DSM generated is shown in figure 3.9.

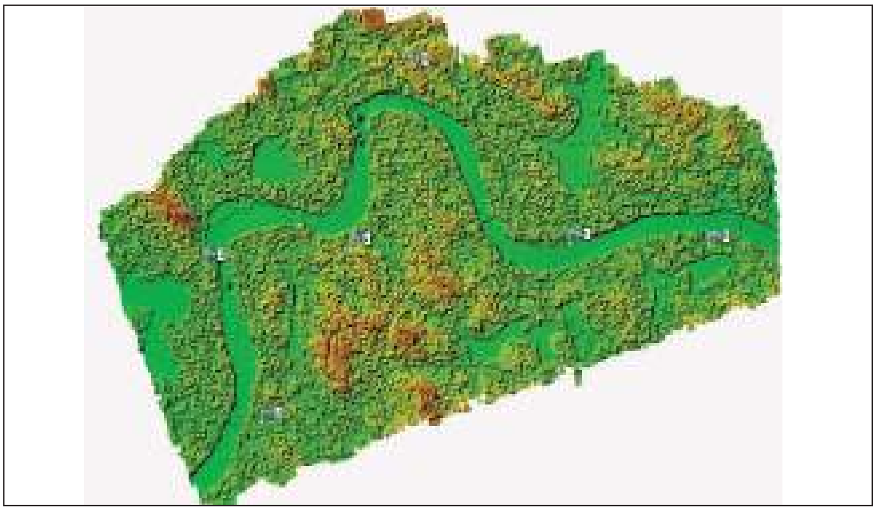


Fig:3.9.Digital Surface Model

3.13. Digital Elevation Model (DEM)

A Digital Elevation Model (DEM) is a representation of elevation of the terrain (bare-earth) at raster gird format. DEM derived from filter out non-ground points such as bridges and roads from DSM. The manmade features (power lines, buildings and towers) and natural features (trees and other types of vegetation) are not included in DEM. It is useful for hydrology, soils and land use planning. In this study DEM was automatically extracted from DSM file using filter algorithm. Further the water areas were refined using manual terrain editing. DEM generated in this study is show in figure 3.10.

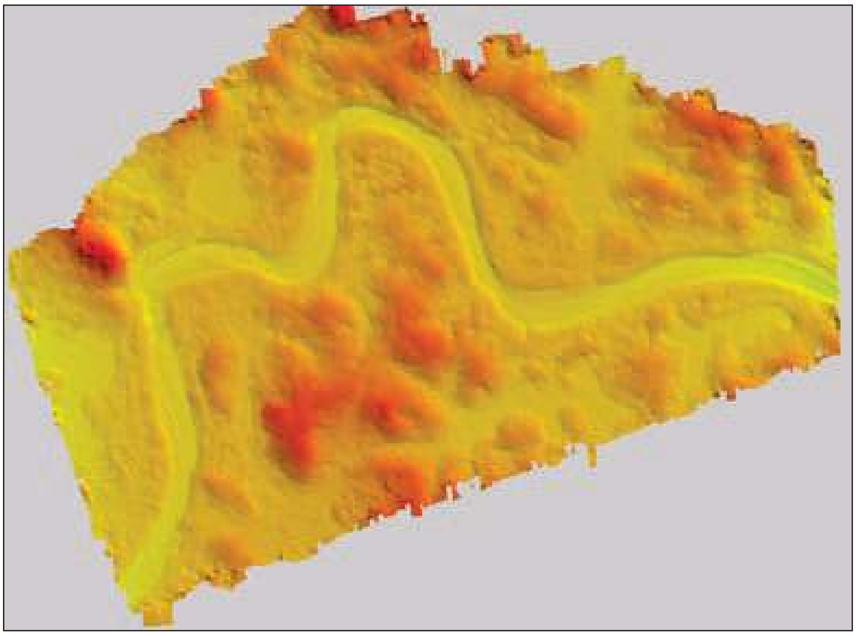


Fig:3.10.Digital Terrain Model

3.14.Orthomosaic Photo Generation

Orthomosaic image is a detailed, precise photo representation of an area/ object, created out of many photographs that have been combined together and geometrically corrected so that, it is accurate as a map. It has been used to measure true distances, because it is a terrain relief displaced and geometrically corrected one. The sample orthomosaic output is shown in figure 3.11. Orthos are generated at 3 centimeter resolution

Fig: 3.11.Orthomosaic Image

viz it can capable to view 3 centimeter level object on ground in 1pixel.The zoom in view of UAV based orthois shown in figure 3.12. The high resolution satellite data view of the zoomed area is shown in figure 3.13.

Fig.3.12. Zoom in View of UAV Orthomosaic

Fig: 3.13. Satellite View for the Zoomed Area

3.15. Contour Generation

Contour represents 2D line connecting equal altitude (elevation) reference to Mean Sea Level (MSL). It is helpful to visualize the terrain elevation from printed maps. These contour lines are used to calculate terrain geometrics such as slope, water flow, cut and fill locations ofundulations or hazards in the existing surface. Contours are generated at 1 meter interval and every fifth contour is considered as major contour. Contours were generated free from self-intersection and depression polygon. Contours were smoothed for better visualization and appearance. The sample contours overlaid on orthophotoof Midland is show in figure 3.14.

Fig:3.14.One meter contour ofMidland

3.16. River Profile Cross Section

River profile provides cross-section of a river's channel and valley at specific user defined interval. River Profile Cross Section consists of River center line, River edge, Buffer for River edge and cross section for river center line at specific interval (150 meter). In this project, all the above mentioned features are digitized with the help of Ortho and DTM. The digitized features are dropped on DTM and converted to 3D shape files. This shape files are used for water flow simulation, erosion identification, identify the potential sand deposit area, water flow change deduction, flood prone area identification etc. River cross sections are generated as DWG and ESRI shape file format for easy interoperability. The sample river cross section file of portion of high land is shown in figure 3.15.

Geo-data generated is highly accurate in terms of its geo-position. The spatial resolution of the derived outputs is below 10 centimeter; hence the accuracy of the analytical result will be more. Lossless compression technique was used to visualize the data quick and it can be easily adopted by any GIS software. The UAV based survey provided all the relevant base data requires to assess the geomorphologic changes of the selected river stretches.

Fig: 3.15. River Profile Cross Section Overlaid on Orthomosaic of High land

CHAPTER IV

SOIL SURVEY, ANALYTICS AND SOIL QUALITY INDEX

4.1. Introduction

The soil characteristics of the study area was surveyed and analysis done by Department of Soil Survey and Soil Conservation Department. The department had done extensive field survey and analysis of the collected data to generate vast information of the soil characteristics of the study area in the context of post flood soil dynamics. The survey was planned in 431 grids covering the study area with the specification depending upon the soil diversity and the flood characteristics, for the purpose of the morphology changes of the Pamba river in the post flood scenario with reference to the groundwater dynamics. Therefore the study requires the permeability and porosity characteristics of the soil strata especially in the flooded region. There is a requirement for information the deposited strata characteristics and original strata characteristics.The depth of the sample collection depends on the deposition.In normal scenario where there is no flood deposition 1 ft by 1 ft sample was taken. In the flood deposit area, the sample result was taken from deposition and the below original layer.The number of samples per grid depends on the number of soil types in one grid.Minimum one sample per soil type from each grid was followed. Micro nutrient parameters were also analysed to identify whether the vegetation loss is dependent onthe groundwater dynamics or on nutrient loss.

The Department of Soil Survey and Soil Conservation had already conducted a study in the 13 disaster affected districts of the state to assess the impact of flood and landslides on the properties of soil, extent of damage caused to the quantitative parameters of soil in general and evaluation of soil quality parameters and their effect on soil agricultural purposes in specific, for evolving strategies for flooded soil management. The Department has been functioning towards the development of an authentic soil information system of the State for the cause of providing better understanding of soils to the community formulating developmental plans, research activities etc for the sustainable management of soils and enhanced productivity.

The report was an attempt to assess the extent of damage caused to soil and its quantitative parameters by the flood, areas affected by flood as well as landslides in each district, for finding out possible mitigatory& revamping measures. The details in the Soil Survey and Soil Conservation Department Study report "Soil Health Status of Kerala in Post Flood Scenario", which has got significance in the present study area is given below.

4.2. Changes in Soils of Distress Affected Areas(Soil Survey and Conservation, 2018)

Large quantity of sand, silt and clay were seen deposited on the surface soils of the affected panchayaths (Fig.4.1. to 4.3). The thickness of deposition varied from 2cm to 10cm. Soil crusting was also reported from these depositional areas of Thiruvalla Taluk viz:Nedumpuram, Peringara, Kadapra, Niranam and Kavumbhagam. These are low land valley areas under upper Kuttanad with wide stretch of punchapaddy fields, except Kavumbhagam, which is a low land valley. Panchayath wise details given by Soil Survey and Soil Conservation department in their report are as follows.

Fig:4.1. Sandy loam deposited in the area- with low organic matter and high pH.3.7 (Soil Survey and Conservation, 2018)

Fig:4.2. Deposited silt (Soil Survey and Conservation, 2018)

Fig:4.3. Clay deposits (Soil Survey and Conservation, 2018)

4.2.1. Nedumpuram village (Nedumpuram Panchayath)

Nedumpuram soil series was the major soil series observed in the area. Silt deposition up to 3-5inches noticed in the area. The depth of silt deposition varied from area to area. 8 soil samples were collected from 4 locations in the village. Soil crusting was observed in many areas. Crops such as Banana and nutmeg withered up after flooding and with development of yellow colour. Nendran variety was the most affected while Poovan, Palyamkodan were not affected.

4.2.2. Peringara village (Peringara Panchayath)

The panchayath is drained by both Pampa and Manimala river. Nedumpuramsoil series was the major soil series observed in the area. 4 soil samples were collected. Organic matter content increased than that in availablepreflood soil data. Nutmeg and banana were affected the most. The depth of silt deposition varied from area to area ranging from 1cm to 10 cm thickness.

4.2.3. Niranam village (NiranamPanchayath)

The panchayath is drained by both Pampa and Manimala river. Nedumpuram soil series was the major soil series observed in the area.3 soil samples were collected. Organic matter content increased compared to preflood condition. Nutmeg and banana were affected the most. The depth of silt deposition varies from area to area and it ranges from 5 cm to 15 cm in thickness.

4.2.4. Kadapra village (Kadapra Panchayath)

The panchayath is drained by both Pampa and Manimala river. Nedumpuramsoil series was the major soil series observed in the area.3 soil samples were collected. The depth of silt deposition varies from area to area and it ranges from15 cm to 25 cm in thickness.

4.2.5. Kavumbhagam village (Thiruvalla Municipality)

The area is drained by streams which drain out to both Pampa and Manimala rivers. Nedumpuram soil series was the major soil series observed in the area.5 soil samples were collected. The depth of silt deposition was less and it ranges from 1cm to 2 cm in thickness.

4.3. Physical Properties

The physical properties such as texture and sediment deposition are as given below.

Sl No	Pre flood	Post Flood	Sediment thickness after flood (cm)
Nedumpuram Panchayath			
PTA/1	Clay loam	Sandy clay loam	2
PTA/2	Clay loam	Sandy clay loam	4
PTA/3	Clay loam	Clay loam	4
PTA/4	Clay	Sandy loam	4
PTA/5	Clay loam	Silt loam	4
PTA/6	Clay	Silt loam	8
PTA/7	Clay loam	Silt loam	6
PTA/8	Sandy clay loam	Silt clay loam	10
Peringara Panchayath			
PTA/9	Clay loam	Sandy clay loam	2
PTA/10	Clay	Sandy clay loam	10
PTA/11	Clay loam	Sandy clay loam	>1
PTA/12	Clay loam	Sandy clay loam	2

Niranam Panchayath			
PTA/13	Clay loam	Sandy clay loam	10-15
PTA/14	clay	Sandy loam	5
PTA/15	Clay loam	Sandy loam	5
Kavumbhagam Panchayath			
PTA/16	Clay loam	Sandy clay loam	3
PTA/17	Clay loam	Sandy clay loam	2
PTA/18	clay	Sandy clay loam	>1
PTA/19	Clay loam	Sandy clay loam	-
PTA/20	Clay loam	Sandy loam	-
Kadapra Panchayath			
PTA/21	Sandy Clay loam	Silt loam	15-25
PTA/22	Sandy Clay loam	Clay loam	25
PTA/23	Sandy Clay loam	Sandy clay loam	15

Table:4.1. Pre and Post flood Soil texture(Soil Survey and Conservation, 2018)

- It can be seen that in all villages except Kadapra there was a shift in texture in general, from clay loam to sandy clay loam.
- In Kadapra village due to increased silt % (15-25cm thick silt) and due to decrease in sand and Clay %, there was shift in texture from sandy clay loam to silt loam / clay loam.
- In Kavumbhagam village, there is increase in sand % and decrease in silt % which shifted the texture towards sandy clay loam from clay loam.
- In Peringara, sand % remained almost same in both period but there was increased clay content and decreased silt which caused a shift in texture towards sandy clay loam from clay loam.
- In Niranampanchayat, although sand % and clay % remained same in both period, there was increased silt % which finally caused a shift to sandy clay loam from clay loam.
- In Nedumpuram, although sand and clay % decreased, increased silt % caused a shift in texture from sandy clay loam from clay loam.

4.4. Materials and Methods

The Soil Survey wing of the Department of Soil Survey and Soil Conservation has undertaken the survey to assess the changes in physico-chemical properties of the soil in the post flood scenario of the study area catchments. The materials and methods employed for the study are given below in detail.

4.4.1. Field Traversing and Site Selection for Soil Sampling

The field was gridded with 431 one sq.km. grids for sample collection from each grid. Field traversing was also conducted in the study area catchments and soil sampling sites were identified based on the destruction. Site characteristics such as sediment deposition, landscape modification etc. were also recorded during survey. The sampling sites were plotted in maps using GPS values.The soil samples were analysed for interpreting the physico chemical and structural changes occurred in soil as a consequence of floods and landslides.

4.4.2. Soil Sample Collection and Analysis

With the help of GPS, surface samples were collected from a depth of 0-30cm. A composite soil sample of 1kg each was collected from these depths from each of the selected grid points with the help of a stainless steel soil auger. Initially, soil samples were collected at random from different locations which were then mixed up to obtain a composite soil sample separately. The soil samples were then spread on a white sheet of paper and about 1 Kg collected from each point were separated by quartering method. The samples were then transferred to plastic bags, brought to the laboratory and prepared for the analyses. For soil physical and chemical analysis, a sub sample of each sample was airdried, ground to powder form and stored in labeled plastic bottles. The soil samples were analyzed and the results are presented on oven dry weight basis.

4.4.3. Sampling Locations

Samples were collected from grids and analyzed for texture (Fig.4.4 and 4.5). It is found that there was a shift in texture from Clay loam to Sandy clay and sandy clay loam due to increase in sand content after land slide. This will obviously decrease the water holding capacity. The soil deposited after landslide showed increased sand content where as the soil deposited in the stream channel showed increased clay content.

4.4.4. Preparation of Sample

The soil samples upon arrival at the laboratory were unpacked and spread on a large sheet of paper for air drying under shade. The dried sample was crushed in a wooden mortar with wooden pestle and sieved through a 2 mm sieve until only coarse fragments remained. The sieved soil sample and coarse fragments were weighed to determine coarse fragment content by weight. The volume of coarse fragment was also recorded. Sub sampling was done to obtain small portions representative of the bulk. The entire 2mm sample was spread evenly by horizontal strokes of a knife on a large sheet of plastic. Small portions were taken at random from all over the sample to obtain a sub sample for each analysis. The samples were analyzed for the following soil quality indicators adopting standard procedures.

1. Soil Reaction / pH
2. Electrical conductivity
3. Organic carbon %
4. Available nutrients like P, K
5. WHC (%)
6. CEC (cmol/kg)
7. Exchangeable bases (Na, K, Ca, Mg) in cmol/kg
8. Available Calcium, Magnesium and Sulphur (ppm)
9. Available micronutrients (Fe, Mn, Cu, Zn, B) in ppm
10. DTPA extractable Heavy metals (Pb, Cd,) in ppm

4.5. Soil Quality Parameter Analysis

Soil quality can be simply defined as a soil's "fitness for use". It is in reality a complex concept and significantly more challenging in its assessment than air or water quality. Soil indicators are often divided into Physical, Chemical and Biological categories depending on how they affect soil function. However, these categories are not always clearly defined since a soil property or indicator can affect multiple soil functions or categories. A soil which is considered to be of high quality for one parameter may not be so for other functions. Therefore potentially many soil properties (micro and surface level nutrients) which might serve as indicators of soil quality is required to identify the most suitable.

4.5.1. Micro Nutrient Level Soil Quality Analysis

4.5.1.1. Boron (B)

Boron (B) is a micronutrient critical to the growth and health of all crops. It is a component of plant cell walls and reproductive structures. It is a mobile nutrient within the soil, meaning it is prone to movement within the soil.

From the analysis ofMicro nutrient soil quality parameter Boron and with the help of GIS platform distribution of Boron within the watershed boundary of Pamba basin was generated and is shown in the figure 4.6.

It is clearly evident that there is adequate element in most of the area in the watershed and deficient in Thiruvanvandoor,Pandanadu,Budhanoor,Puliyoor, Ala, some portion of Kadapra panchayaths of lowland region which is marked as dark green.

Because of boron's involvement in cell growth, symptoms of boron deficiency are expressed at growing tips of the root or shoot, and generally include stunting and distortion of the growing tip that can lead to tip death, brittle foliage, and yellowing of lower leaf tips. Using a small amount of boric acid (1/2 tsp. per gallon of water) as a foliar spray can fix the problem of deficiency.

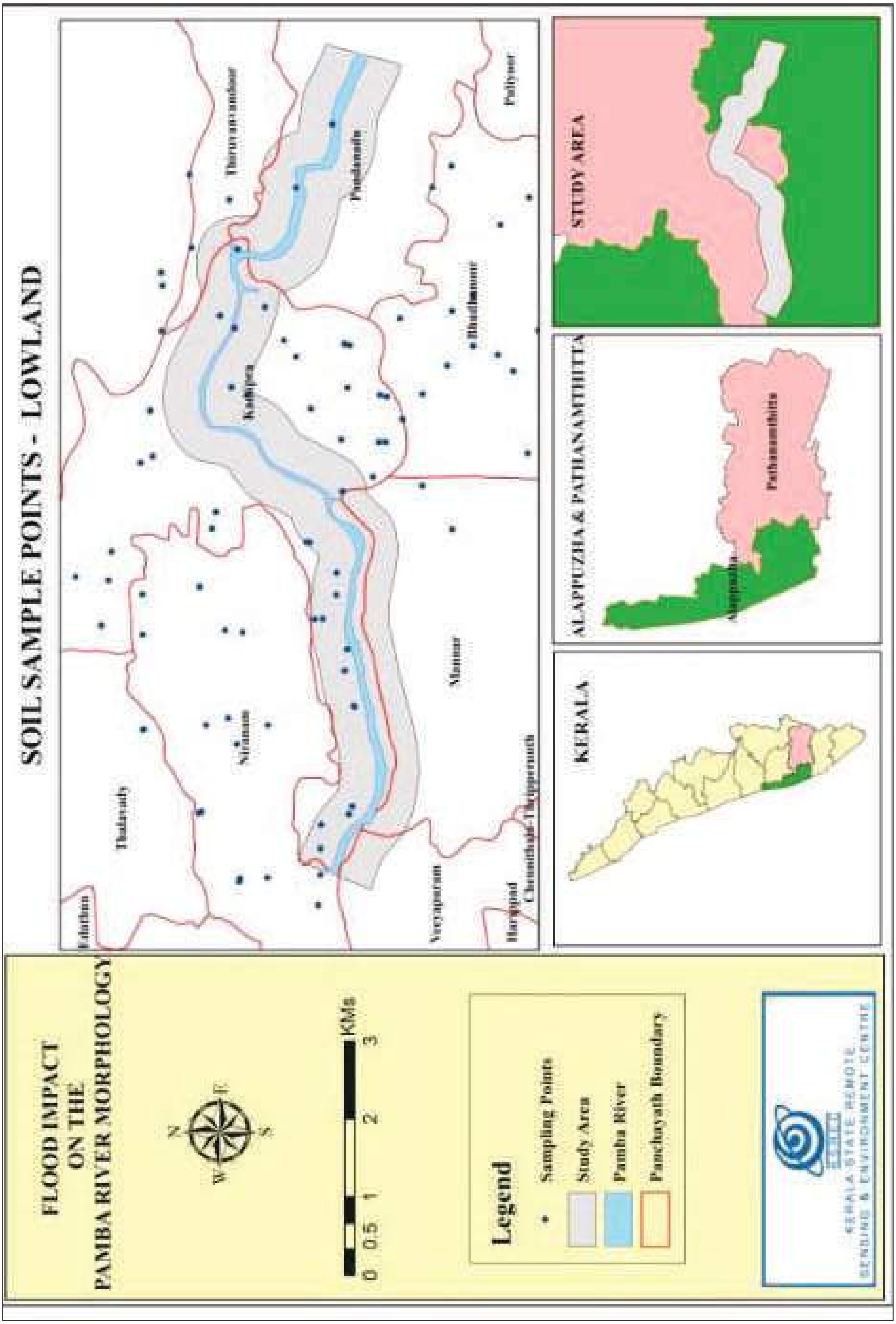


Fig:4.4. Sample Pointsin Low land

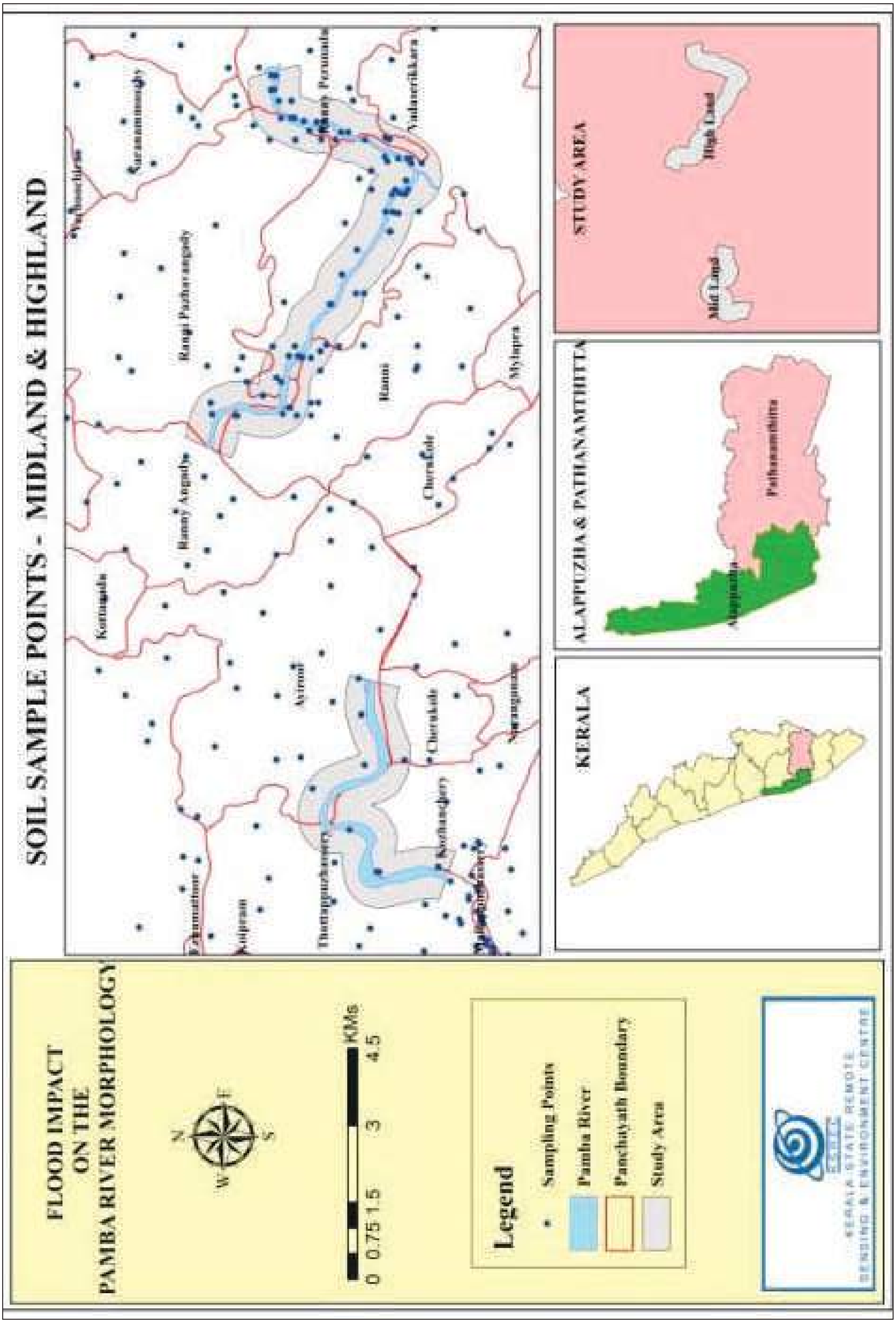


Fig:4.5. Sample Pointsin Mid land & High Land

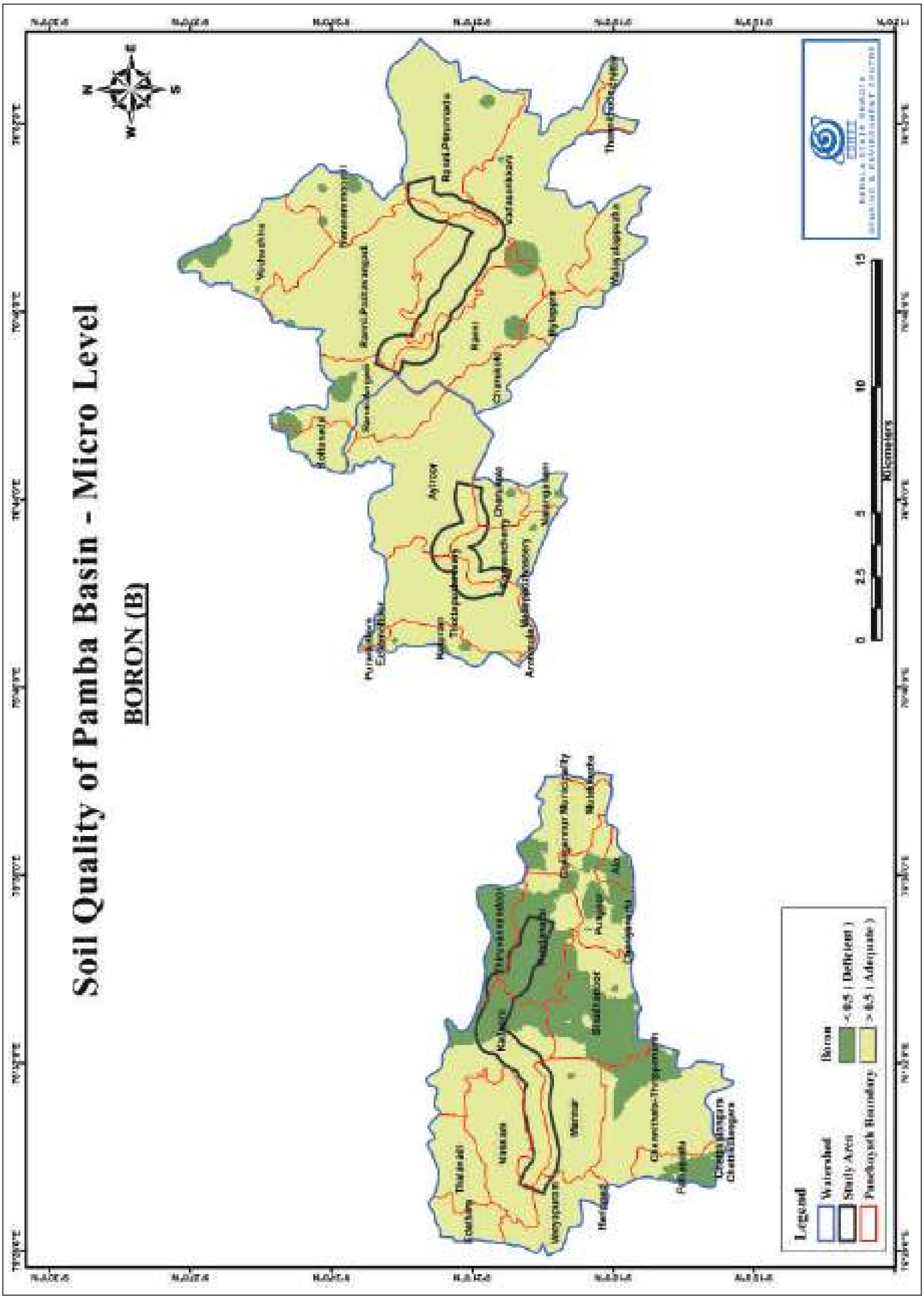


Fig: 4.6. Soil Quality of Boron (Micro Nutrient)

4.5.1.2. Calcium (C)

Calcium plays a very important role in plant growth and nutrition, as well as in cell wall deposition. Calcium is essential, not only to correct soil acidity but also as a nutrient element necessary for normal plant growth. From the analysis of Micro nutrient soil quality parameters, distribution of Calcium (C) within the watershed boundary of Pamba basin is shown in the figure 4.7.

The distribution shows that there is deficiency in element value towards west side of lowland region and Ayiroor, Ranni, Pazhavangadi, Vadaserikkara panchayaths of midland and highland region. Analyses also indicates Calcium is adequate in Puliyoor and adjacent panchayaths of lowland region, Kozhanchery and surrounding panchayathsof midland, Ranni and its surrounding panchayaths of highland region.

Deficiency in calcium may leads to problems to the crops and yields which includes hindering of early root formation and growth, Plants lack vigor and stiffness and will show diseased and dead tissues,it will slow down the improvement of soil texture and crumb texture of heavy clay soils etc.Farmyard manure, Calcium Chloride, Gypsum, dolomite, lime pyrites, single superphosphate or triple superphosphate or lime nitrate can be used as calcium sources.

4.5.1.3. Copper (Cu)

Copper activates some enzymes in plants which are involved in lignin synthesis and it is essential in several enzyme systems. It is also required in the process of photosynthesis, is essential in plant respiration and assists in plant metabolism of carbohydrates and proteins.

Distribution of Copper in Pamba basin generated using the soil analytical data in the GIS platform is shown in the figure 4.8.

It is observed that there is adequate amount of Copper micronutrient in the study area segments oflowland, midland and highland.

4.5.1.4. Iron (Fe)

Plants only need a tiny amount of iron to be healthy, but that small amount is crucial. First of all, iron is involved when a plant produces chlorophyll, which gives the plant oxygen as well as its healthy green color. This is why plants with an iron deficiency, or chlorosis, show a sickly yellow color to their leaves.

From the analysis of soil quality parameters, distribution of Iron (Fe) in the Pamba river basin study area is area shown in the figure 4.9.

The spatial distribution of the soil analytical data for the miro nutrient Iron (Fe) shows that there is adequate quantityof element available in the whole area oflowland,midland and highland region of the study area. No deficiency is observed in the study area.

4.5.1.5. Magnesium (Mg)

Magnesium is an essential plant nutrient. One of the magnesium's well-known roles is in the photosynthesis process, as it is a building block of the Chlorophyll, which makes leaves appear green. Magnesium deficiency might be a significant limiting factor in crop production.

From the analytical resultsofsoil quality parameter elements and analysis of the data in the GIS platform, distribution of Magnesium in the study area is generated and the same is shownin the figure 4.10.

It is clearly evident from the thematic distribution that there is adequate amount of mineral in most of the parts of midland and highland region. Some portions of the Ranni and its adjacent panchayathsand a major portion of the lowland area shows deficiency in the mineral value.

Deficiency in the amount of Magnesium can be due to several reasons like high potassium levels in the soil. Due to this deficiency the plant may suffer problems like adverse affects inthe process of photosynthesis, hampers metabolism, absorption, and deposition of Phosphorus, it inhibits the movement of carbohydrates from leaves to stemand increases potential for leaching etc.

4.5.1.6. Zinc (Zn)

Zinc (Zn) is one of the eight essential micronutrients. It is needed by plants in small amounts, but yet crucial to plant development. In plants, zinc is a key constituent of many enzymes and proteins. It plays an important role in a wide range of processes, such as growth hormone production and internode elongation.

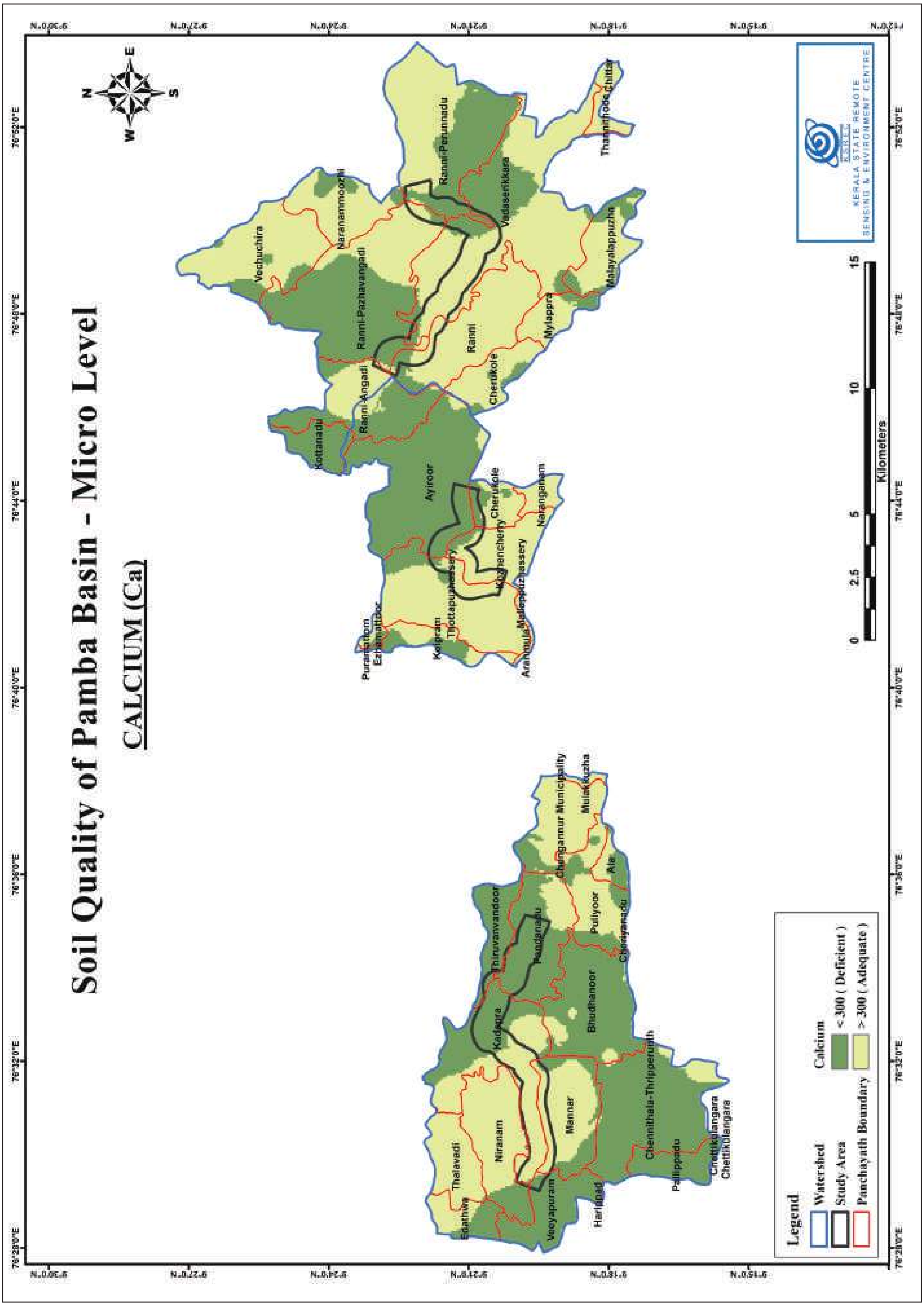


Fig: 4.7. Soil Quality of Calcium (Micro Nutrient)

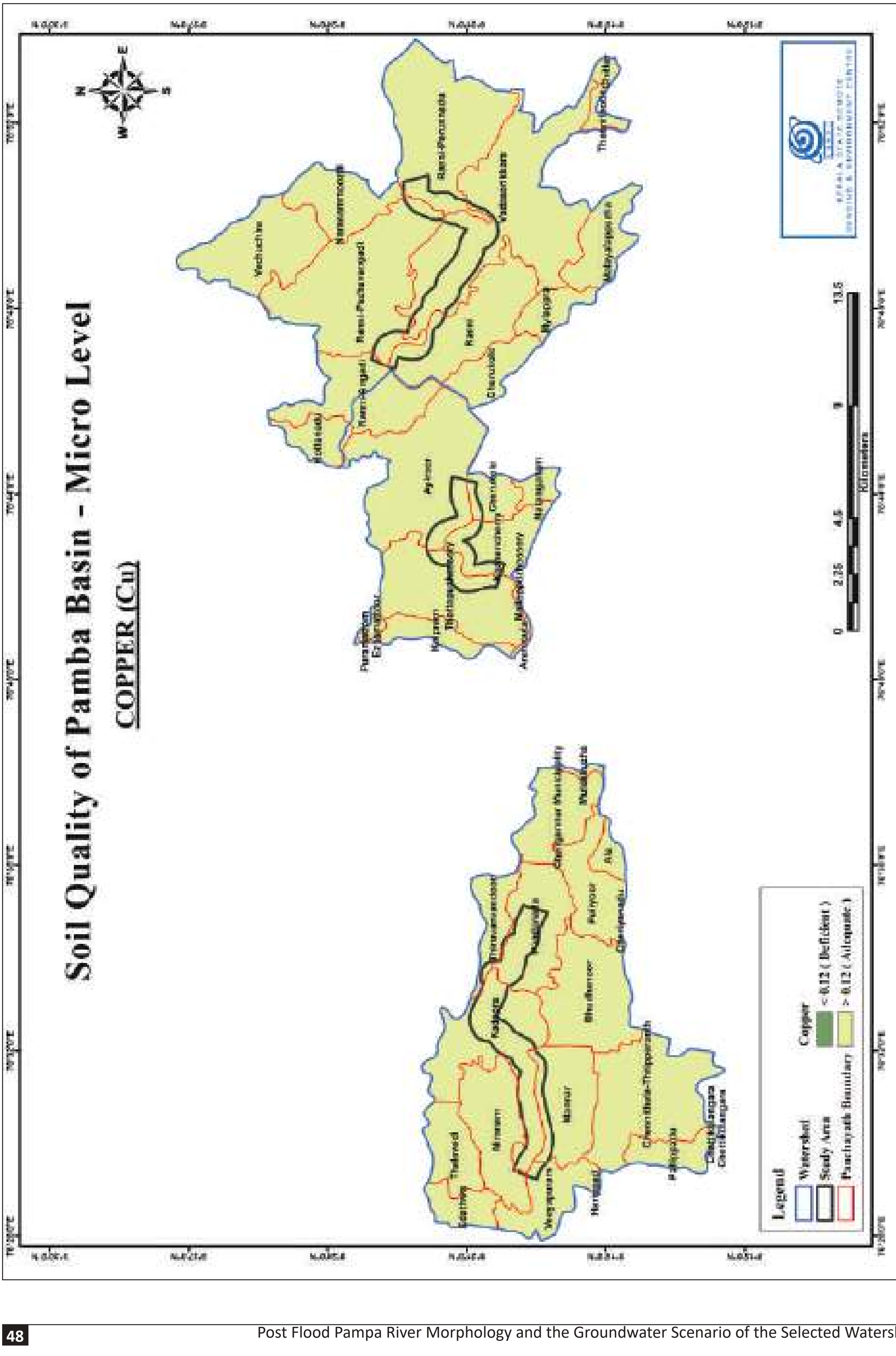


Fig:4.8. Soil Quality of Copper (Micro Nutrient)

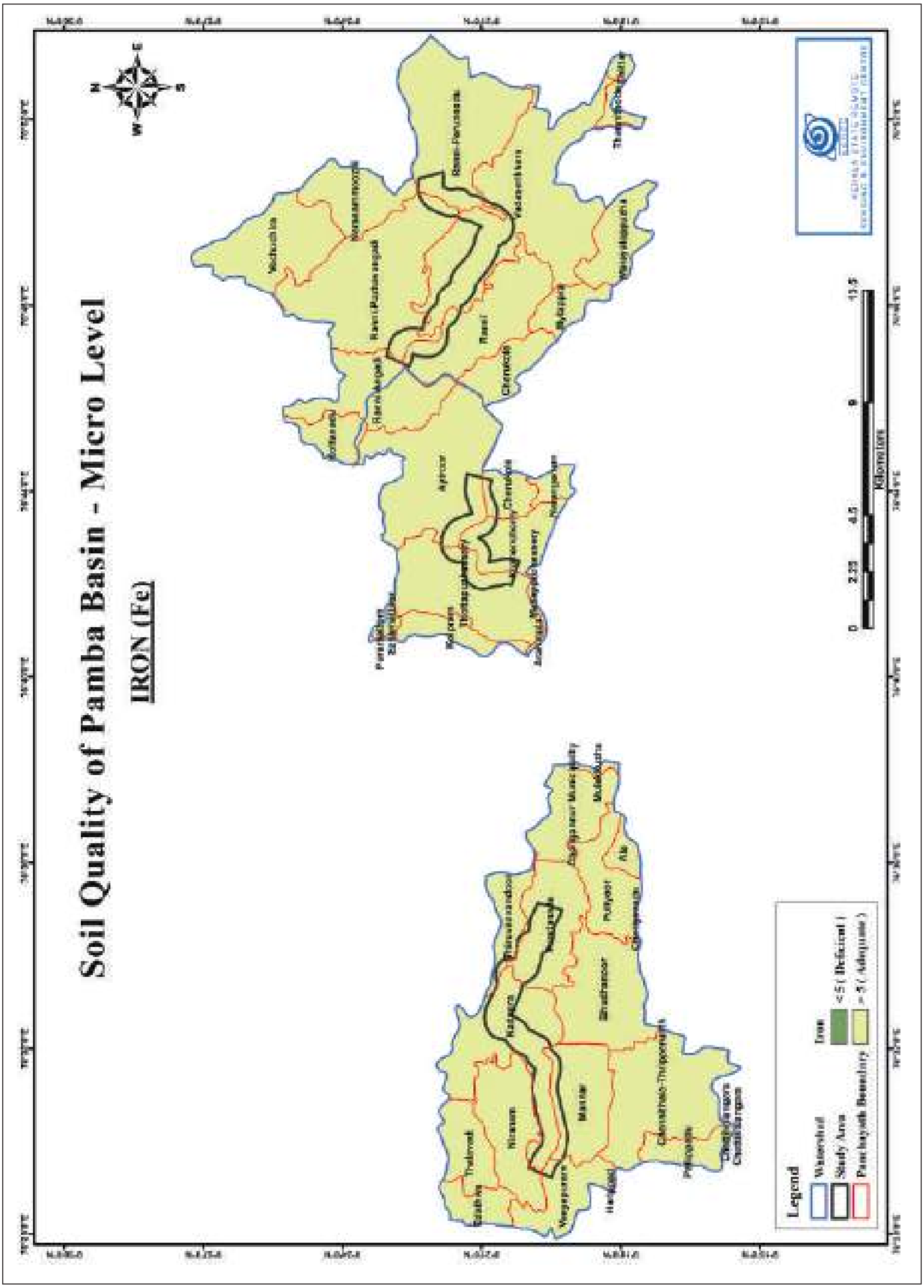


Fig: 4.9. Soil Quality of Iron (Micro Nutrient)

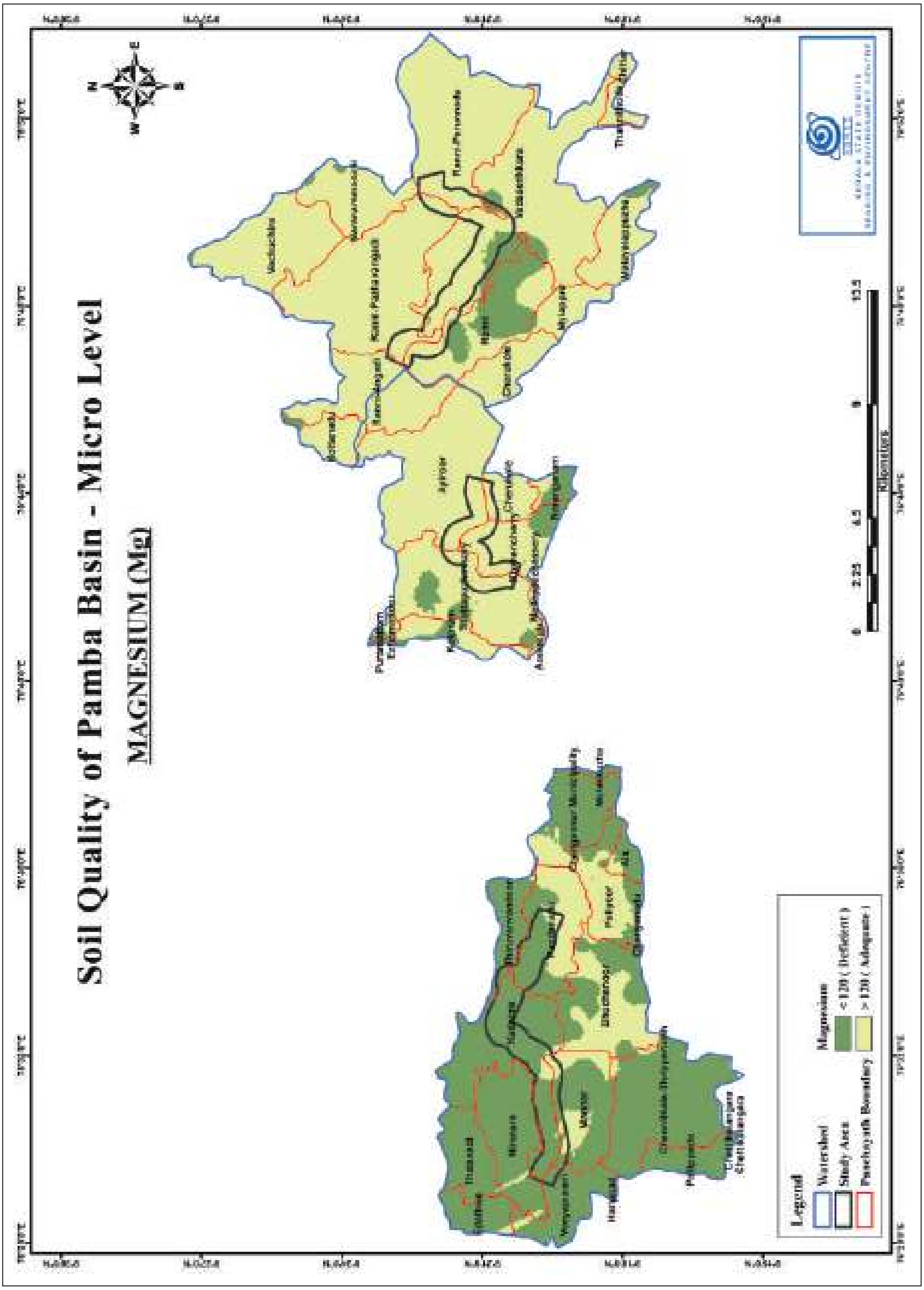


Fig:4.10. Soil Quality of Magnesium (Micro Nutrient)

From the analysis of soil quality parameters, distribution of Zinc in the study area of Pamba basin, generated is shown in the figure 4.11.

The distribution of the zinc in the study area shows that there is deficiency in the mineral value in Thottappuzhasserypanchayath in the midland region which is marked as dark green and the rest of the portion has adequate amount of mineral.

The amount of zinc is observed to be deficient in a small portion of the midland region, the deficiency in the mineral may be caused by excess calcium content, which will cause the plant to have poor growth and vigor and can also leads to lowers its disease resistance capacity. It adversely affects themetabolism,pollination and reproduction.

Zinc is an important component of various enzymes that are responsible for driving many metabolic reactions in all crops. Growth and development would stop if specific enzymes were not present in plant tissue. Zinc appears to be scattered throughout the mineral fraction of soils. Zinc deficiencies are frequently found on soils, with restricted root zones.Increasing the pH decreases the solubility of Zinc in soils.

4.5.1.7. Manganese (Mn)

Manganese is used in plants as a major contributor to various biological systems including photosynthesis, respiration, and nitrogen assimilation. Manganese is also involved in pollen germination, pollen tube growth, root cell elongation and resistance to root pathogens.

Distribution of Manganese in the study area in Pamba basin,generated from the soil analytical results analysed in the GIS platform is represented in the figure 4.12.

From the distribution pattern it is clearly evident that there is adequate quality ofelement availablein the whole area of lowland ,midland and highland region of the study area. There is no impact in the availability of Manganese in the study area after the flood.

4.5.1.8. Sulphur(S)

In plants, sulfur is essential for nitrogen-fixing nodules on legumes, and necessary in the formation of chlorophyll. Plants use sulfur in the processes of producing proteins, amino acids, enzymes and vitamins. Sulfur also helps the plant’s resistance to disease, aids in growth, and in seed formation.

Analysis of soil quality parameters shows the distribution ofSulphur in the study area of Pamba basin and the same is shown in the figure 4.13 below.

The amount of Sulphurmineral is found ‘More than Adequate’in lowland region and most parts of midland,highland region. Some portions of Ranni Pazhavangadi and its adjacent panchayaths shows adequate amount of the mineral value,whereas the Vechuchira panchayath and adjacent parts shows deficiency in mineral value.

Most portion of the study area is observed to have excess amount of Sulphur. The excess amount of Sulphur in the soil may leads to poor utilization of nitrogen, affects magnesium, sodium, molybdenum, calcium, and copper assimilation,it will affect the management of calcium and magnesium.It also causes changes in pH by increasing acid or hydrogen in soil.

4.5.2. Surface Level Soil Quality Analysis

4.5.2.1. Boron (B)

From the analysis of soil quality parameters, distribution of Boron in Pamba basin is shown in the figure 4.14. It is observed that adequate amount of Boron is distributed all over the midland and highland regions and deficiency in mineral value is observed in the Ranni Pazhavangadi panchayath and nearby Mylappra area. No data is available for lowland region and so not represented.

4.5.2.2. Copper (Cu)

The distribution of Copper in Pamba basin is shown in the figure 4.15. Adequate amount of Calcium is distributed all over of the midland and highland regions. No data is available for lowland region and hence not represented for the case of surface samples.

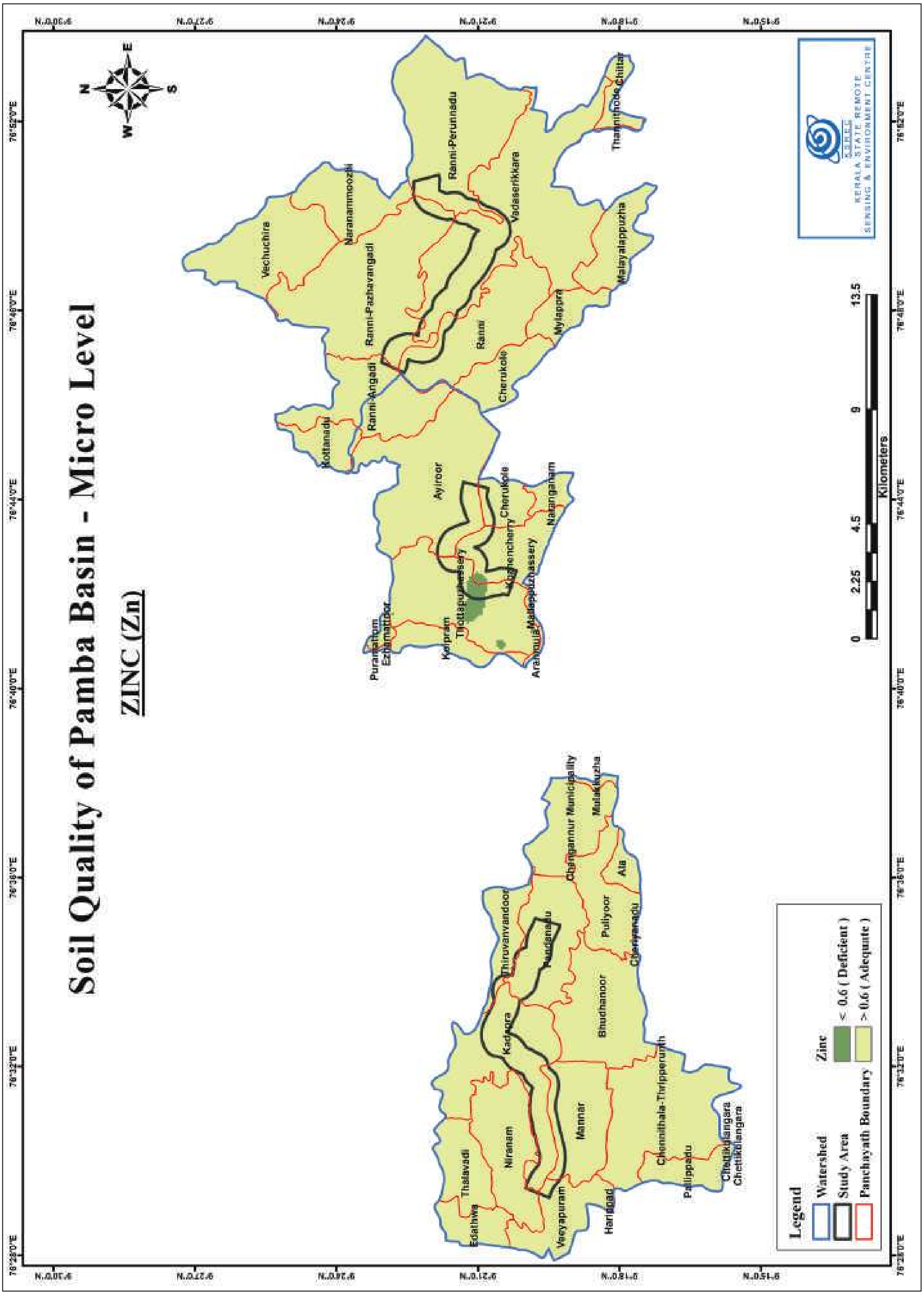


Fig:4.11. Soil Quality of Zinc (Micro Nutrient)

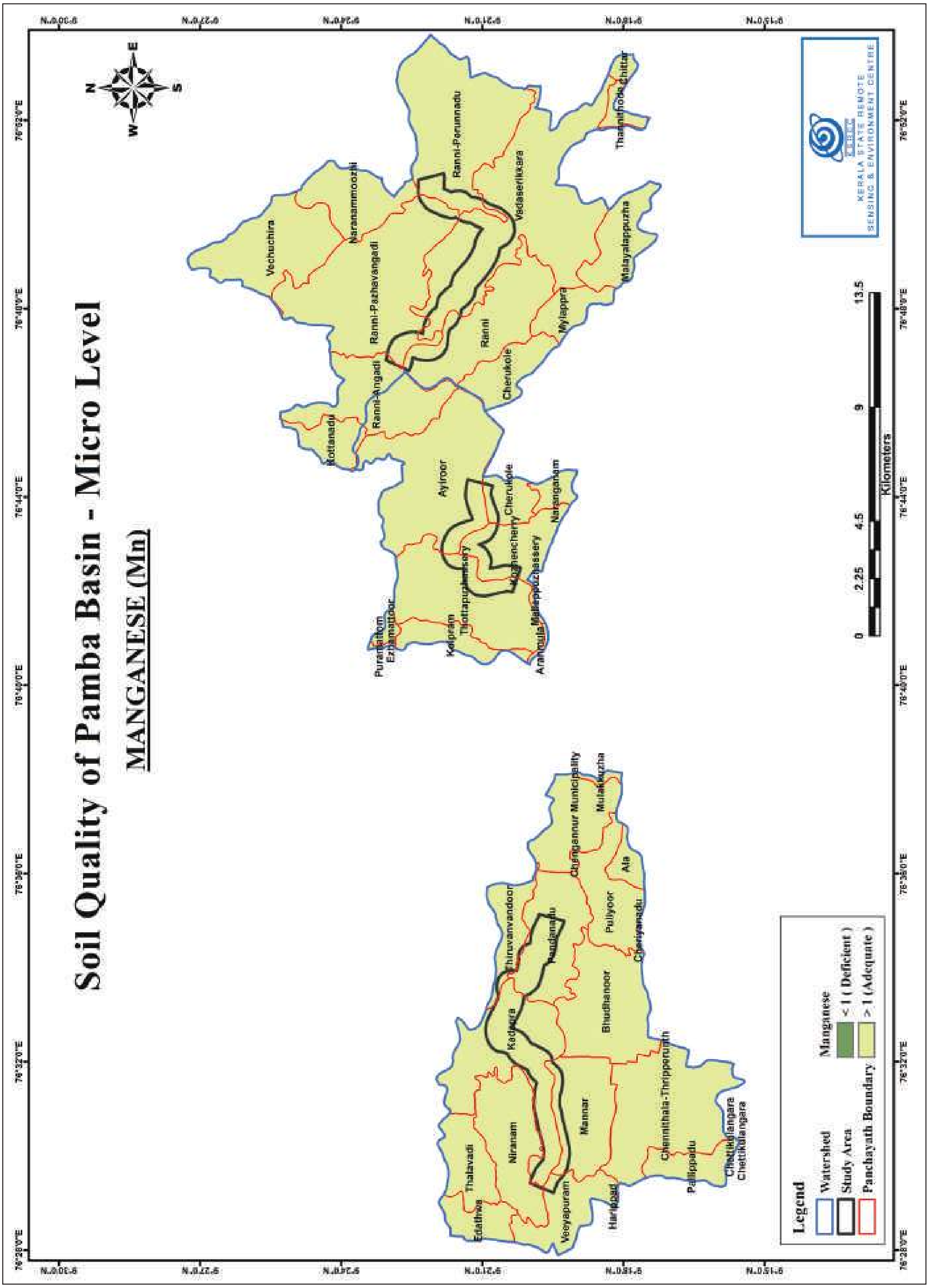


Fig:4.12. Soil Quality of Manganese(Micro Nutrient)

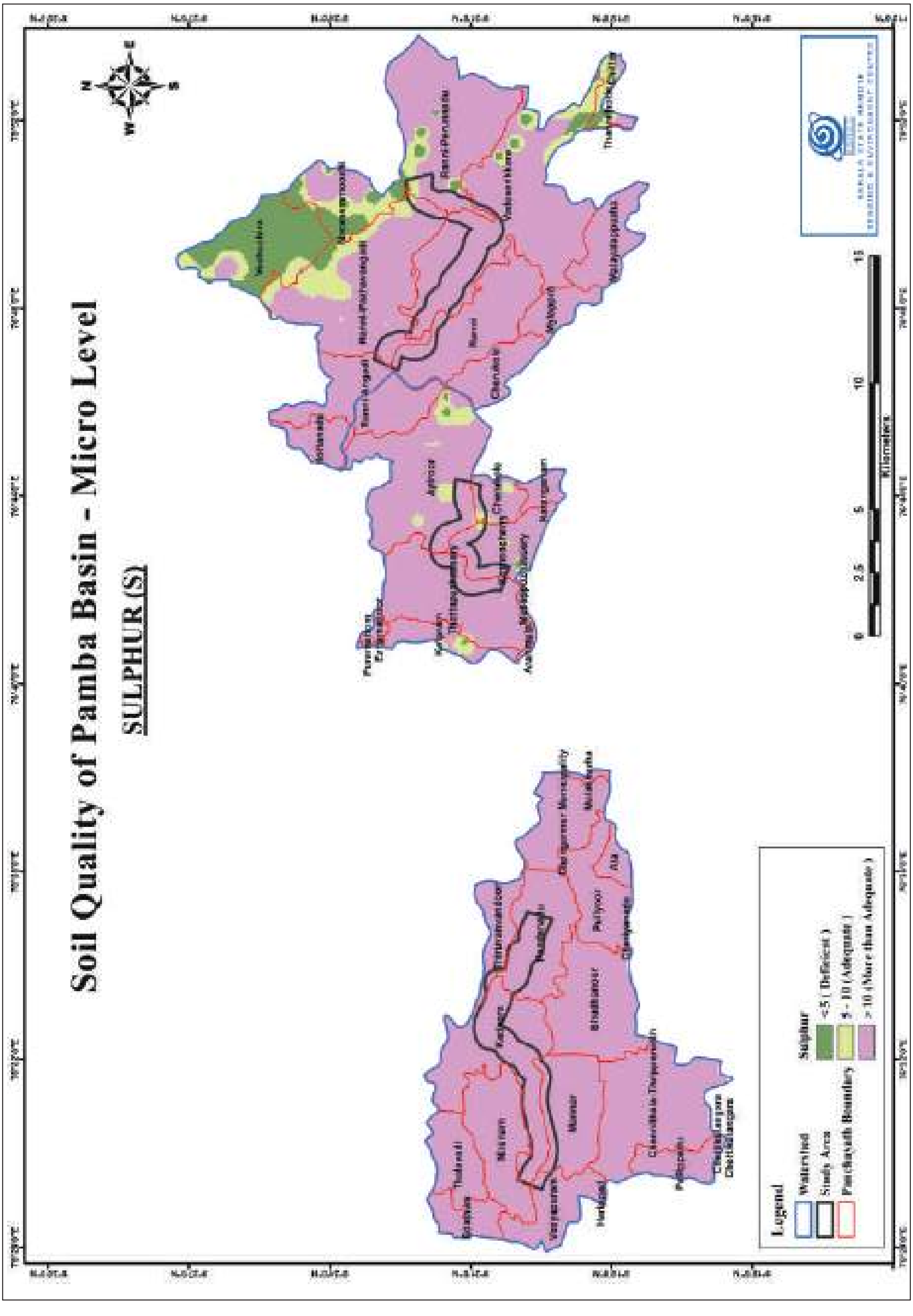


Fig:4.13. Soil Quality of Sulphur (Micro Nutrient)

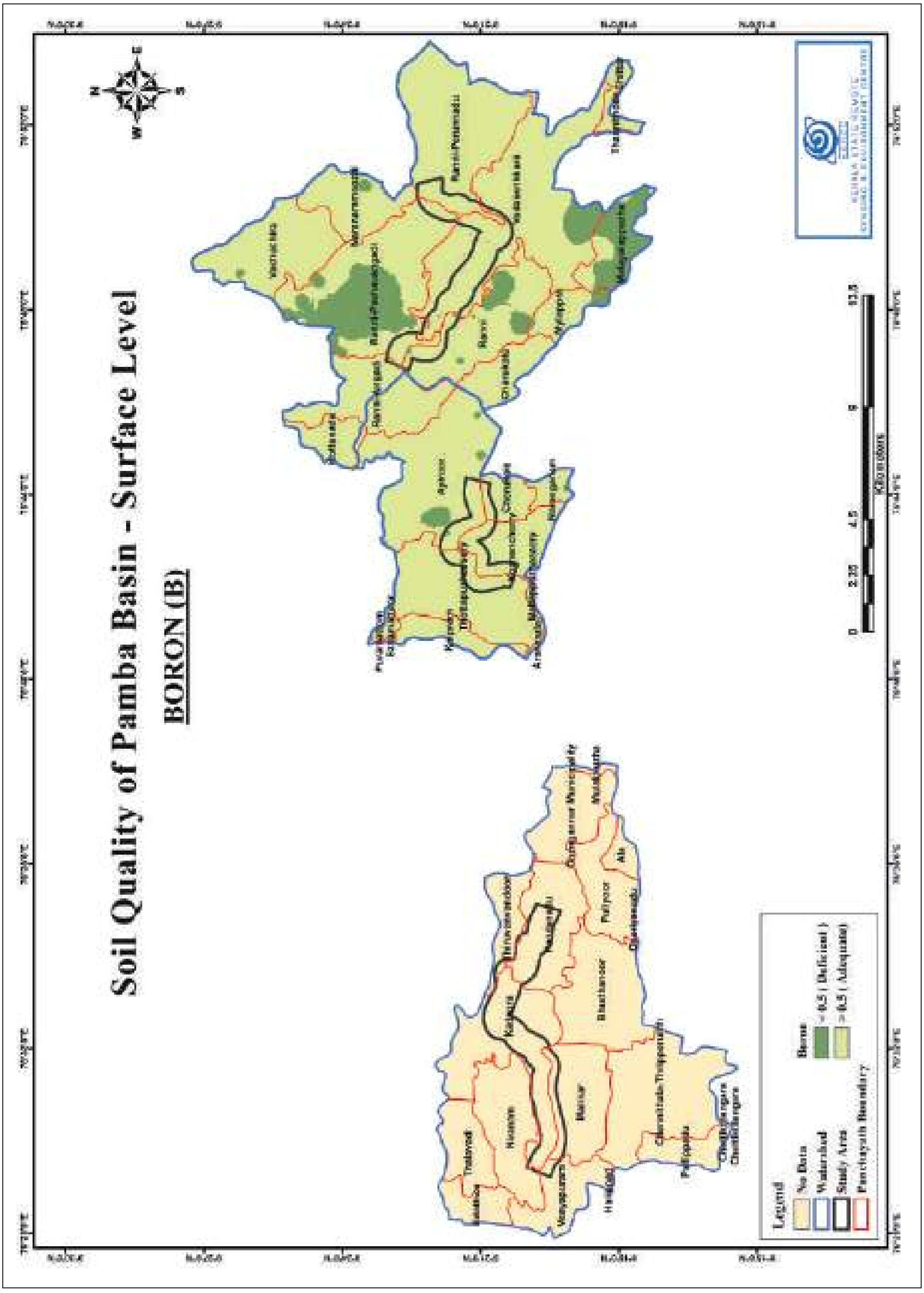


Fig: 4.14. Surface level Boron Distribution

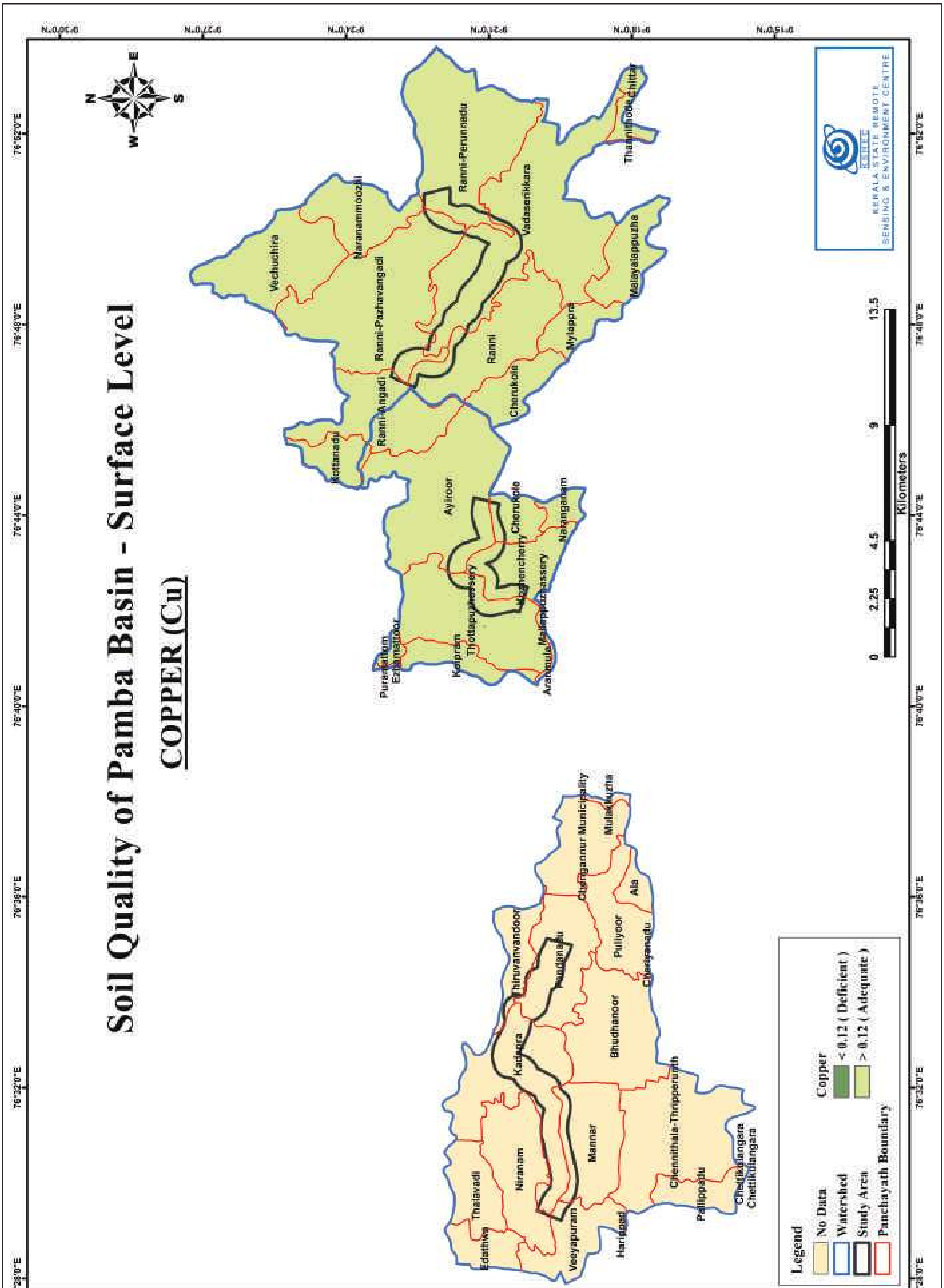


Fig: 4.15. Surface level Copper Distribution

4.5.2.3. Iron (Fe)

From the analysis of soil quality, distribution of Iron in Pamba basin is shown in the figure 4.16. Boron is distributed in adequate amount all over the midland and highland regions. No data is available for lowland region.

4.5.2.4. Calcium (Ca)

Distribution of Calcium in Pamba basin is depicted in the figure 4.17. It is clearly evident that adequate amount of Calcium is distributed in most parts of midland, highland region and deficiency is observed in the RanniPazhavangadi,vechuchira and adjacent panchayaths.No data is available for lowland region.

Deficiency of calcium may lead to several problems. Some of them includethe promotion of toxicity of certain soil constituents such as aluminum and manganese, slows down the growth of both symbiotic and non-symbiotic types of nitrogen fixing bacteria and also it will leadto poor roots and stems etc. Additional calcium can be applied through the nutrient solution by means of liquid lime fertilizers such as a calcium nitrate solution.

4.5.2.5. Magnesium (Mg)

From the analysis of soil quality parameter elements, the distribution of Magnesium in Pamba basin is as given in the figure 4.18. It is clearly evident that there is adequate amount of Magnesium distributed in most parts of the study region and it is deficient in the Ranni, Pazhavangad vechuchira and adjacent panchayaths. No data is available for lowland region.

When a shortage is diagnosed, the best thing to do is spray with a 2% solution of Epsom salts. Farmyard manure/ cow manure, Magnesium chloride, dolomite etc can also be used as magnesium sources. The deficiency may hamper metabolism, absorption, and deposition of Phosphorus and affects the process of photosynthesis etc.

4.5.2.6. Manganese (Mn)

Figure 4.19. shows the distribution of Manganese in the study area. It represents that there is adequate amount of Manganese distributed all over the midland and highland region. No data is available for lowland region.

Magnesium is the central core of the chlorophyll molecule in plant tissue. Thus, if Mg is deficient, the shortage of chlorophyll results in poor and stunted plant growth. Magnesium is a mobile element in the plant and deficiency symptoms will occur first in the oldest leaves. In low-pH soils, the solubility of magnesium decreases and it becomes less available. Photosynthesis as the central process for crop production depends on the plant's Mg status in several respects. The application of Dolomitic limestone is the most cost effective method for applying the Mg that is needed. The Mg content of Dolomitic limestone varies from 8-10%.Magnesium also helps to activate specific enzyme systems. Enzymes are complex substances that build, modify, or break down compounds as part of a plant's normal metabolism.

4.5.2.7. Phosphorous (P)

The distribution of Phosphorus in Pamba basin,as shown in the figure 4.20., clearly shows that there is high amount of Phosphorus available all over the lowland and most of the midland and highland regions. Adequate amount is distributed in north and eastern part of highland region. Lower stretches of Midland region is also showing medium distribution.

As phosphorus plays an important role in controlling osmotic pressure, the deficiency in the amount of phosphorus will affect the plant in several manners, it is non-mobile so the deficiencies will appear in younger parts of the plant. It slows and reduces the growth and growth hormone production. Decrease resistance to the invasion of pathogenic micro-organisms and diseases. Affect enzyme system including vitamin D, nucleic acid, and every cell as they are rich in phosphorus. It can be created by excesses of iron, aluminum, calcium, and magnesium. It will adversely affect reproductive process and pollination activities of the plant.

Similarly, the excess amount of phosphorus also affects the plants in many ways. Some of them includes, causing crop to mature too rapidly, increases the need for iron, calcium, and magnesium, reduces zinc, copper, and iron availability and reduces uptake of manganese, zinc, copper, and molybdenum.

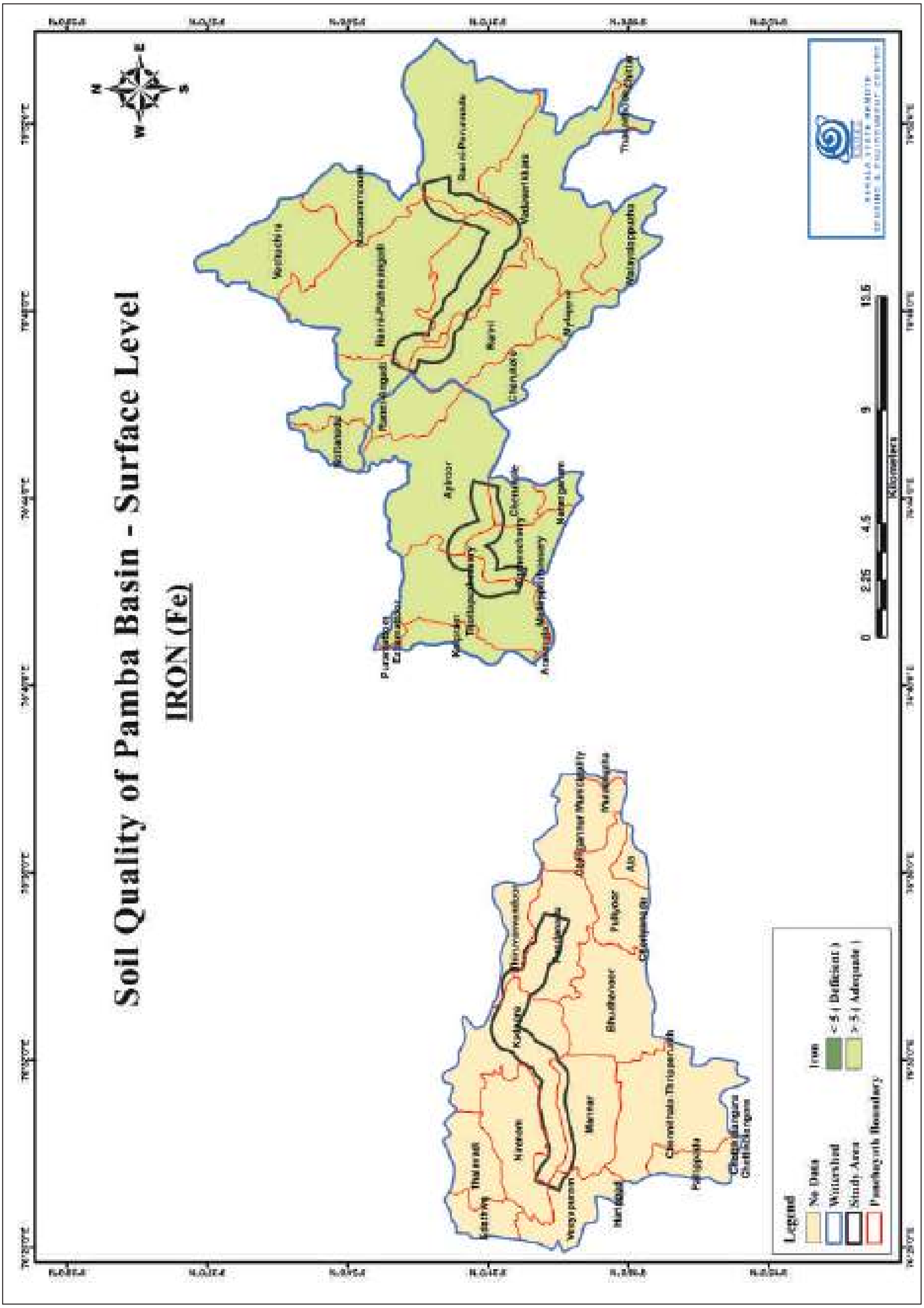


Fig:4.16. Soil Quality of Fe in Surface level

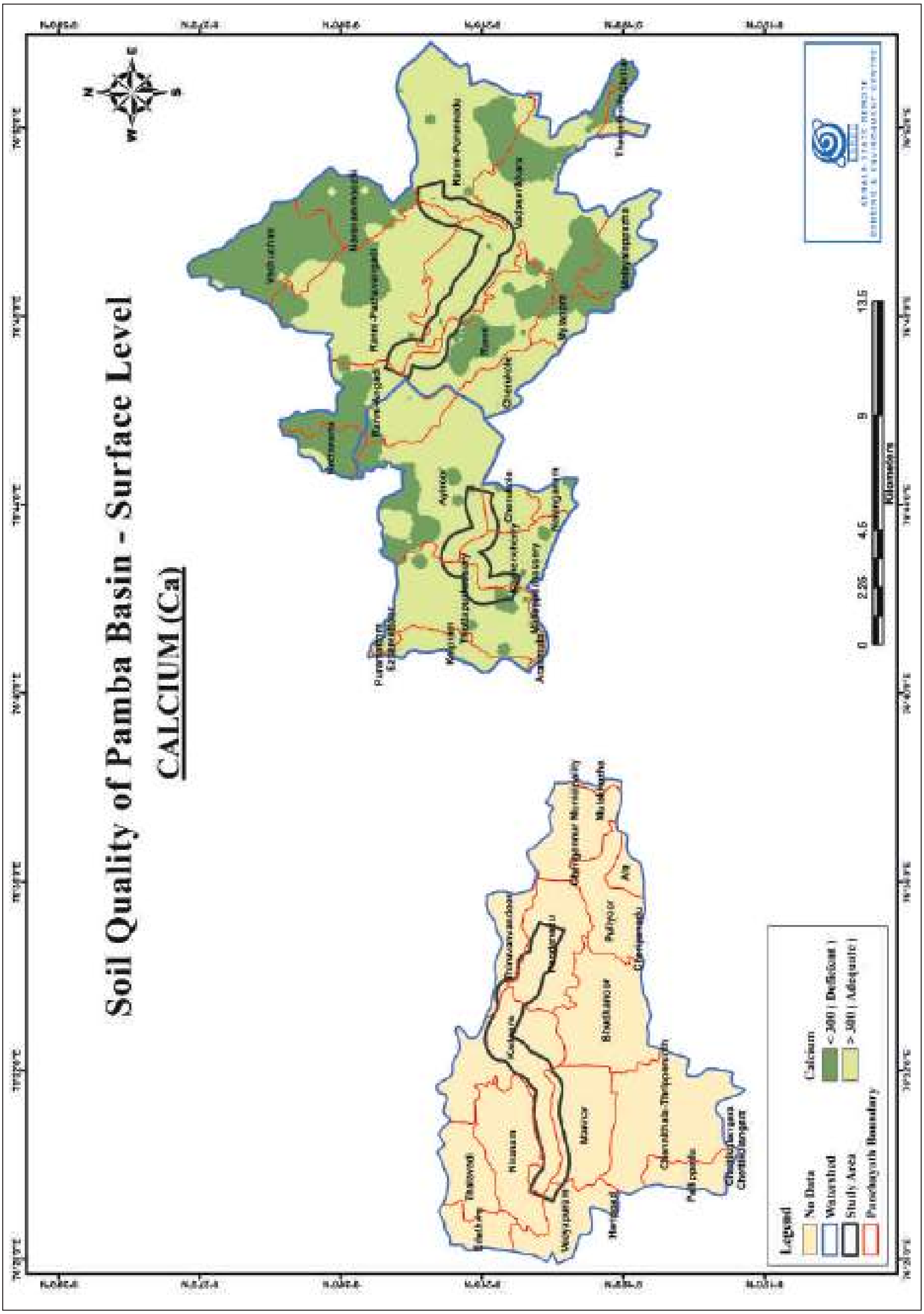


Fig: 4.17. Surface level Calcium Distribution

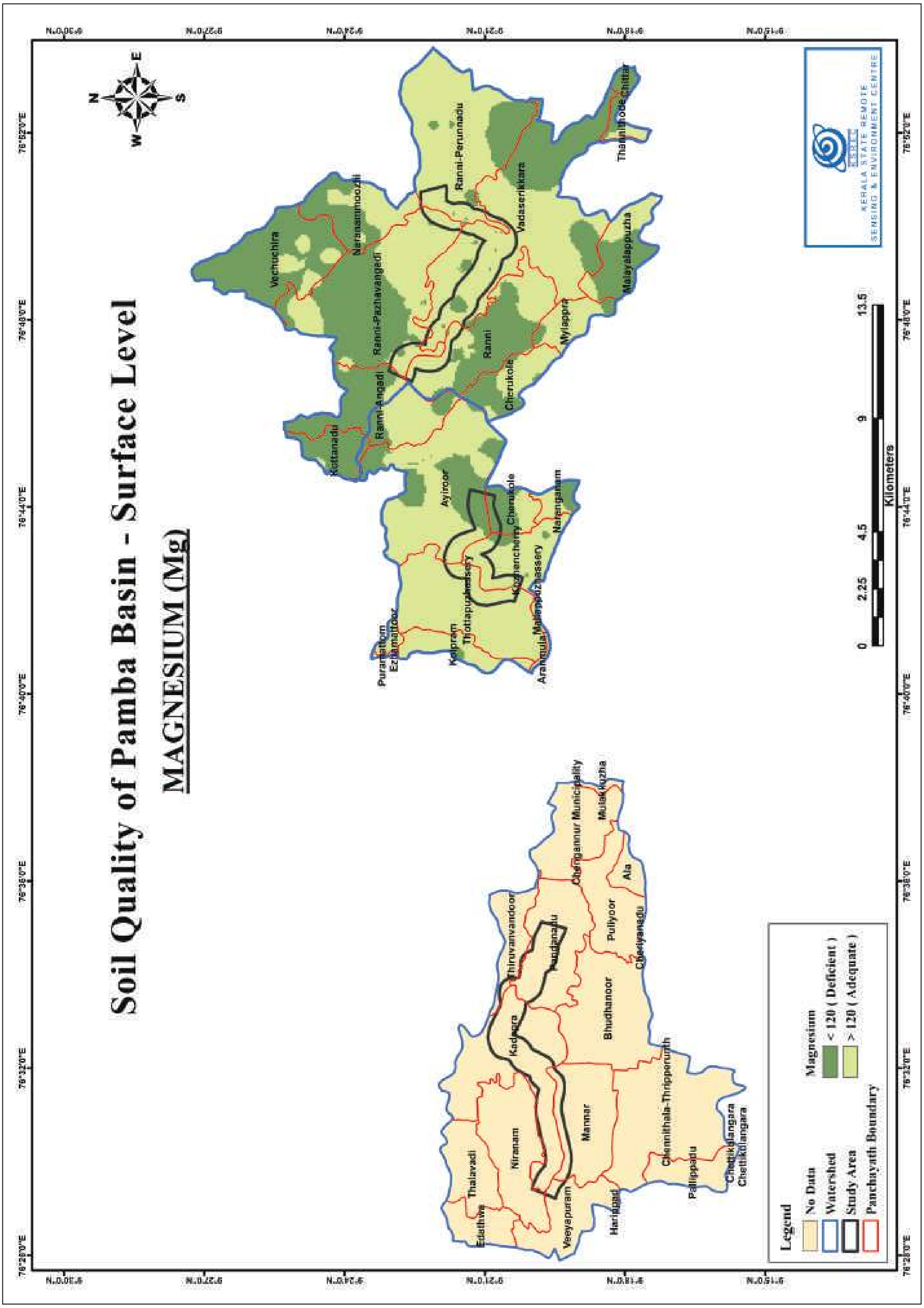


Fig: 4.18. Surface level distribution of Magnesium

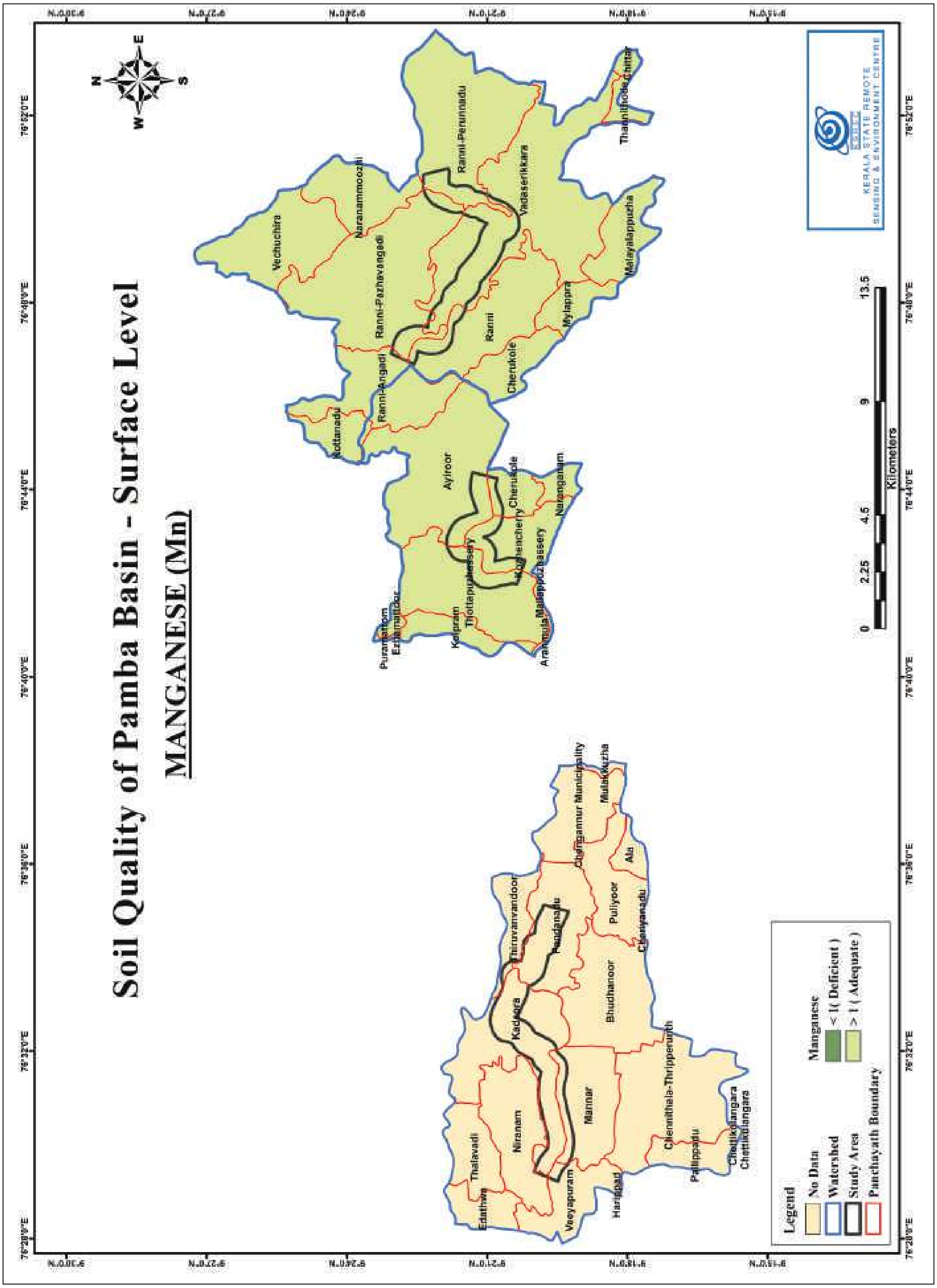


Fig: 4.19. Surface level Manganese distribution

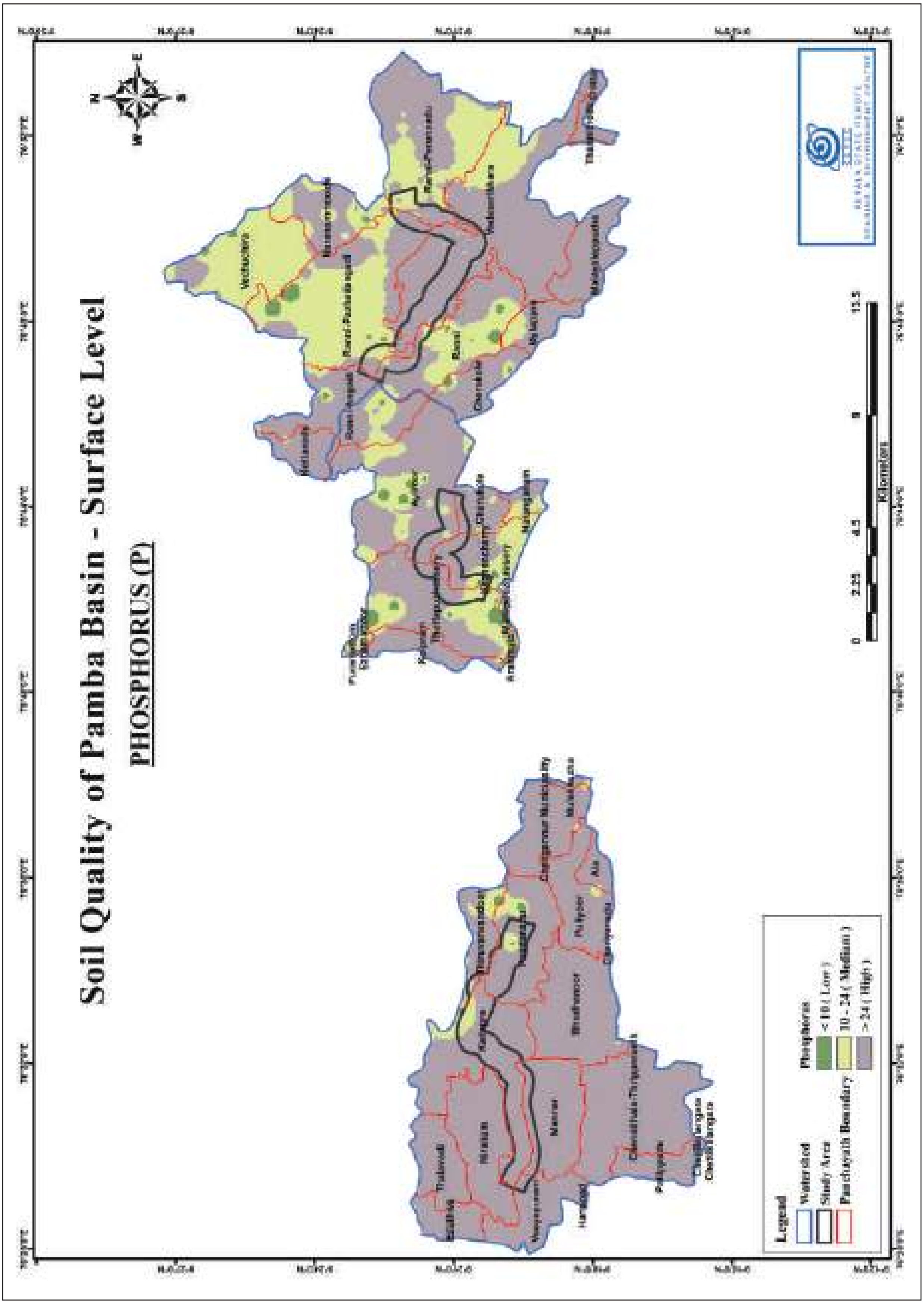


Fig:4.20. Surface level Phosphorous distribution

4.5.2.8. Pottasium(K)

As shown in the figure 4.21., the study area shows a high amount of Phosphorus distributed all over the midland region. Low amount (< 115) of Potassium is observed in Thiruvanvandoor,chennithala-Thriperunth and its adjacent panchayaths of lowland region. Adequate amount is distributed in north and eastern part of highland region and in the northern part of lowland region also.

Potassium deficiency in the soil can be caused by excess applications of nitrogen. It decreases the formation of carbohydrates.Potassium is mobile so older leaves or parts of the plant show signs of stress.Slows growth, reduces vigor, and affects reproduction activity at time of pollination.Keeps other nutrients from moving to the growing points and promotes lodging by reducing stalk and straw strength.When the amount of potassium exceeds the limit it causes poor fertilizer efficiency, high osmotic pressure, leafy and stalk vegetables to be tough and stringy, alkaline soil unless excessive chlorine is present and slows bacterial growth and multiplication. Reduces uptake of calcium, magnesium, and boron etc.

The mitigation of potassium can be done by Distributing excess potassium more evenly by thoroughly working dense soil until it is loose and friable. Dilute and flush out large amounts of potassium by watering the soil any time it appears dry to a depth of one inch. Schedule any fertilizing within several weeks before planting, so that the potassium doesn't have time to accumulate during the off-season. To minimize long-term potassium buildup, consider using aged or composted animal manure as a substitute for commercial fertilizers, as its components break down more slowly to keep up with plant demand.

4.5.2.9. Sulphur(S)

Sulphur distribution of the study area is represented in the figure 4.22. It is evident that high amount of-Sulphuris distributed in most of the portion of midland and all over the highland region but apart from this trend the analysis shows Sulphur deficiency in Thottapuzhaserry panchayath in the midland region. No data is available for lowland region.

The excess amount of sulphur may cause several problems to the soil like poor utilization of nitrogen, changes in pH by increasing acid or hydrogen in soil etc. Like that the deficiency may be caused by excess nitrogen on low organic matter soils and shows similar appearance to nitrogen deficiency. It may leads to problems like increased disease potential and will affect amino acids methionine and cystine in protein etc. Ammonium sulfate, Single superphosphate, Potassium sulfate, gypsum and S-coated urea can be used as Sulphur sources.

4.5.2.10. Zinc (Zn)

Zinc distribution derived from the analysis of soil quality parameter elements ofthe study area in Pamba basin is shown in the figure 4.23.The distribution shows that there is adequate amount of Zinc distributed all over the area of midland and highland region. No data is available for lowland region.

Zinc (Zn) is an essential micronutrient for plant life. The amount of zinc present in the soil depends on the parent materials of that soil. Sandy and highly leached acid soils generally have low plant available zinc. Mineral soils with low soil organic matter also exhibit zinc deficiency. Zn plays an important role in auxin formation and in other enzyme systems. A high pH decreases the desorption of Zn from soil surfaces, which also reduces the availability of Zn to plants. Zn can precipitate in the form of $Zn(OH)_2$, $ZnCO_3$ and Zn_2SiO_4 at high pH. The Zn concentration in the soil solution is largely dependent on pH .The movement of Zn to plant roots is dependent on the intensity factors (concentration) and on the capacity factors (ability to replenish). A constant and continuous supply of zinc is needed for optimum growth and maximum yield.

4.5.2.11. pH

The pH distribution of the study area derived with the help of soil analytical data shows that most of the area of lowland shows acidic soil which has ranges from slightly acidic to extremely acidic as shown in the figure 4.24.Kadapra, Thiruvanvandoor region shows strong to extremely acidic nature. Chennithala Thripperunth area shows neutral soils. The midland soils are also acidic as in the case of low land. The highland river stretch and the Vadaserikkara -Malayalapuzha stretchshows generally neutral soil with some pockets of alkaline soil. On the other hand the remaining regions of Highland is showing acidic soil with slightly to extremely acidic nature.

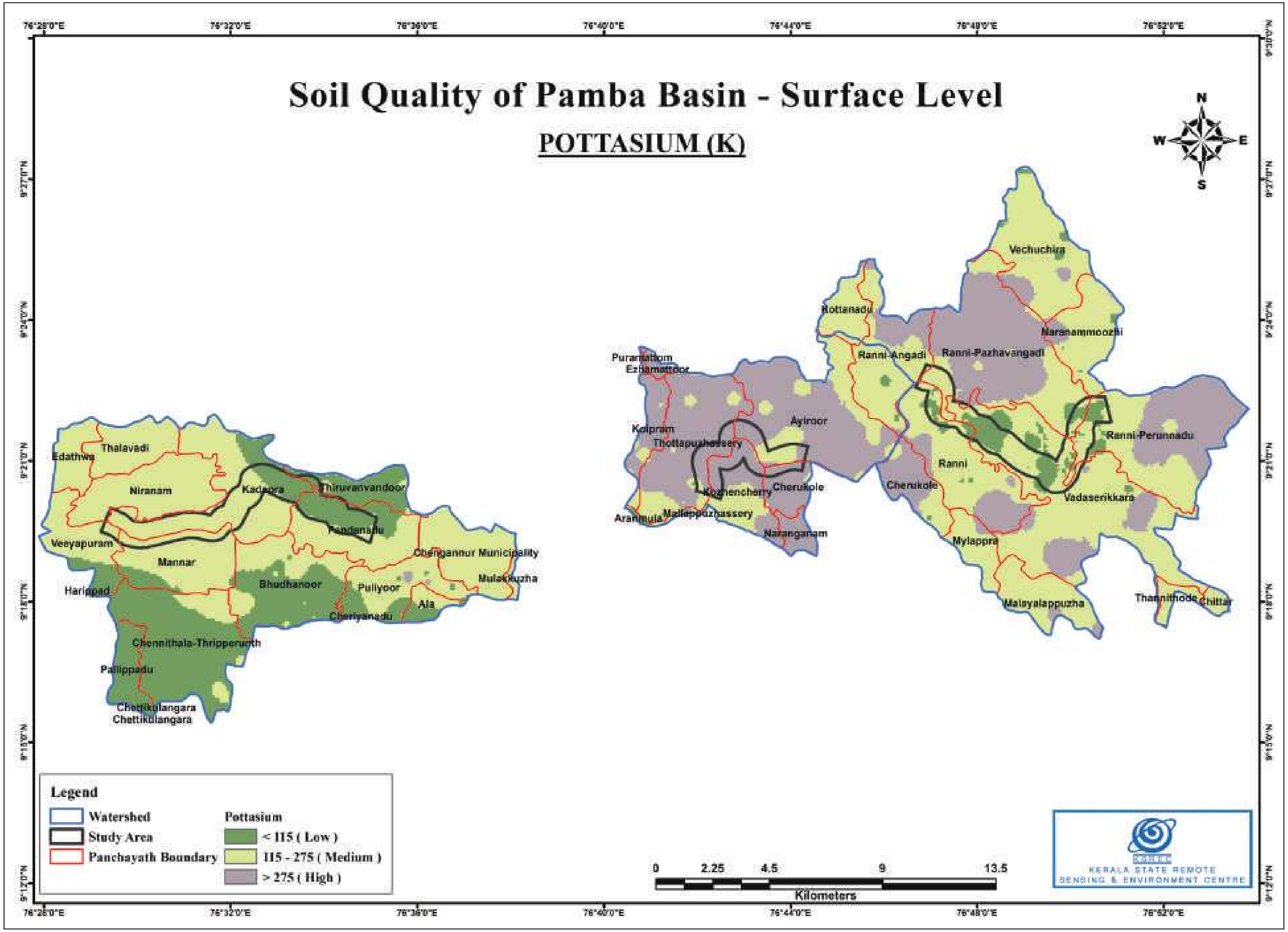


Fig: 4.21. Surface levelPottasium distribution

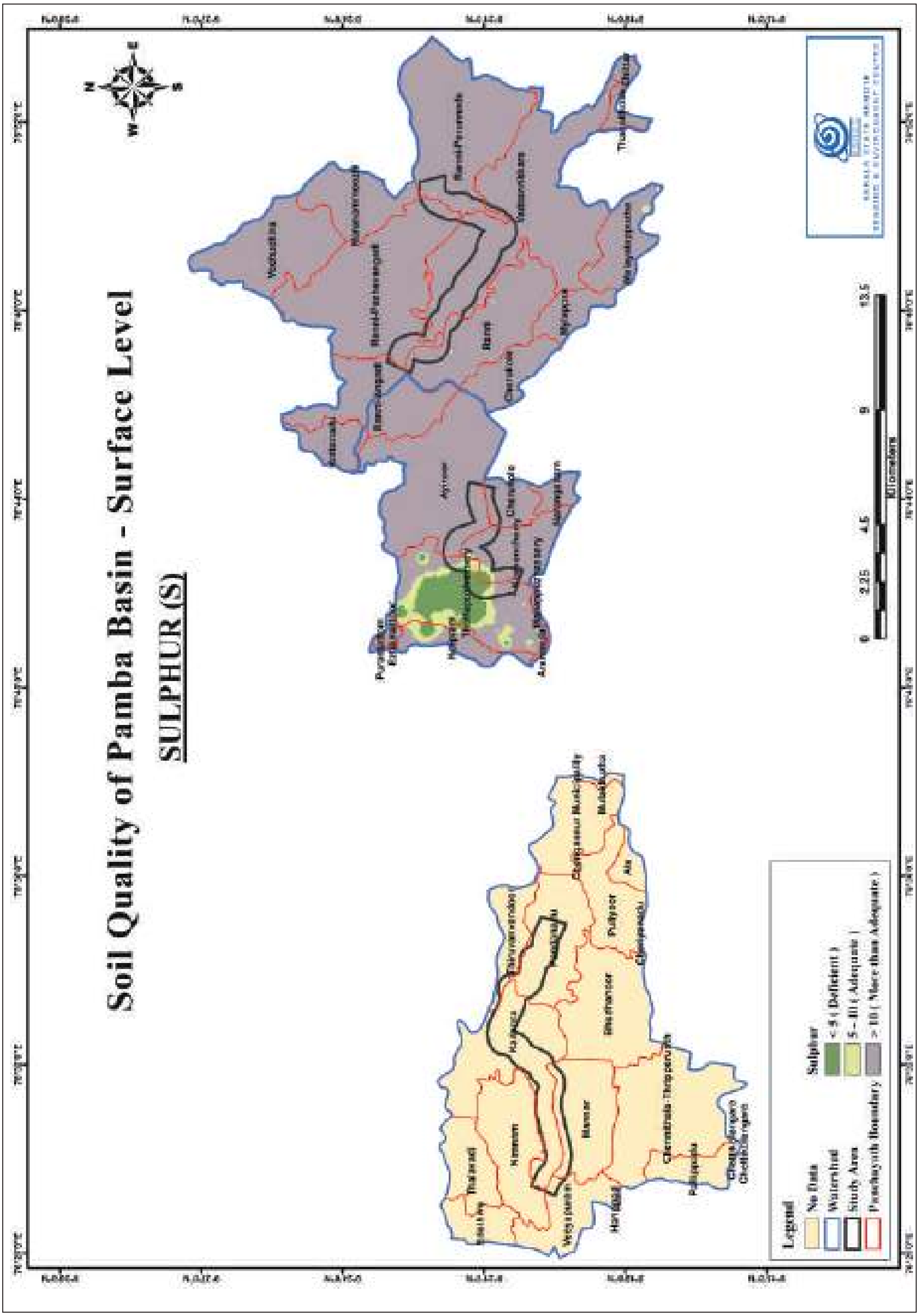


Fig: 4.22. Surface levelSulphur Distribution

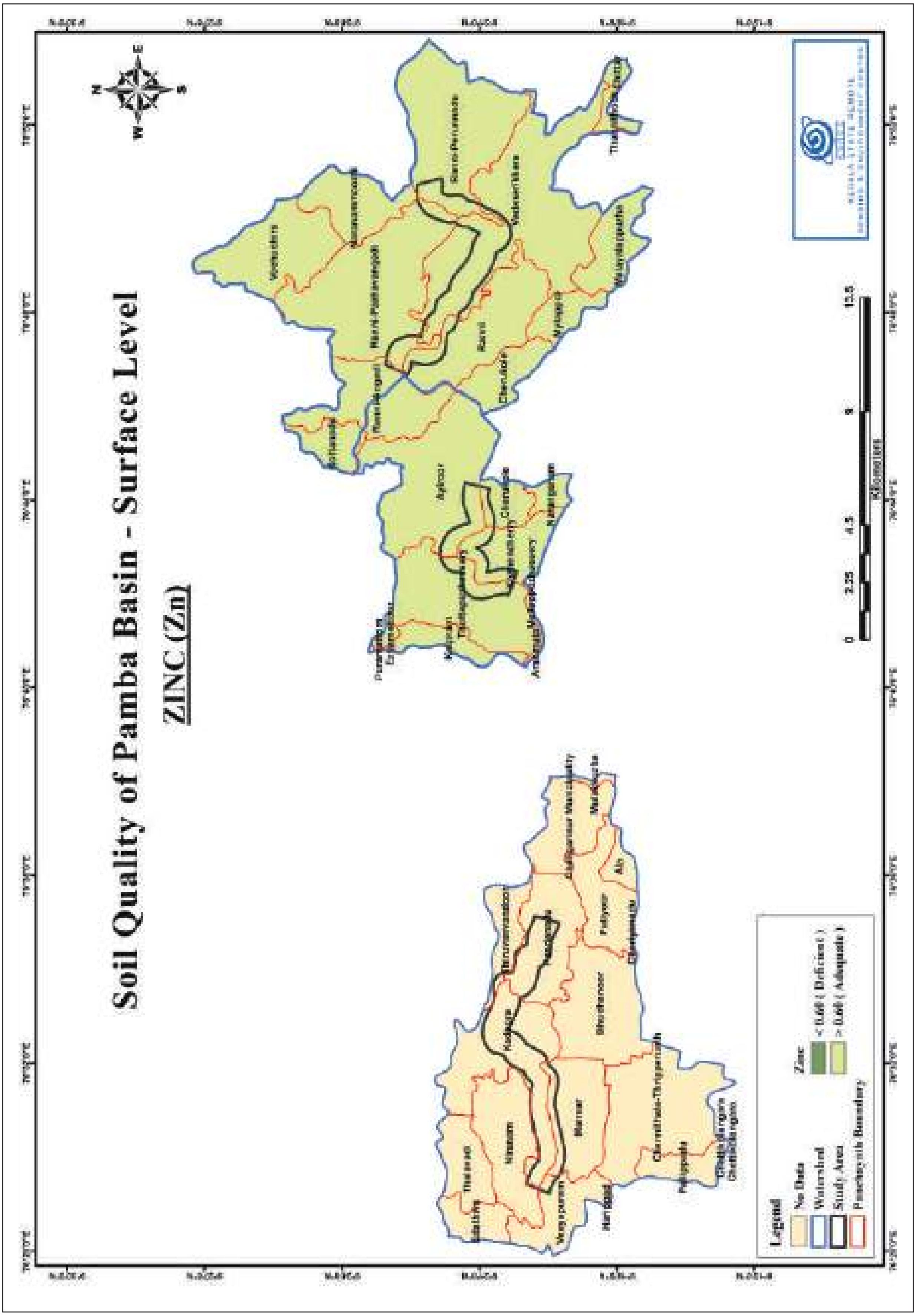


Fig: 4.23. Surface level Zinc Distribution

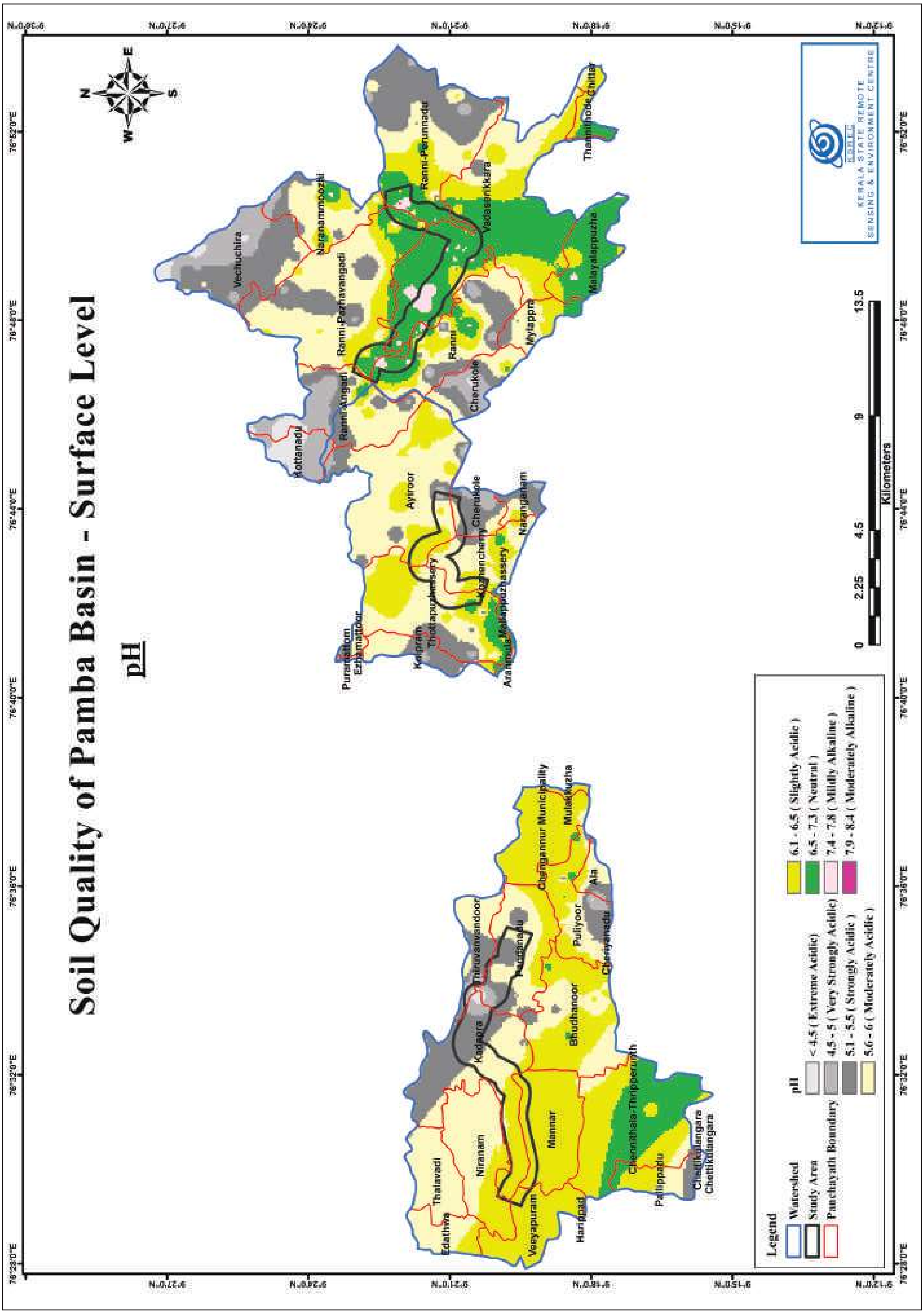


Fig: 4.24. Surface level pH Distribution

In high-rainfall areas, soils are often acidic. Alkaline soils, in contrast, are typically found in low-rainfall areas. Lime, available in either ground or powdered form, is often suggested to raise pH. Ground limestone is the slightly less potent and raises pH more slowly. The amount needed depends on the soil texture (for example, more is needed for clay than for sandy soil) and other factors.

To lower pH, common sulfur is the least expensive choice, though ferrous sulfate and aluminum sulfate are sometimes recommended instead. Ferrous sulfate, which also adds iron to the soil, is of most help to plants that show yellow leaves as well as overall poor health.Also lower the pH of alkaline soil over time by regularly applying organic amendments such as compost and manure. If the pH of soil is greater than 7.5, then the soil may contain a large amount of free calcium carbonate. This compound strongly resists changes in soil pH. Lowering the pH becomes difficult or impractical on soils that have a pH above 7.5. The pH of highly acidic soils can be raised by incorporating limestone into the soil. Hydrated lime works quicker, but over liming is more likely.

4.5.2.12. Organic Carbon (OC)

The figure 4.25shows the distribution of different levelsof organic matter content in the study area surface soil. Southern part of lowland shows low value (< 1.7) of organic matter content whereas the northern part shows medium range except Thiruvandoor and a small portion of Kadapra panchayath. Midland and highland region shows randomly distributed ranges of organic content. But the overall portion of high land region is observed with low organic matter content.

Organic carbon is an important soil property that influences all the other chemical, physical, and biological soil properties and functions. In view of this, soil organic carbon plays a pivotal role in providing the main ecosystem services.The adoption of soil management practices that reduce soil disturbance and increase the input and stabilization of organic matter can contribute not only to store carbon (C) for climate regulation, but also to enhance other ecosystem services derived from soil, such as soil stability, primary production, water-holding capacity, biodiversity, nutrient cycles, and soil fertility etc.

4.5.2.13. Porosity

The figure 4.26 shows the distribution of different levels of porosity in the study watersheds. All of midland and most area of highland region shows extreme porosity range (> 40) where eastern side shows a porosity range of 25 – 40.Northern side of lowland indicates extreme high values while southern side shows a porosity range of 25-40.

The accumulation of contents of organic matter and clay will maximize the level of the total porosity of soil in the gentler slopes of the watershed.Higher total porosity can make the soil workable and will have favorable plant rooting conditions. The reduction in total porosity may have a negative impact on the infiltration capacity and moisture content of the soil. Soils with high total porosity (e.g., clayey soil in the gentler slope areas of the study watershed) possibly results in surface water accumulation which can initiate soil erosion. From this point of view, soil and water management technology selection and implementation should consider the texture of the soil and the slope gradients of the study area.

4.5.2.14. Electrical Conductivity (EC)

The electrical conductivity distribution of the surface soil of the study area watersheds in Pamba river basin is shown in the figure 4.27. Almost every region in the basin shows low value while a small portion shows high value (>4), which is observed in Kozhanchery and Ranni- Peerumedu panchayaths. Some portions of Vadasserikkara and Ranni- Perunnadu shows the medium range of values.

Soil electrical conductivity is an important indicator of soil health. It affects crop yields, crop suitability, plant nutrient availability, and activity of soil micro-organism’s .Soil EC is affected by cropping, irrigation, land use, and application of fertilizer, manure, and compost. The electrical conductivity of soils varies depending on the amount of moisture held by soil particles. EC correlates strongly to soil particle size and texture. Soil micro organism activity declines as EC increases. This impacts important soil processes such as respiration, residue decomposition, nitrification, and denitrification. Inherent factors affecting EC include soil minerals, climate, and soil texture which cannot be changed.

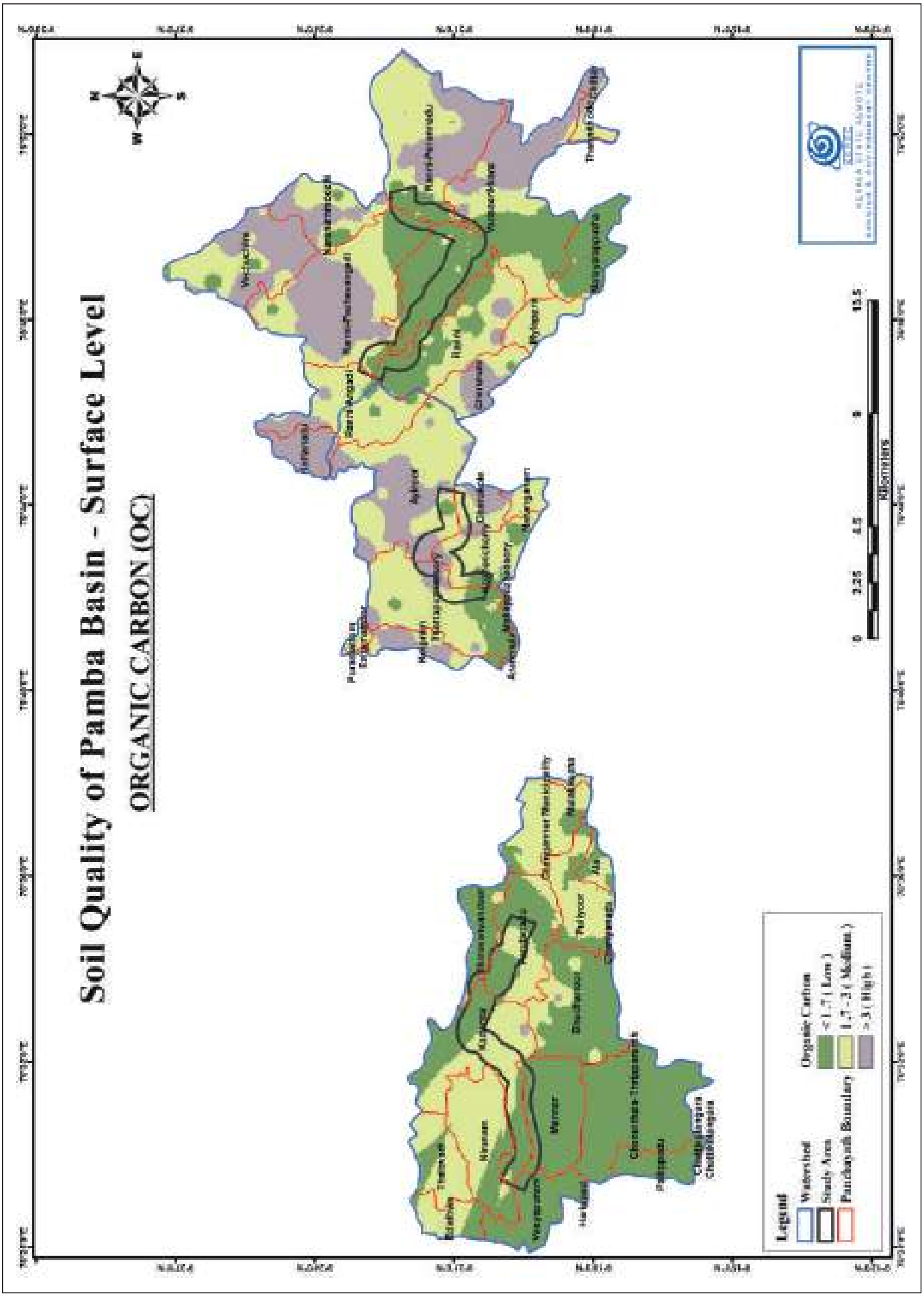


Fig: 4.25. Surface level Organic Carbon Distribution

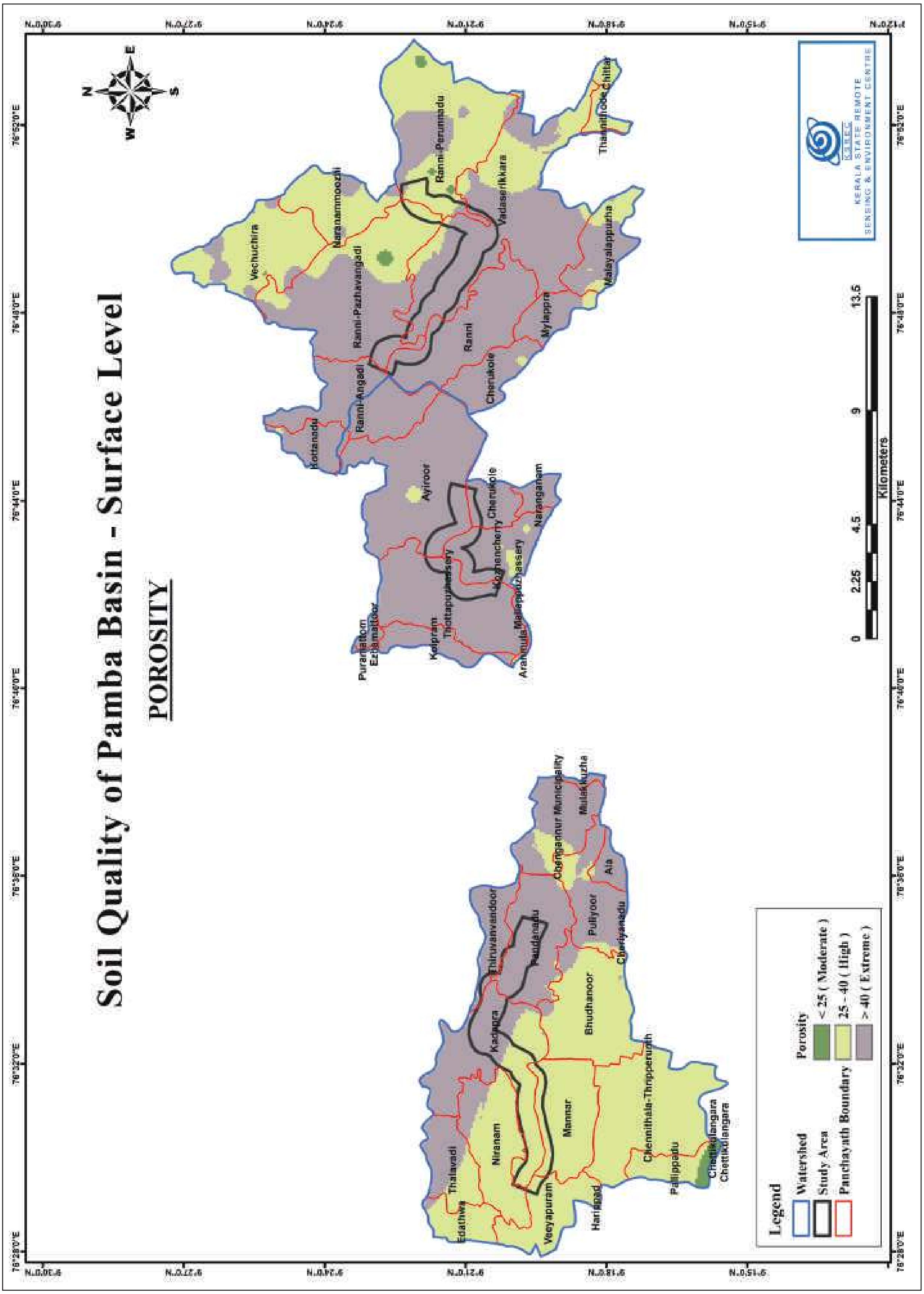


Fig: 4.26. Surface level Porosity Distribution

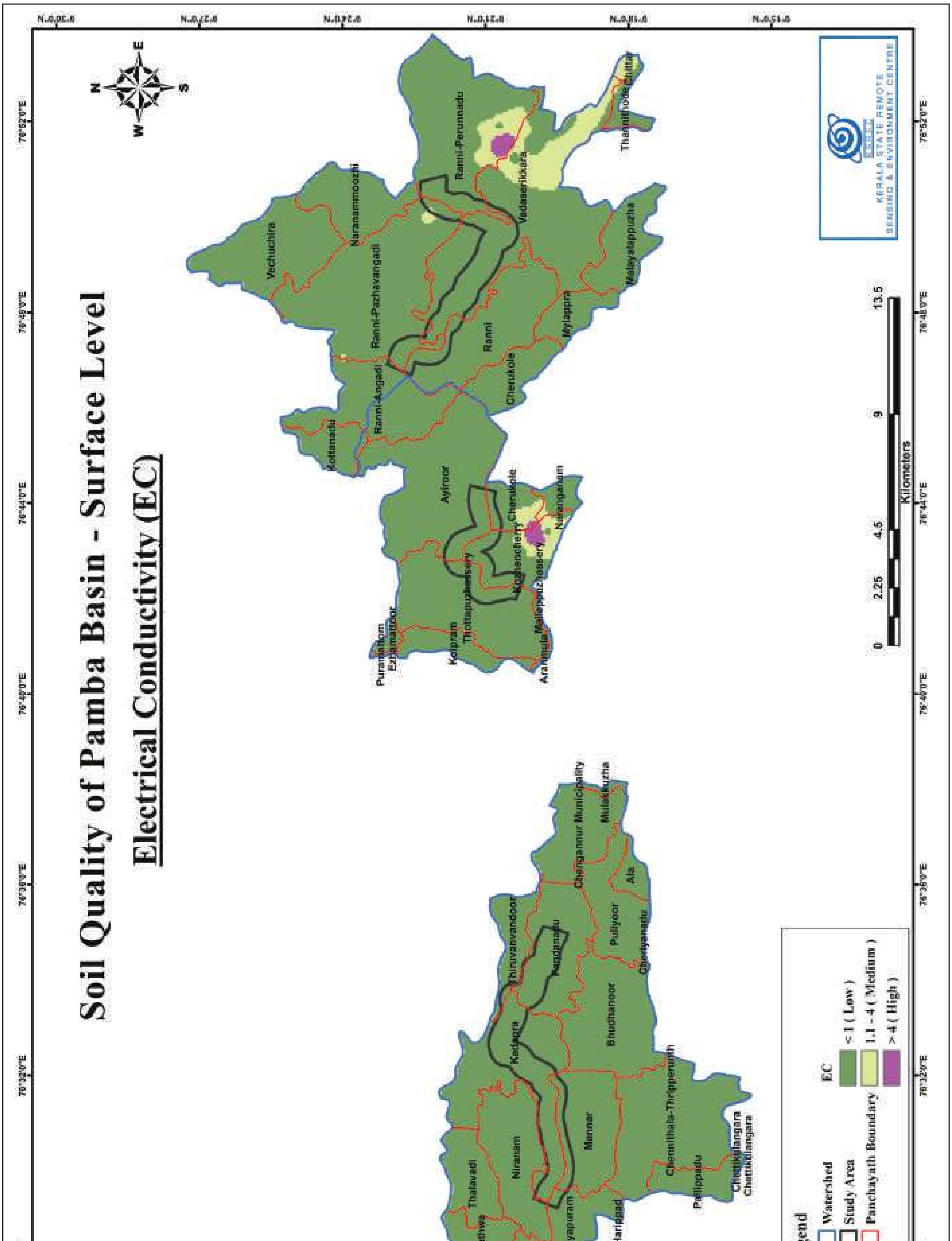


Fig: 4.27. Surface levelElectrical Conductivity Distribution

4.5.2.15. Slope

The figure 4.28 shows the different slope levels of the study area. No slope data is available for the low land portion. A small portion of the Pazhavangady panchayath and Vadasserikkara panchayath has moderately steep to steep sloping soil and all other portions have strongly sloping soil.

Cultivated land and steeper slopes have the highest bulk density and lowest total porosity. Cation exchange capacity, exchangeable magnesium total nitrogen, available phosphorus and potassium negatively correlated with slope gradient. Inhibitory effects of crops on slope runoff rate and sediment yield were enhanced with crop growth and decreased with increasing slope gradient. Crop growth and coverage could offset the impact of increasing slope gradient on runoff and sediment to some extent and reduced water and soil loss on slopes.Crop planting can effectively reduce the impact of slope gradient on soil erosion, especially during the flourishing period of crop growth.

4.5.2.16. Water Holding Capacity

Soils are made up of three main components: sand, silt and clay. The proportion of each component determines the soil texture. Each soil texture has its own Water Holding Capacity (WHC). The amount of organic matter in the soil also affects water holding capacity to a degree.Clay particles have the ability to physically and chemically “hold” water molecules to the particle more tightly than sands or silts.Soil texture and organic matter are the key components that determine soil water holding capacity.

The figure 4.29 shows the water holding capacity characteristic of the study watersheds in the Pamba river basin. Most of the areaof lowland shows low value (< 30) whereas north eastern region shows medium value. Apart from this a small region distributed in both Thiruvanvandoor and Panadanadupanchayath shows high value (> 50). High and medium range of Water Holding Capacity (WHC)is found randomly distributed in the areas of midland and highland region.

4.6. Soil Quality Model

Soil quality is defined as the soil’s capacity to function within natural or managed ecosystem boundaries and to sustain plant productivity while reducing soil degradation. Assessment of management-induced changes in soil quality is important to sustaining high crop yield.

The quality Index was built with the data generated using the weighted overlay method of spatial data analysis. The soil analytical data was converted into spatial platform as presented above. Each layer was generated with the help of ranges of variables for each class assigned as per the discussion with experts in the field of Soil Survey and Soil Conservation, Agriculture, Irrigation, Geology etc. These layers are further integrated in the spatial platform by assigning ranks to each class and weightages to each layer.

4.6.1. Surface Parametric Model 1

As the data availability has got some limitations as shown in the above layers the integrated analysis using the weighted overlay technique was done in three phases. The first model named “Surface Parametric Model 1” was built with the parameters having complete data availability in the surface samples (Fig.4.30). Further and integrated model with all the surface sample data was generated as “Surface Parametric Model 2” (Fig.4.31). The classification followed for the Surface Parametric Model is given in the table 4.2.

The figure 4.30 shows the distribution of surface level soil quality in the study watersheds of the Pamba river basin. For this analysis pH,EC,OC,P,K,WHC, Porosity values observed from the study areawas used. The model shows that the lowland surface soil is good for agriculture with only a stretch in the Chengannur Municipality area is not suitable for agriculture.In the case of midland and highland major stretches of Puramattom Ezhamattoor- Ayiroor – Cherukole – Naranganamand Ranni Pazhayangadi – Vadaserikkara - Malayalapuzha show not suitable for agriculture.The Aranmula – Thottapuzhasseri –Kozhenchery stretch, Kottanadu- Ranni Angadi – Ranni Stretch and the eastern stretch including Veluchira have surface soil adequate for agriculture.

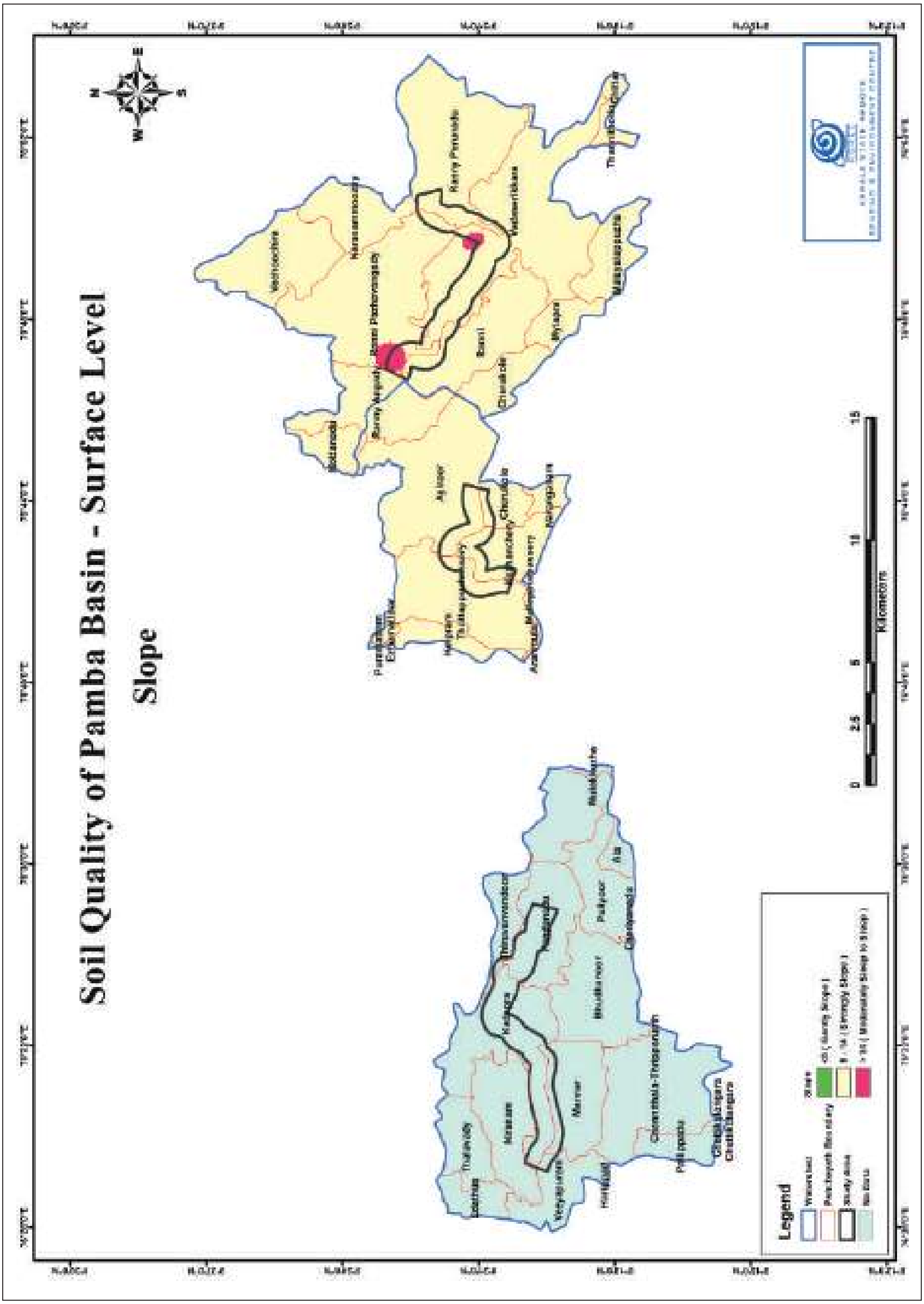


Fig: 4.28. Slope Distribution of Surface Soil

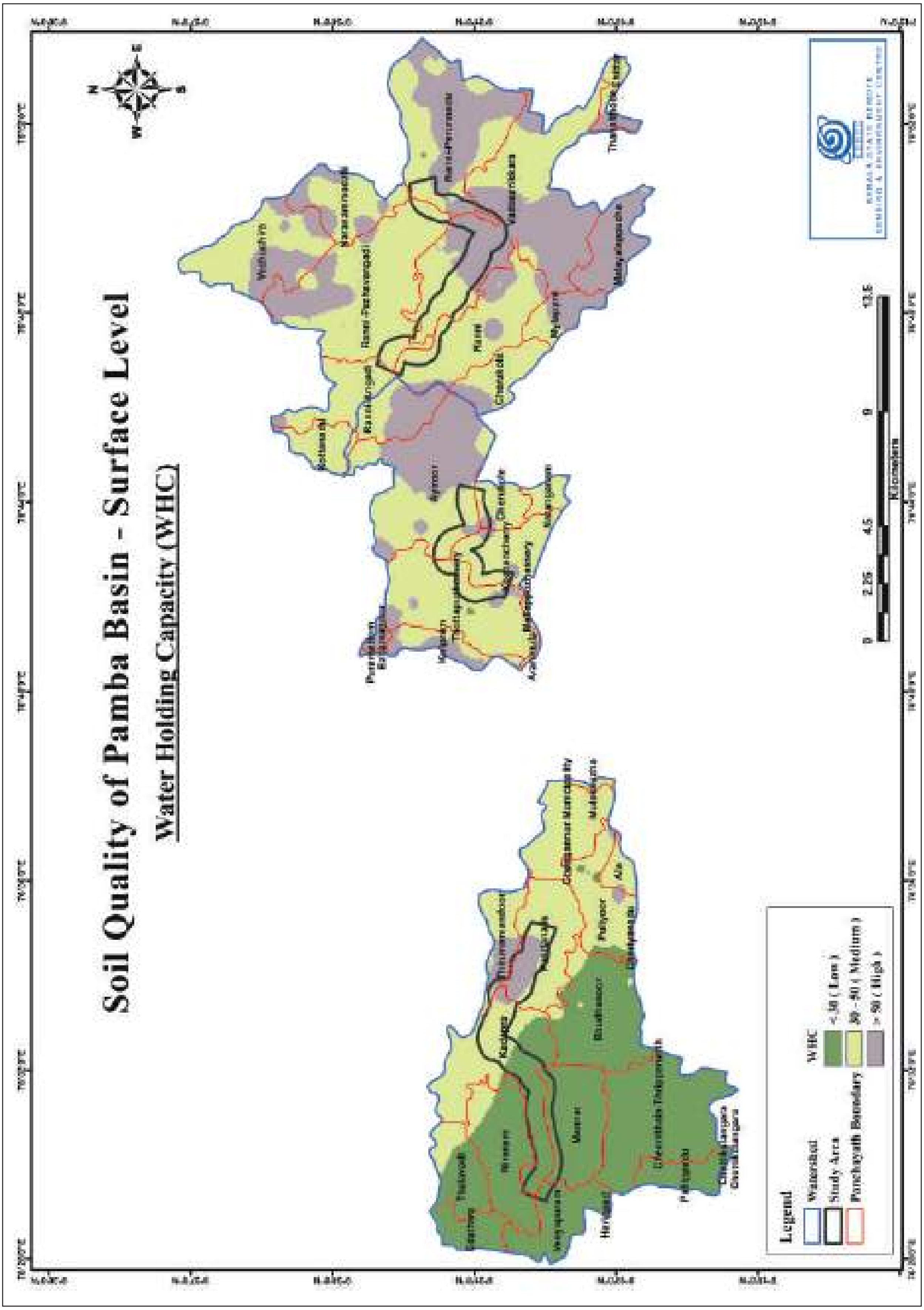


Fig: 4.29. Water Holding Capacity of Surface Soil

Surface Minerals	Range	Quality	Surface Minerals	Range	Quality
pH	<4.5	Extremely acid	Water Holding Capacity	<30	Low
	4.5 – 5.0	Very Strongly acid		30 -50	Medium
	5.1 – 5.5	Strongly acid		>50	High
	5.6 – 6.0	Medium acid	Porosity	<25	Moderately Porous
	6.1 – 6.5	Slightly acid		25 – 40	Highly Porous
	6.6 – 7.3	Neutral		>40	Extremely Porous
	7.4 – 7.8	Mildly alkaline	Iron	<5	Deficient
	7.9 – 8.4	Moderately alkaline		>5	Adequate
	8.5 – 9.0	Strongly Alkaline	Manganese	<1	Deficient
	>9.0	Very Strongly Alkaline		>1	Adequate
Organic carbon	<1.7	Low	Zinc	<0.60	Deficient
	1.7 - 3	Medium		>0.60	Adequate
	>3	High	Copper	<0.12	Deficient
Electrical Conductivity	<1	Low		>0.12	Adequate
	1 - 4	Medium	Calcium	<300	Deficient
	>4	High		>300	Adequate
Phosphorus	<10	Low	Magnesium	<120	Deficient
	10 - 24	Medium		>120	Adequate
	>24	High	Boron	<0.5	Deficient
Potassium	<115	Low		>0.5	Adequate
	115 - 275	Medium	Sulphur	<5	Low
	>275	High		5 – 10	Medium
				>10	High

Table 4.2. Classification derived for parameters of surface samples

4.6.2. Surface Parametric Model 2

As there was information not available for all the parameters for the low land region, the complete list of Surface Sample parameters was not used for the Surface Parametric Model 1. Inorder tohave thecomplete knowledge of parameteric influence on the soil quality a weighted overlay analysis for all the Surface Sample variables were used to build the Surface Parametric Model 2.The classification followed for the Surface Parametric Model 2 is given in the table 4.2.

The model shown in the figure 4.31explains the surface level soil quality of the study area. For the analysis of this all the surface parametric values include pH, OC, EC, Potassium, Phosphorous, Water holding capacity, Porosity, Iron, Zinc, Manganese, Copper, Calcium, Magnesium, Boron, Sulphur were considered. On the basis of this analysis some patches of midland and high land, especially the RanniPerunadu, Vadaserikkara and South of RanniAngadihave high parametric value which shows that these areasare not suitable for Agriculture. It can be found that there is a decrease in the not suitable areas when all the parametric values are considered for the model. The overall distribution of the soil quality is adequate for agriculture.As there was missing information for the lowland portion, that segment was not considered and will be the same as Surface Parametric model 1.

4.6.3. Surface Nutrient Model

Plants need thirteen different minerals from the soil in order to fully develop. Six of these nutrients are needed in large quantities. These six essential nutrients are nitrogen, phosphorus, potassium, magnesium, sulfur and calcium. They help create new cells, which then organize into plant tissue. Without these nutrients, growth and survival would not occur.

As the influence of nutrients in plant growth is highly important a nutrient model with the available nutrient values alone were worked out to build a Nutrient model leaving other physical parameters of soil quality. Surface level nutrients like Fe, Mg, Mn, Zn, Cu ,Ca, B,S were taken for the analysis purpose.The weighted overlay method for the eight nutrient data available for the high land and mid land region were used to build the Nutrient model as shown in the figure 4.32.

The model explains the nutrient based surface level soil quality of the study area.All the portions of midland and highland have adequate soil quality. This shows that these portions are good for agricultural purposes.Only a very minute portion of Vechuchira panchayath showed deficient mineral value.

4.6.4. Micro Nutrient Model

The plant nutrients are divided into two groups. Those required by plants in large amounts are called macronutrients; these are nitrogen, phosphorus, potassium, calcium, magnesium.Plant micronutrients, needed in tiny amounts include iron,zinc, boron, manganese, copper and sodium. Macronutrients and micronutrients are all critical to normal plant growth and development; they are simply needed in different amounts.

Among the micronutrients, Fe, Mn, Cu, Zn are taken up by plants in their cationic forms, and B and Cl are taken up by plants in their anionic forms. Fe and Mn are often present in large quantities in most soils, and adsorption reactions play little role in controlling their plant availability in soils.

The available Micro nutrient values were analyzed in the spatial domain as explained earlier using the weighted overlay analysis to build the Micro Nutrient Model. The micro minerals Fe, Mn, Zn, Cu, Ca, Mg, B, and S were considered for the model. The classification of the Micro Nutrient values is as given in the Table 4.3.

Micro Minerals	Range	Quality	Micro Minerals	Range	Quality
Iron	< 5	Deficient	Calcium	< 300	Deficient
	> 5	Adequate		> 300	Adequate
Manganese	< 1	Deficient	Magnesium	< 120	Deficient
	> 1	Adequate		> 120	Adequate
Zinc	< 0.60	Deficient	Boron	< 0.5	Deficient
	> 0.60	Adequate		> 0.5	Adequate
Copper	< 0.12	Deficient	Sulphur	< 5	Low
	> 0.12	Adequate		5-10	Medium
				> 10	High

Table 4.3.Classification derived for parameters of Micro Nutrient Samples

The Micro Nutrient Model shown in figure 4.33 explains the micro level soil quality of the study area. A very small portion of Vechuchira and Vadasserikkara panchayaths have deficient mineral value. All other portions have adequate mineral range suitable for agriculture. From the Micro Nutrient model point of view it can be considered that most portion of the study area is suitable for agricultural purposes with adequate amount of Micro Nutrients.

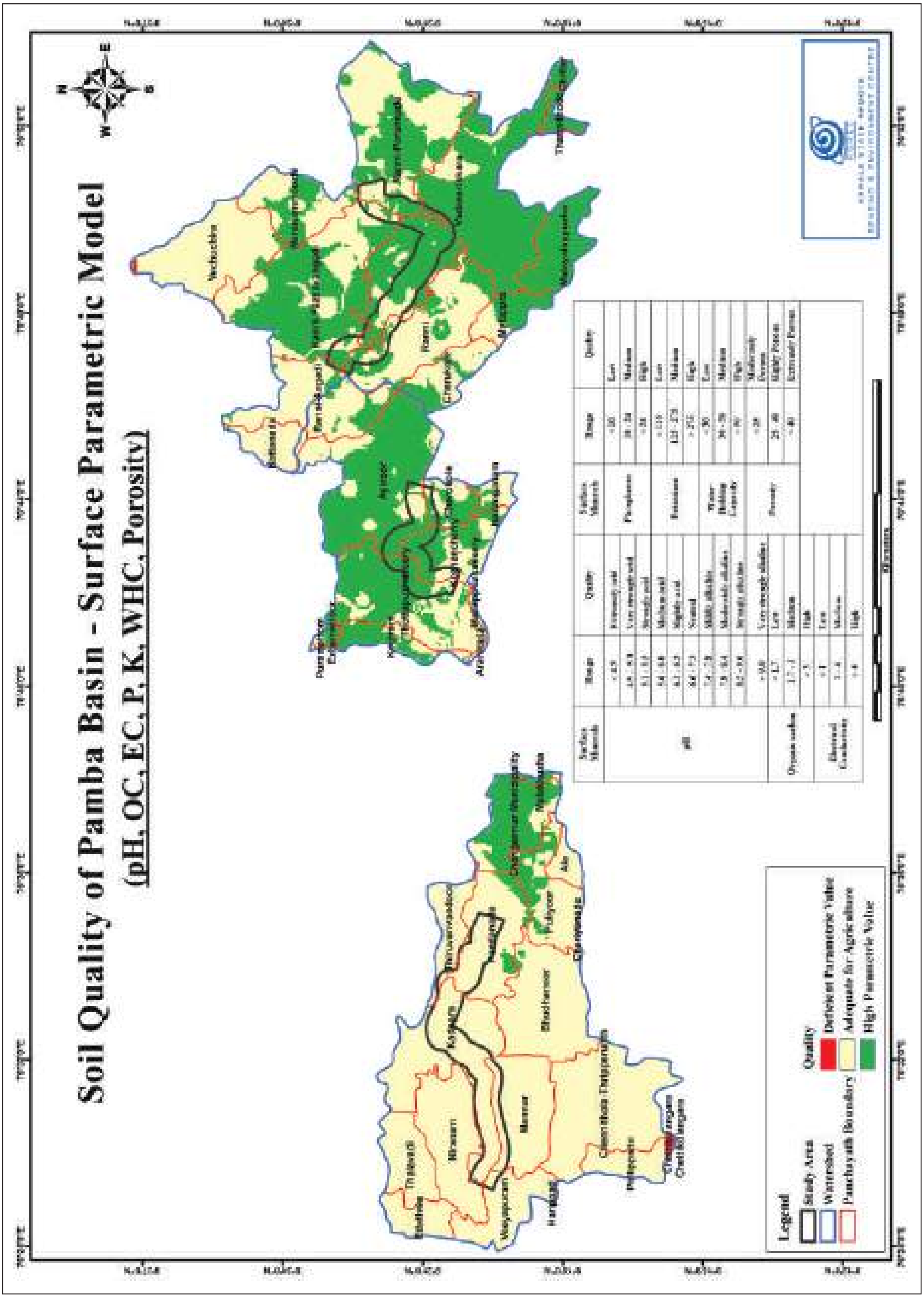


Fig: 4.30 SurfaceParametric Model - 1

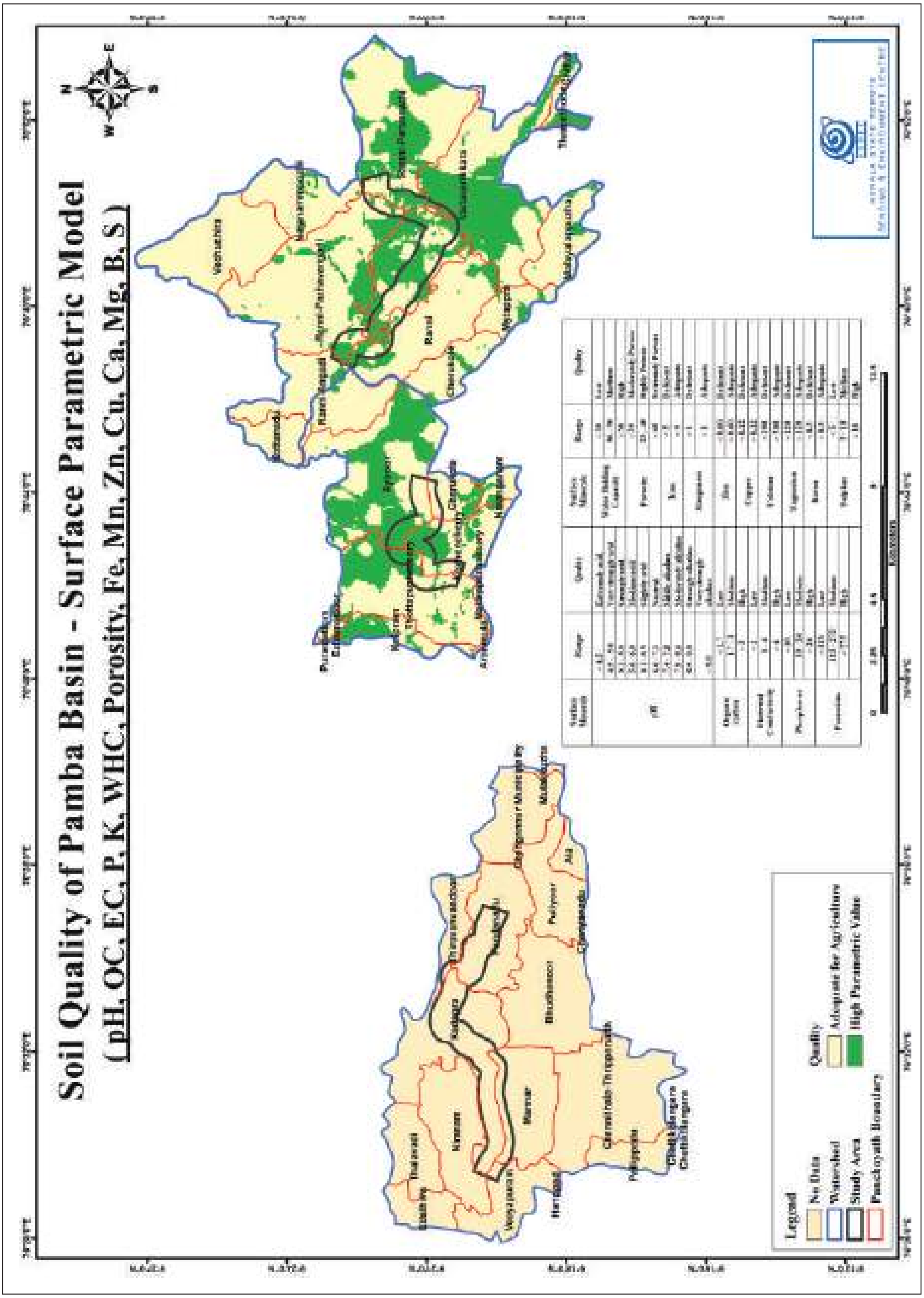
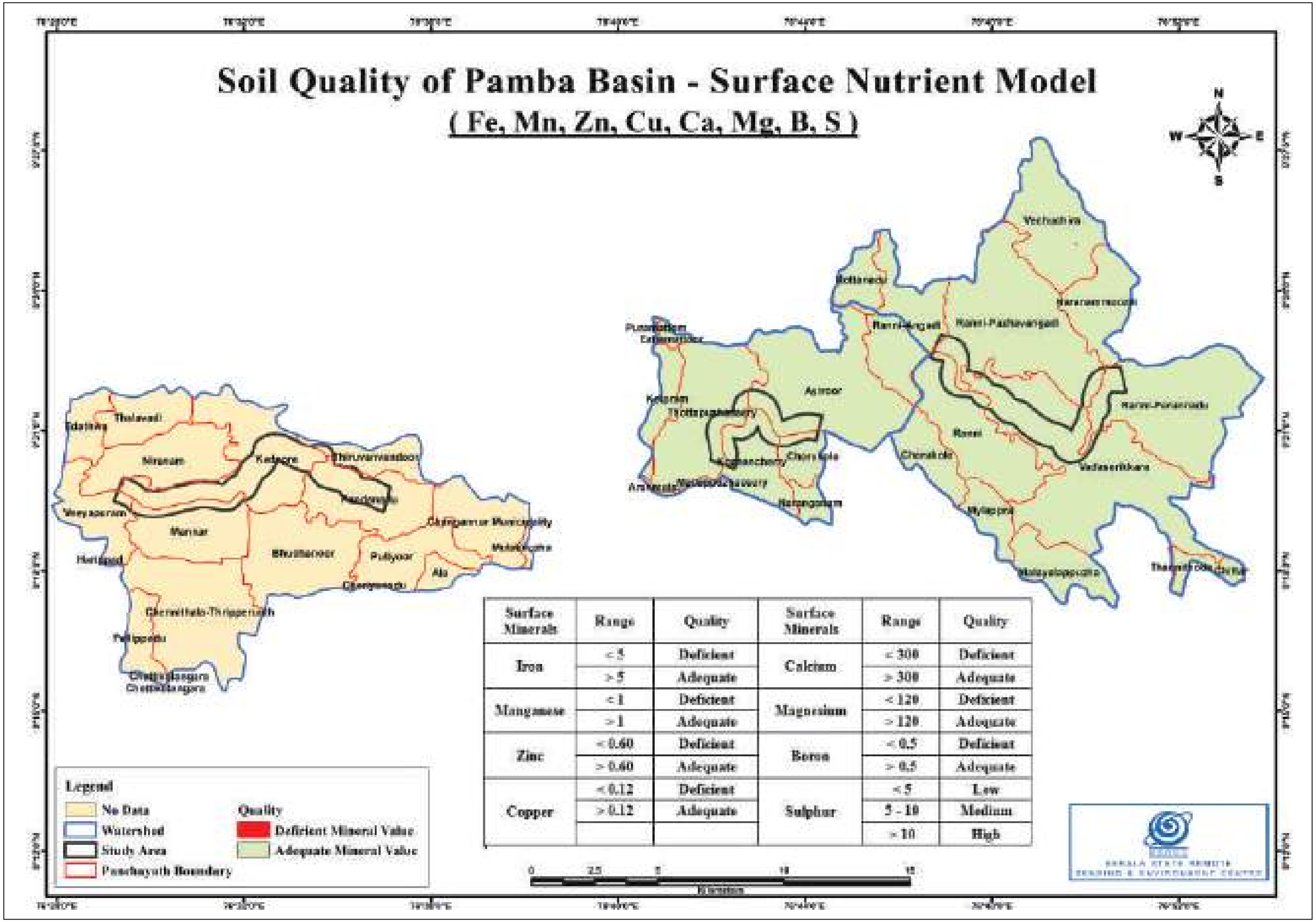


Fig: 4.31. Surface Parametric Model - 2



Surface Minerals	Range	Quality	Surface Minerals	Range	Quality
Iron	< 5	Deficient	Calcium	< 300	Deficient
	> 5	Adequate		> 300	Adequate
Manganese	< 1	Deficient	Magnesium	< 120	Deficient
	> 1	Adequate		> 120	Adequate
Zinc	< 0.60	Deficient	Boron	< 0.5	Deficient
	> 0.60	Adequate		> 0.5	Adequate
Copper	< 0.12	Deficient	Sulphur	< 5	Low
	> 0.12	Adequate		5 - 10	Medium
				> 10	High

Fig: 4.32. Surface Nutrient Model

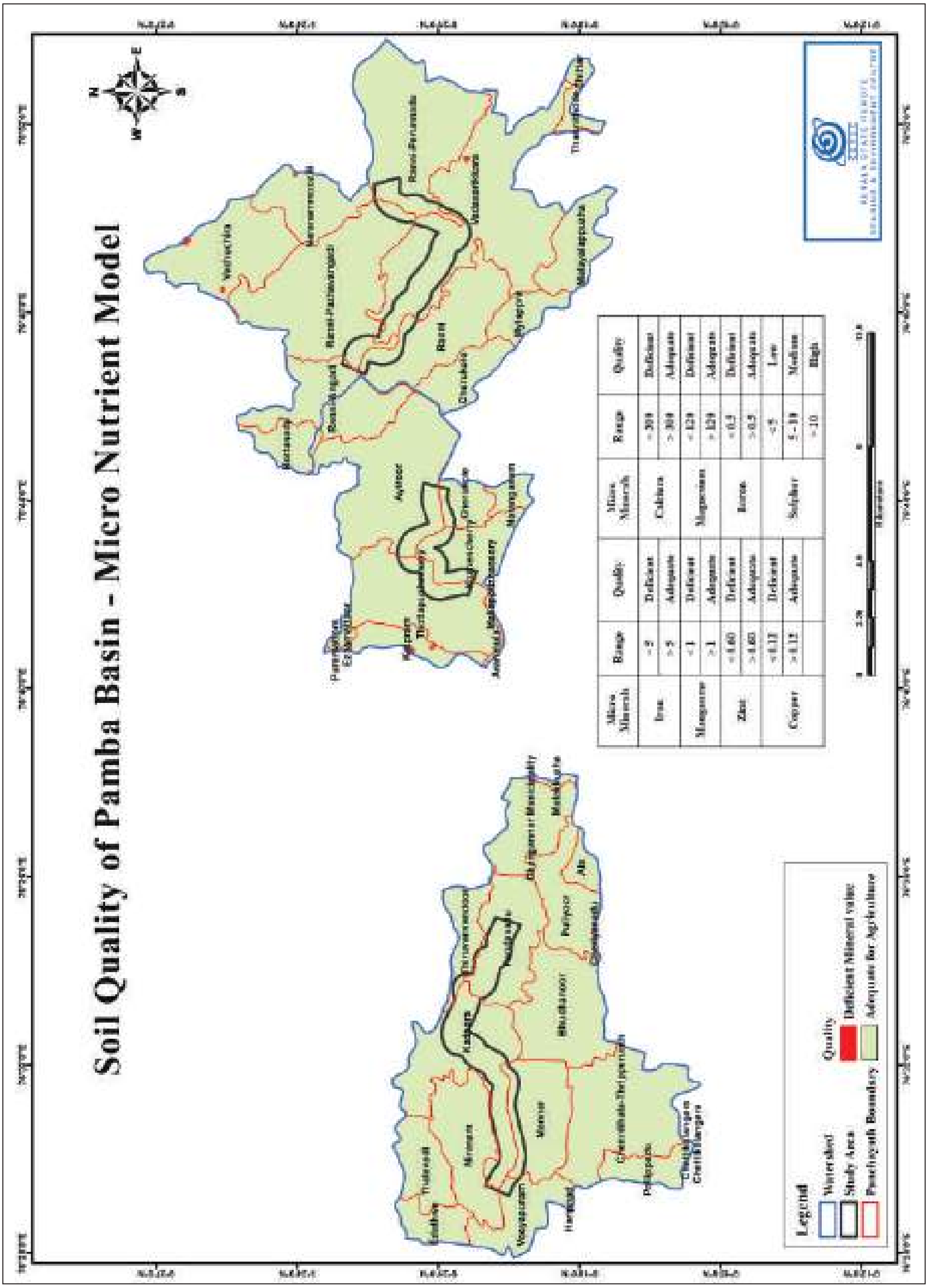


Fig: 4.33. Micro Nutrient Model

CHAPTER V

RIVER MORPHOLOGY AND LANDUSE DYNAMICS

5.1. Introduction

Changes in the morphology of river channels and flood plains over a short span of time has got bearing to the human intervention either in the form of Land Use changes like Dam construction, sand mining etc. or will have bearing to the natural events like extreme rainfall and large floods. In an extreme rainfall event different types of floods (including catastrophic, extreme, large, and flash floods) could occur in a watershed. The type of flood depends on watershed metric characteristics, rainfall characteristics (duration, intensity, and depth), and human activities (urban area, hydrological/hydraulic contorting activities, etc.) in watershed and floodplain areas. Millennia of human disturbances in watershed areas have changed flood characteristics and river channel morphology (Phillips, 2002; Cenderelli and Wohl, 2003; Alayande and Ogunwamba, 2010; Hooke, 2016a; Yousefi et al., 2017b). The power and the kinetic energy of extreme floods is very high, the role of extreme floods in erosion and deposition processes of fluvial landscape evolution is very important, especially in large river systems where the concentrations of human population and activities are high (Alayande and Ogunwamba, 2010; Hazarika et al., 2016; Maantay and Maroko, 2009; Van De Wiel et al., 2011; Yousefi et al., 2017a).

5.2. Morphology Changes and Land Use Change Dynamics(Pre &Post Flood)

For the purpose of analyzing the Land Use dynamics and morphology changes of the three segments of the study area before and after the flood, the Drone survey derived data (2018 ----) was used for the development of post flood land use and World View data (2017 -----) was used for the pre flood land use. The land use data generated is for the 1 km buffer of each river segment. Very high resolution land use data of the area was generated with the help of drone derived data for the post flood period and World view data for the pre flood period which was used for identifying the land use changes using the spatial data analysis techniques in the GIS platform.

The morphological aspects of the river were derived with high level of accuracy for the pre and post flood periods and were used to identify the changes using the spatial analysis methods. The study segments in the low land, mid land and the high land were individually mapped and analysed to derive the change characteristics at each segments. The morphological changes of the river as a component of the land use dynamics for each study segment are characterized below.

5.2.1. Low Land Morphology and Land Use Characteristics

5.2.1.1. River Morphology and Land Use of Low Land- 2017(Pre Flood)

The morphological aspects of the low land river segment were mapped along with the land use, for the pre flood period of 2017 and were generated with the help of visual interpretation and onscreen digitizing of the very high resolution data from World View. The land use classes derived and the area of each class is given in the table 5.1. The land use map along with the morphological characteristics of the river generated is shown in the figure 5.1.

Year_2017 Land Use	Count_2017	Sum_Area_Sq.km.	Percentage Area
Banana	2	0.00573539300	0.04518200000
Builtup	6499	1.09120759074	8.59626000000
Canal	2	0.00140908053	0.01110040000
Channel Bar	31	0.13690016026	1.07846000000
Coconut	42	0.19476179738	1.53428000000
Fallow	44	0.53393084711	4.20617000000
Mixed Plantation	217	6.96807872566	54.89270000000
Paddy	99	1.81080671453	14.26510000000
Pond	15	0.01436626155	0.11317400000
River	6	1.42454756058	11.22220000000
Road	10	0.21728043418	1.71168000000
Sugarcane Field	9	0.04859862390	0.38284800000
Vegetable Crop	19	0.03407565858	0.26843900000
Wasteland	26	0.11876004500	0.93556100000
Water Logged	31	0.09352947013	0.73680100000
	Total	12.69398836313	100.00000000

Table 5.1. Land Use Statistics Low Land 2017 (Pre flood)

Figure 5.1 shows landuse distributionin low land portion of Pamba basin for the year 2017. In the lowest elevation of the terrain the river is flowing without completely occupying the available width of the river leaving channel bars on either sides which are generally stabilised to form a landuse class. There is no midchannel bars or the braided bars identified. The locations of bars are determined by the geometry of the river and the flow through it. Bars reflect sediment supply conditions, and can show where sediment supply rate is greater than the transport capacity.

The terrain is undulating such that the next level of elevation occupies the paddy fields and fallow landwhich covers a predominant area along with the mixed plantation found in the residual mounts of the terrain. The other predominant category of land use in the residual mounts is the coconut plantation. The other landuse features also includes sugarcane, grassland, wasteland, waterlogged area etc. Covering the entire stretch of land without elevation restrictions is the major land use class of Built up and roads. The development of built up and roads are increasing unprecedentedly in the region which has invaded the paddy fields, low lying area and other natural water holding structures leading to the development heavy impact of floods.

5.2.1.2. River Morphology and Land Use of Low Land - 2018 (Post Flood)

Similarly the morphological aspects of the low land river segment were again mapped along with the land use, for the post flood period of 2018 in order to identify the changes that happened due to the flood of August 2018. For the same very high resolution images were generated based on drone survey and interpreted to derive the river characteristics and land use classes and the area of each class is given in the table 5.2. The land use map along with the river morphological characteristics generated is shown in the figure 5.2.

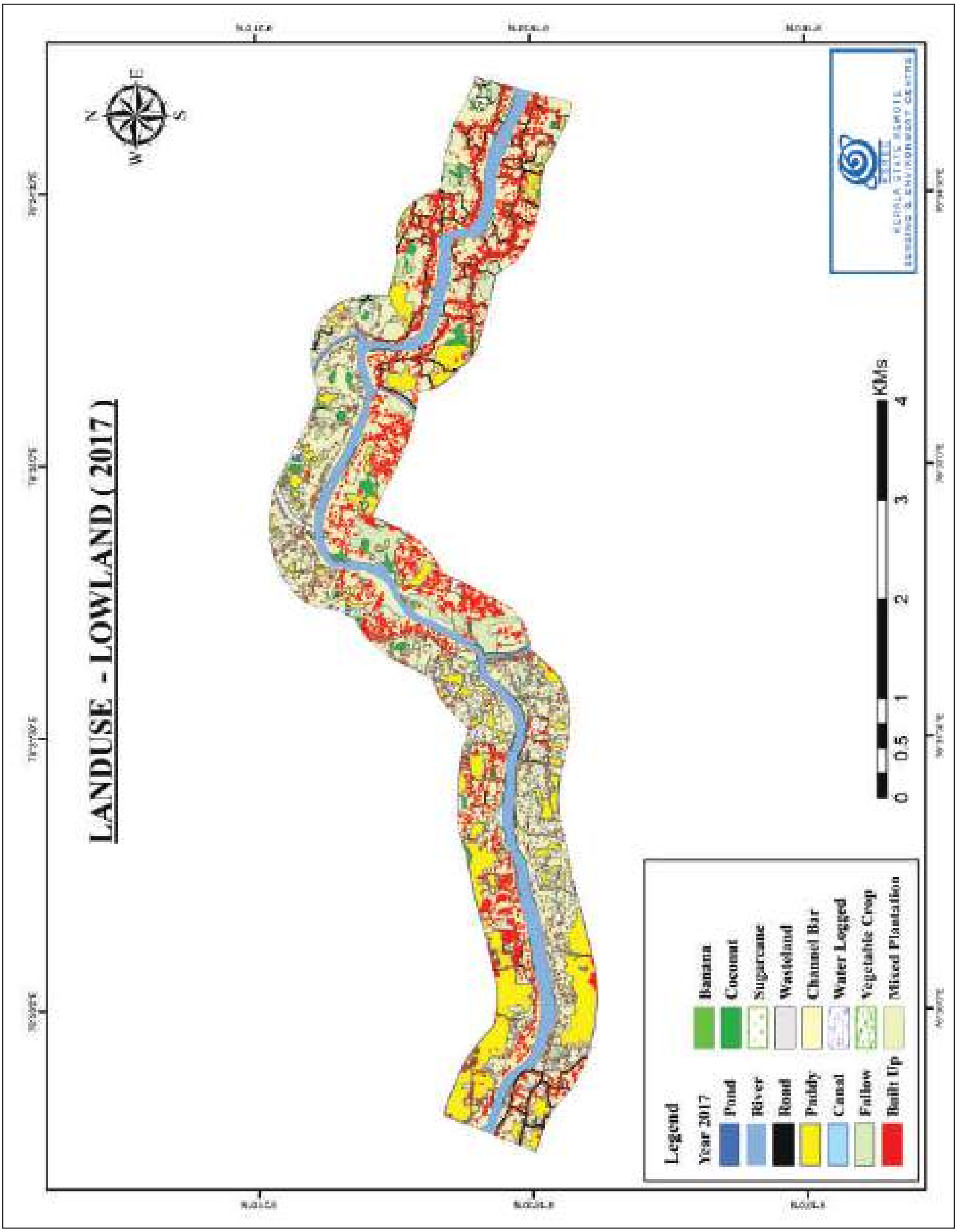


Fig: 5.1. Land Use of Low land 2017 (Pre flood)

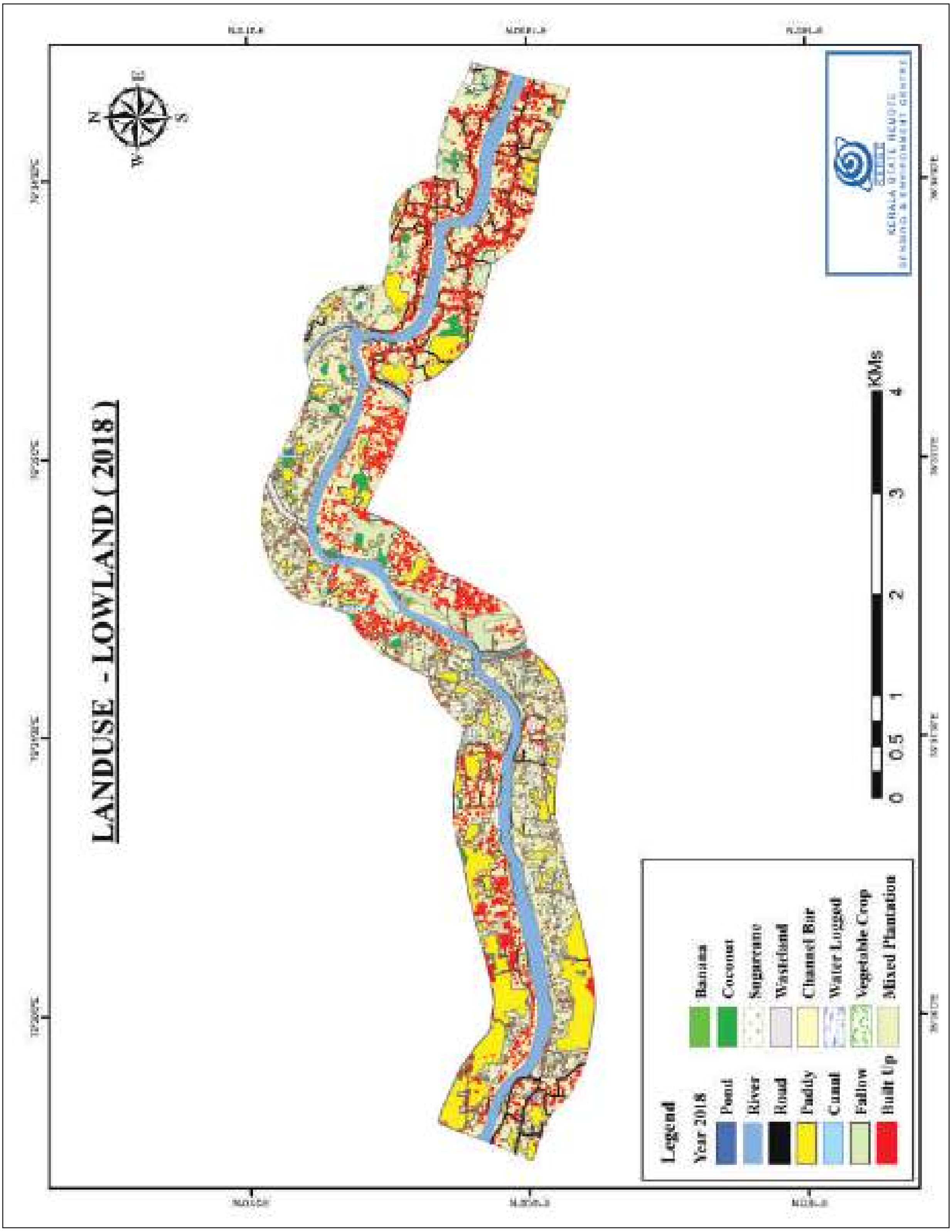


Fig: 5.2. Land Use of Low land 2018 (Post flood)

Year_2018 Land Use	Cnt_Year_2	Sum_Area_S	Percentage
Banana	2	0.00573539300	0.04518200000
Builtup	6499	1.09120759074	8.59626000000
Canal	2	0.00140908053	0.01110040000
Channel Bar	31	0.13690016026	1.07846000000
Coconut	42	0.19476179738	1.53428000000
Fallow	48	0.53718375622	4.23180000000
Mixed Plantation	213	6.96482581654	54.86710000000
Paddy	99	1.81080671453	14.26510000000
Pond	15	0.01436626155	0.11317400000
River	6	1.42454756058	11.22220000000
Road	10	0.21728043418	1.71168000000
Sugarcane Field	9	0.04859862390	0.38284800000
Vegetable Crop	19	0.03407565858	0.26843900000
Wasteland	26	0.11876004500	0.93556100000
Water Logged	31	0.09352947013	0.73680100000
	Total	12.69398836313	100.00000000

Table 5.2. Land Use Statistics Low Land 2018 (Post flood)

It is found that, as shown in the Figure 5.2, landuse inlow land portion of post flood Pamba basin for the year 2018, does not have a major change except for the river channel boundaries and the sand bar cahracteristics. Most of the landuse features is observed same as that of the features observed during 2017. Small portion of mixed vegetation area is converted to grassland. The other features in the map includes roads, pond, built ups, canal structures etc. All land use and land cover features derived can be visualized in the figure 5.2.

5.2.1.3. Post flood Morphology and Land Use Change Characteristic of Low Land

The land use dynamics of the low land region as a result of the flood impact is found to be limited to the river morphology where there is erosion and submergence of sand bars and river occupying its width. The flooding to the river banks has resulted in flood deposits but has not changed or destroyed the land use, except for the case of waterlogging in the paddy region. The pivot table 5.3 shows the change of classes from one to other representing the loss in area and the gain in area on the other class.Figure 5.3 helps visualise land use change in lowland portion of Pamba basin during the years 2017-18.Major change observed is that the river banksare occupied by the river and the same is represented in the map as river boundary change. Other change observed is that the mixed vegetation is converted to grass land. All other features which are having no observable change are represented using grey colour in the figure 5.3.

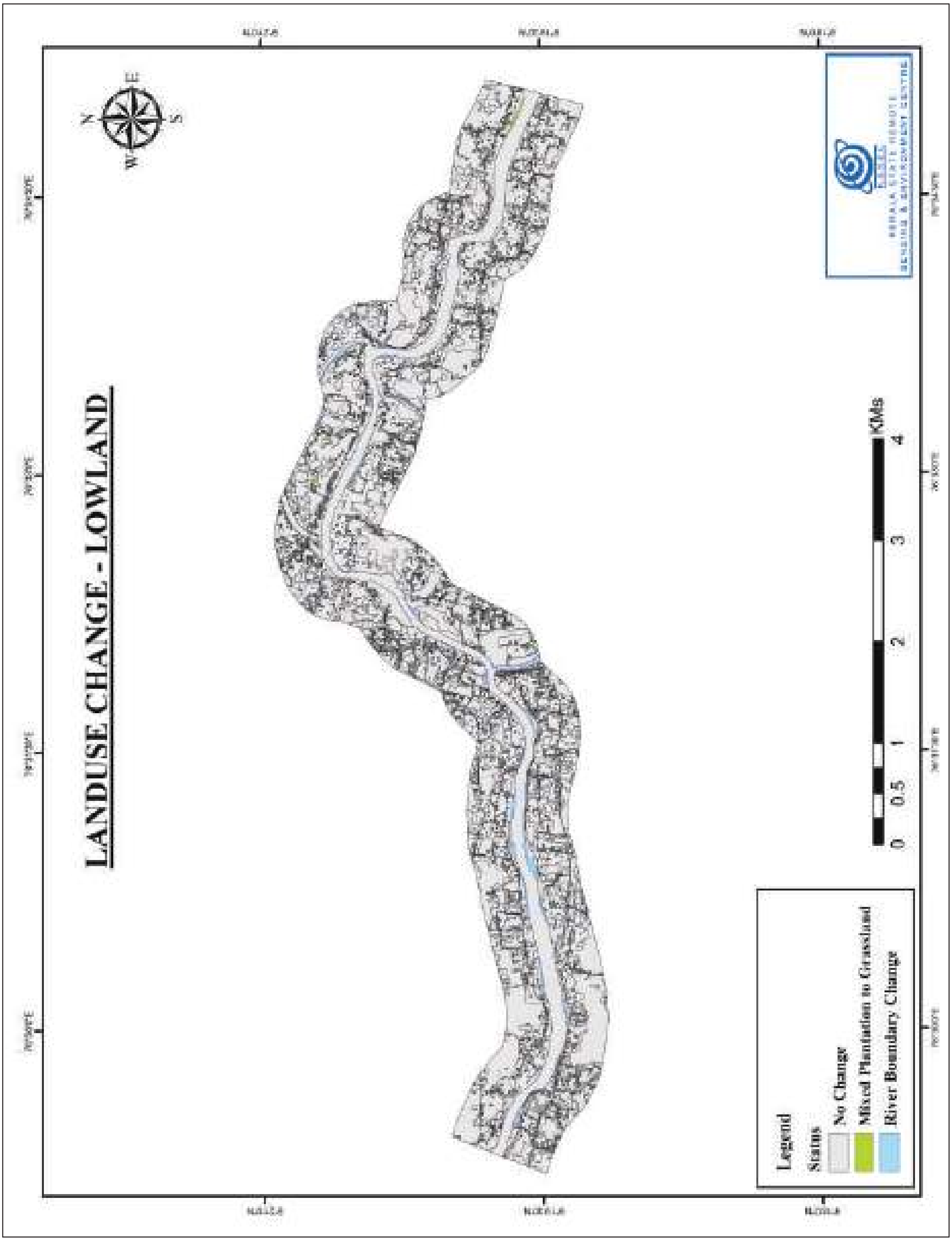


Fig: 5.3. Land Use Dynamics of Low land

2017/2018 Sq.Km.	Banana	Builtup	Canal	Chan-nel_Ba	Coconut	Fallow	Mix ed_ Plan	Paddy	Pond	River	Road	Vege-table	Waste-land	Sugar-cane_	Water_ Logg
Banana	0.005735393	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Builtup	0	1.091207591	0	0	0	0	0	0	0	0	0	0	0	0	0
Canal	0	0	0.001409081	0	0	0	0	0	0	0	0	0	0	0	0
Channel Bar	0	0	0	0.13690016	0	0	0	0	0	0	0	0	0	0	0
Coconut	0	0	0	0	0.194761797	0	0	0	0	0	0	0	0	0	0
Fallow	0	0	0	0	0	0.533930847	0	0	0	0	0	0	0	0	0
Mixed Plan-tation	0	0	0	0	0	0.003252909	6.964825817	0	0	0	0	0	0	0	0
Paddy	0	0	0	0	0	0	0	1.810806715	0	0	0	0	0	0	0
Pond	0	0	0	0	0	0	0	0	0.014366262	0	0	0	0	0	0
River	0	0	0	0	0	0	0	0	0	1.424547561	0	0	0	0	0
Road	0	0	0	0	0	0	0	0	0	0	0.217280434	0	0	0	0
Sugarcane Field	0	0	0	0	0	0	0	0	0	0	0	0	0	0.048598624	0
Vegetable Crop	0	0	0	0	0	0	0	0	0	0	0	0.034075659	0	0	0
Wasteland	0	0	0	0	0	0	0	0	0	0	0	0	0.118760045	0	0
Water Logged	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.09352947
Grand Total	0.005735393	1.091207591	0.001409081	0.13690016	0.194761797	0.537183756	6.964825817	1.810806715	0.014366262	1.424547561	0.217280434	0.034075659	0.118760045	0.048598624	0.09352947

Table 5.3. Land use dynamics of Low land 2017-2018

5.2.2. Mid Land Morphology and Land Use Characteristics

5.2.2.1. River Morphology and Land Use of Mid Land - 2017(Pre Flood)

The morphological aspects of the mid land river segment were also mapped along with the land use, for the pre flood period of 2017 and the details were generated as described in the case of low land. The land use classes derived and the area of each class is given in the table 5.4. The major classes derived include mixed crops, built up and channel bars. The river morphology of the area shows depositional characteristics as shown by the channel bars. There is substantial area of the river covered by channel bars and braided bars in the river segment. The land use map along with the morphological characteristics of the river generated is shown in the figure 5.4.

Year_2017 Land use	Cnt_Year_2017	Area	Percentage
Banana	5	0.00632225510	0.09347830000
Built_Up	2562	0.53979024819	7.98112000000
Channel Bar	17	0.23634423520	3.49449000000
Coconut	1	0.00245879685	0.03635480000
Fallow	12	0.02687580018	0.39737500000
Mixed Plantation	106	4.62587675583	68.39630000000
Paddy	38	0.23881281285	3.53099000000
Pond	1	0.00013558632	0.00200472000
River	41	0.74361322298	10.99480000000
Road	158	0.18692485082	2.76379000000
Rock	7	0.02016381722	0.29813400000
Vegetable Crop	11	0.13522560731	1.99939000000
Water logged	1	0.00079638773	0.01177510000
	Total	6.76334037659	100.00000000

Table 5.4. Land Use Statistics Mid Land 2017 (Pre flood)

Figure 5.4 shows landuse distributionin mid land portion of Pamba basin for the year 2017. In the lowest elevation of the terrain the river is flowing without completely occupying the available width of the river leaving channel bars on either sides which are generally stabilised to form a landuse class. There are channel bars and braided bars identified showing the depositional nature of the river segment. The locations of bars are determined by the meandering geometry of the river and the amount of water flow. The mid land segment of the river thus generally shows high sediment supply which is greater than the transport or the carrying capacity of the river.

The terrain is undulating and is genrally elevated on either side of the river segment and is covered by mixed plantation, settlements or built ups and roads in general. The other predominant category of land use in the lower elevation is the paddy fields. Covering the entire stretch of land without elevation restrictions is the major land use class of Built up and roads. The development of built up and roads are increasing unprecedentedly in the region which has invaded the paddy fields, low lying area and other natural water holding structures leading to the development and heavy impact of floods in the mid land region also.

5.2.2.2. River Morphology and Land Use of Mid Land - 2018(Post Flood)

As in the case of low land, the morphological aspects of the mid land river segment were again mapped along with the land use, for the post flood period of 2018 in order to identify the changes that happened due to the flood of August 2018. Very high resolution images were generated based on drone survey and interpreted to derive the river characteristics and land use classes. The area of each class derived is given in the table 5.5. The land use map along with the river morphological characteristics generated is shown in the figure 5.5.

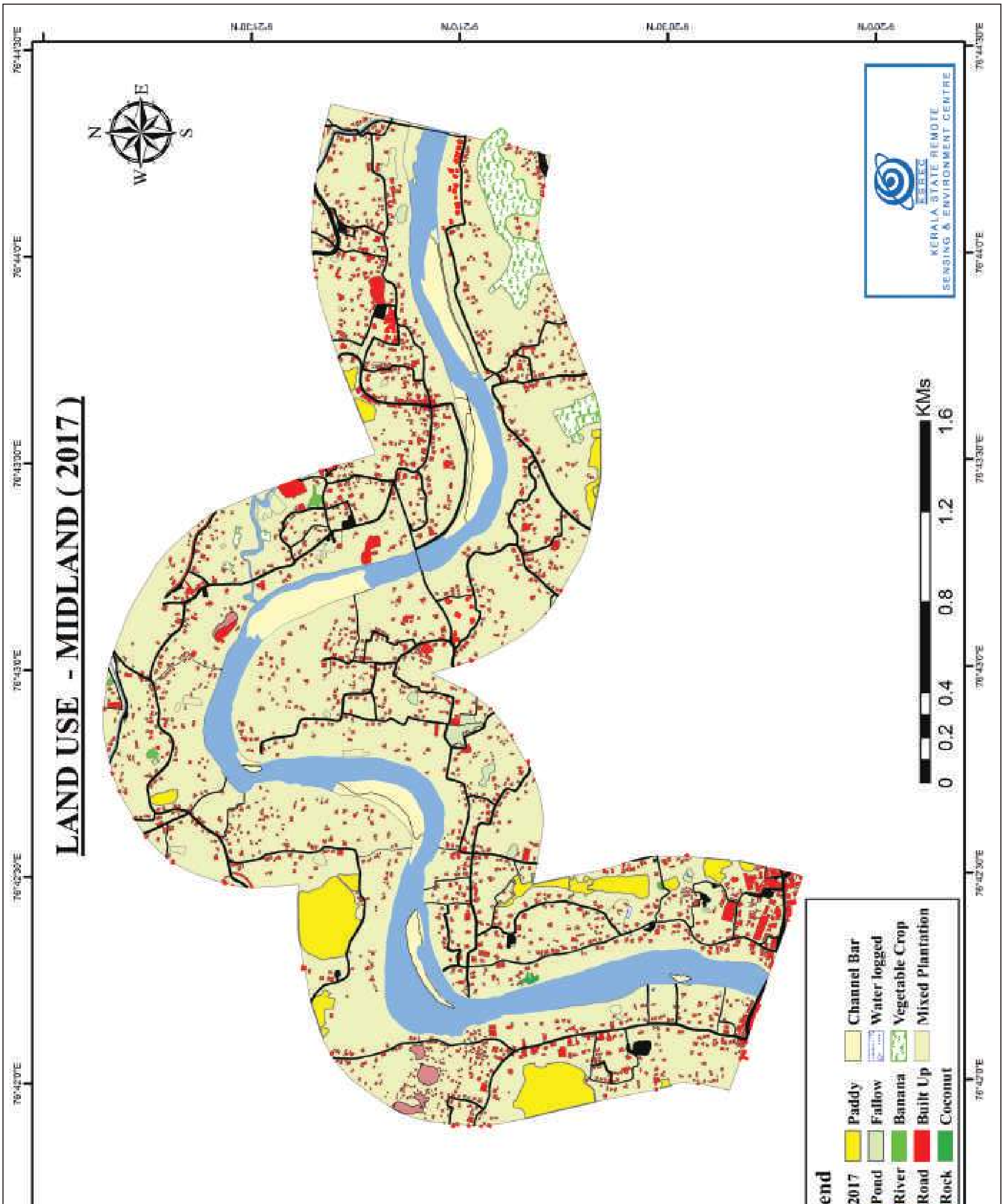


Fig: 5.4. Land Use of Mid land 2017 (Pre flood)

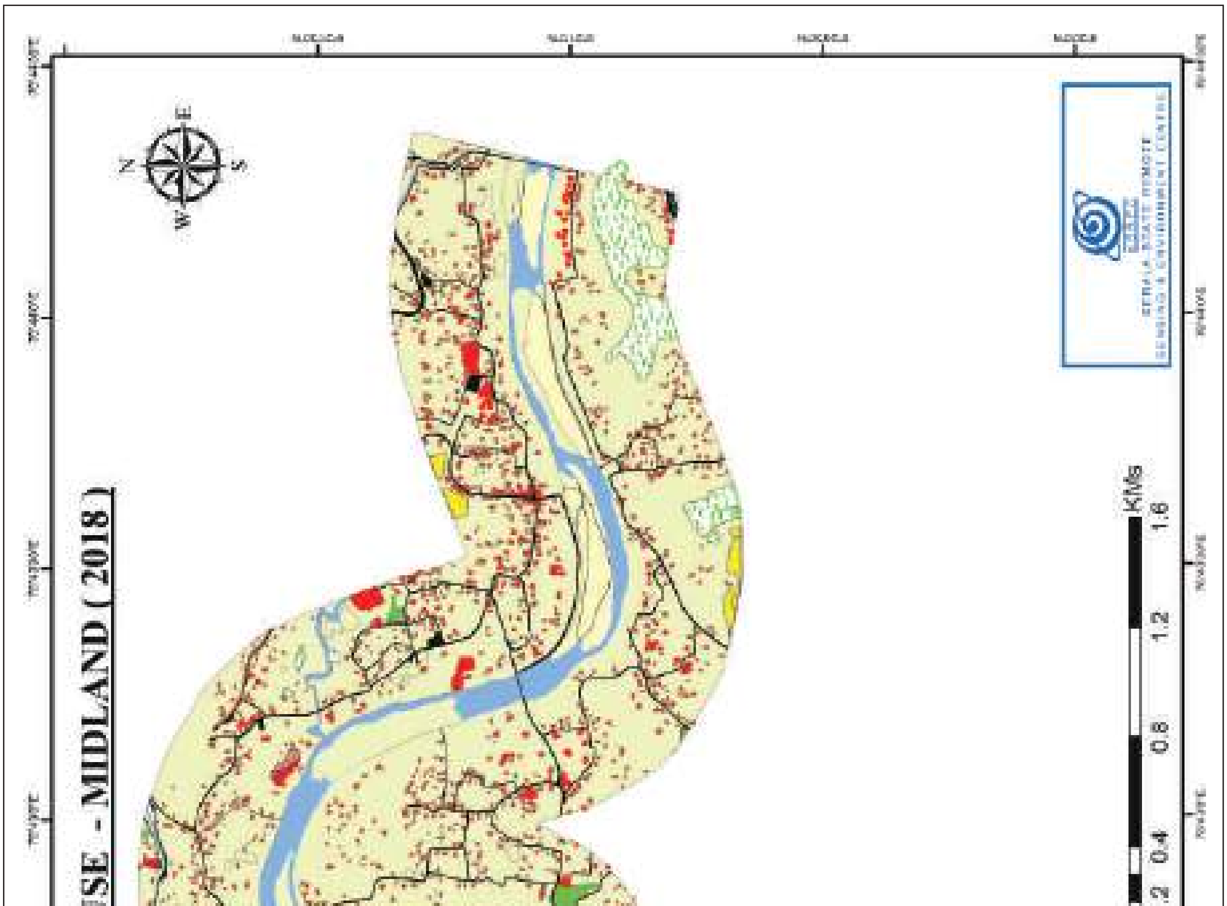


Fig: 5.5. Land Use of Mid land 2018 (Post flood)

Year_2018 Land Use	Cnt_Year_2018	Area	Percentage
Banana	11	0.01951515412	0.28854300000
Built_Up	2562	0.53979024819	7.98112000000
Channel Bar	24	0.20061332460	2.96619000000
Mixed Plantation	123	4.86895928345	71.99050000000
Paddy	38	0.23881281285	3.53099000000
Pond	1	0.00013558632	0.00200472000
River	25	0.55315293761	8.17869000000
Road	158	0.18692485082	2.76379000000
Rock	7	0.02016381722	0.29813400000
Vegetable Crop	10	0.13447597367	1.98831000000
Water logged	1	0.00079638773	0.01177510000
	Total	6.76334037658	100.0000000000

Table 5.5. Land Use Statistics Mid Land 2018 (Post flood)

Landuse in mid land portion of post flood Pamba basin for the year 2018, does not have a major change except for the river channel boundaries and the sand bar chracteristics. Most of the landuse features is observed same as that of the features observed during 2017.There is a drastic change in the depositional characteristic of the river which has increased the number of channel bars and also the area. As in the 2017 case the mixed plantation dominates with the spread of built up and roads. Paddy and vegetable crops also dominates in the land use features. The morphology of the river is drastically changed which will surely had reduced the carrying capacity of the river except in the western side major bend where there is erosion on both banks and deposition in the central region. The change of paddy land to crop land and to plantation crops, fallow land to plantation etc. are the other post flood changes found.All land use and land cover features derived can be visualized in the figure 5.5.

5.2.2.3. Post flood Morphology and Land Use Change Characteristic of Mid Land

River Morphology and the land use dynamics of the mid land region as a result of the flood impact is found to be dominant on the river morphology where there is massive deposition with increase in number of channel bars and also erosion on the river banks. The flooding on either sides has resulted in flood deposits but has not changed or destroyed the land use, except for the case of waterlogging in the paddy region. The pivot table 5.5 shows the change of classes from one class to other representing the loss in area of a particular class and the gain in area on the other class. Figure 5.6 helps visualise land use change in mid land portion of Pamba basin during the years 2017-18.Major change observed is that the development of channel bars and that the river bank area is changed into river which is labeled as river boundary change in the figure 5.6. Other changes observed are change of different classes to plantation as shown in the pivot table 5.6. All other features which are having no observable change are represented using grey colour in the figure 5.6.

2017/2018 Sq.Km.	Banana	Built_Up	Channel_Ba	Mixed_Plan	Paddy	River	Pond	Road	Rock	Vegetable_	Water_logg
Banana	0.006322255	0	0	0	0	0	0	0	0	0	0
Built_Up	0	0.539790248	0	0	0	0	0	0	0	0	0
Channel Bar	0	0	0.13147913	0.085860108	0	0.019004997	0	0	0	0	0
Coconut	0	0	0	0.002458797	0	0	0	0	0	0	0
Fallow	0.009563684	0	0	0.017312117	0	0	0	0	0	0	0
Mixed Plantation	0.002879582	0	0	4.622997174	0	0	0	0	0	0	0
Paddy	0	0	0	0	0.238812813	0	0	0	0	0	0
Pond	0	0	0	0	0	0	0.000135586	0	0	0	0
River	0	0	0.069134195	0.140331088	0	0.53414794	0	0	0	0	0
Road	0	0	0	0	0	0	0	0.186924851	0	0	0
Rock	0	0	0	0	0	0	0	0	0.020163817	0	0
Vegetable Crop	0.000749634	0	0	0	0	0	0	0	0	0.134475974	0
Water logged	0	0	0	0	0	0	0	0	0	0	0.000796388
Grand Total	0.019515154	0.539790248	0.200613325	4.868959283	0.238812813	0.553152938	0.000135586	0.186924851	0.020163817	0.134475974	0.000796388

Table 5.6 Land Use dynamics of Mid land 2017 – 2018

5.2.3. High Land Morphology and Land Use Characteristics

5.2.3.1. River Morphology and Land Use of High Land - 2017(Pre Flood)

The morphological aspects of the high land river segment were also mapped along with the land use, for the pre flood period of 2017 and details were generated as described in the case of low land. The land use classes derived and the area of each class is given in the table 5.7. The major classes derived include mixed plantation, built up and plantations like rubber and cocconut. The river morphology of the area shows depositional characteristics towards the western side or towards the lower elevation as represented by the substantial area of channel bars. The eastern side or towards the higher elevation the river bed is rocky with minor amount of channel bars. The land use map along with the morphological characteristics of the river generated is shown in the figure 5.7.

Year_2017 Land Use	Cnt_Year_2017	Area	Percentage
Pond	2	0.00241766300	0.02127900000
Banana	13	0.04848715942	0.42675900000
Built_Up	5031	0.64361171415	5.66474000000
Channel Bar	43	0.14362112302	1.26408000000
Coconut	2	0.01654000045	0.14557700000
Fallow	6	0.01418631896	0.12486100000
Mixed Plantation	6	9.35993597773	82.38130000000
Paddy	2	0.02821555035	0.24833900000
River	99	0.92617982689	8.15176000000
Road	39	0.02710002183	0.23852000000
Rock	18	0.02048656866	0.18031200000
Rubber	2	0.01399265975	0.12315600000
Vegetable crop	25	0.11694259093	1.02927000000
	Total	11.36171717514	99.99995300000

Fig: 5.7. Land Use of High land 2017 (Pre flood)

Figure 5.7 shows landuse distributionin high land portion of Pamba basin for the year 2017. In the lowest elevation of the terrain the river is flowing without completely occupying the available width of the river leaving channel bars on either sides and braid bars at places which are generally stabilised to form a landuse class. These channel bars and braid bars identified showing the depositional nature of the river segment. The locations of bars are determined by the geometry of the river obtained from the rolling terrain, slope, and the amount of water flow. The high land segment of the river is also showing high sediment supply, as in the case of mid land, which is greater than the transport or the carrying capacity of the river.

The terrain is undulating and is genrally elevated on either side of the river segment or the river is incising the terrain.The either sides of the river is covered with mixed plantation, settlements or built ups and roads in general. The other predominant category of land use includes rubber, coconut and banana plantations. Covering the entire stretch of land without elevation restrictions is the major land use class of Built up and roads. The development of built up and roads are increasing unprecedentedly in this region also which has invaded the paddy fields, low lying area and other natural water holding structures leading to the development and heavy impact of floods in the high land region also.

5.2.3.2. River Morphology and Land Use of High Land - 2018(Post Flood)

As in the case of low land, the morphological aspects of the high land river segment were again mapped along with the land use, for the post flood period of 2018 in order to identify the changes that happened due to the flood of August 2018. Very high resolution images were generated based on drone survey and interpreted to derive the river characteristics and land use classes. The area of each class derived is given in the table 5.8. The land use map along with the river morphological characteristics generated is shown in the figure 5.8.

Year_2018 Land Use	Cnt_Year_2018	Area	Percentage
Banana	13	0.04848715942	0.42675900000
Built_Up	5031	0.64361171415	5.66474000000
Channel Bar	46	0.26166399133	2.30303000000
Coconut	2	0.01654000045	0.14557700000
Fallow	1	0.00265010004	0.02332480000
Mixed Plantation	20	9.39877752177	82.72320000000
Paddy	1	0.02624060027	0.23095600000
Pond	2	0.00241766300	0.02127900000
River	96	0.80813695857	7.11281000000
Road	39	0.02710002183	0.23852000000
Rock	18	0.02048656866	0.18031200000
Rubber	2	0.01399265975	0.12315600000
Vegetable crop	17	0.09161221590	0.80632400000
	Total	11.36171717514	100.0000000000

Fig: 5.8. Land Use of High land 2018 (Post flood)

Landuse in High land portionof post flood Pamba basin for the year 2018, does not have a major change except for the the channel bar chracteristics. Most of the landuse features is observed same as that of the features observed during 2017.There is a drastic change in the depositional characteristic of the river which has increased the number of channel bars and also the channel bar area. As in the 2017 case the mixed plantation dominates with the spread of built up and roads. Other plantation crops like Rubber, Coconut and banana are also found to be of importance. There is some stretch of paddy also observed. The morphology of the river is drastically changed which will surely had reduced the carrying capacity of the river. The class change to mixed plantation from various classes found to be the other dominant difference. All land use and land cover features derived can be visualized in the figure 5.8.

5.2.3.3. Post flood Morphology and Land Use Change Characteristic of High Land

River Morphology and the land use dynamics of the high land region as a result of the flood impact is found to be dominant on the river morphology where there is massive deposition with increase in number of channel bars and also slight erosion on the river banks. The flooding on either sides has resulted in waterlogging in the paddy region and the surroundings. The pivot table 5.9 shows the change of classes from one class to other representing the loss in area of a particular class and the gain in area on the other class. Figure 5.9 helps visualise land use change in high land portion of Pamba basin during the years 2017-18. Major change observed is that the development of channel bars. Other changes observed are change of paddy, crops and fallow area into the plantation as shown in the pivot table 5.9. All other features which are having no observable change are represented using grey colour in the figure 5.9.

2017/2018 Sq.Km.	Banana	Built_Up	Chan-nel_Bar	Road	Pond	Coco-nut	Fallow	Rock	Mixed_Plan	Rubber	Paddy	River	Vegetable
Banana	0.048487159	0	0	0	0	0	0	0	0	0	0	0	0
Built_Up	0	0.643611714	0	0	0	0	0	0	0	0	0	0	0
Channel Bar	0	0	0.098212153	0	0	0	0	0	0	0	0	0.045408969	0
Coconut	0	0	0	0	0	0.01654	0	0	0	0	0	0	0
Fallow	0	0	0	0	0	0	0.0026501	0	0.011536219	0	0	0	0
Mixed Plantation	0	0	0	0	0	0	0	0	9.359935916	0	0	0	0
Paddy	0	0	0	0	0	0	0	0	0.00197495	0	0.0262406	0	0
Pond	0	0	0	0	0.002417663	0	0	0	0	0	0	0	0
River	0	0	0.163451837	0	0	0	0	0	0	0	0	0.762727962	0
Road	0	0	0	0.027100022	0	0	0	0	0	0	0	0	0
Rock	0	0	0	0	0	0	0	0.020486569	0	0	0	0	0
Rubber	0	0	0	0	0	0	0	0	0	0.01399266	0	0	0
Vegetable crop	0	0	0	0	0	0	0	0	0.025330375	0	0	0	0.091612216
Grand Total	0.048487159	0.643611714	0.26166399	0.027100022	0.002417663	0.01654	0.0026501	0.020486569	9.39877746	0.01399266	0.0262406	0.808136931	0.091612216

Table 5.9. Pivot table for the Land Use change - High Land

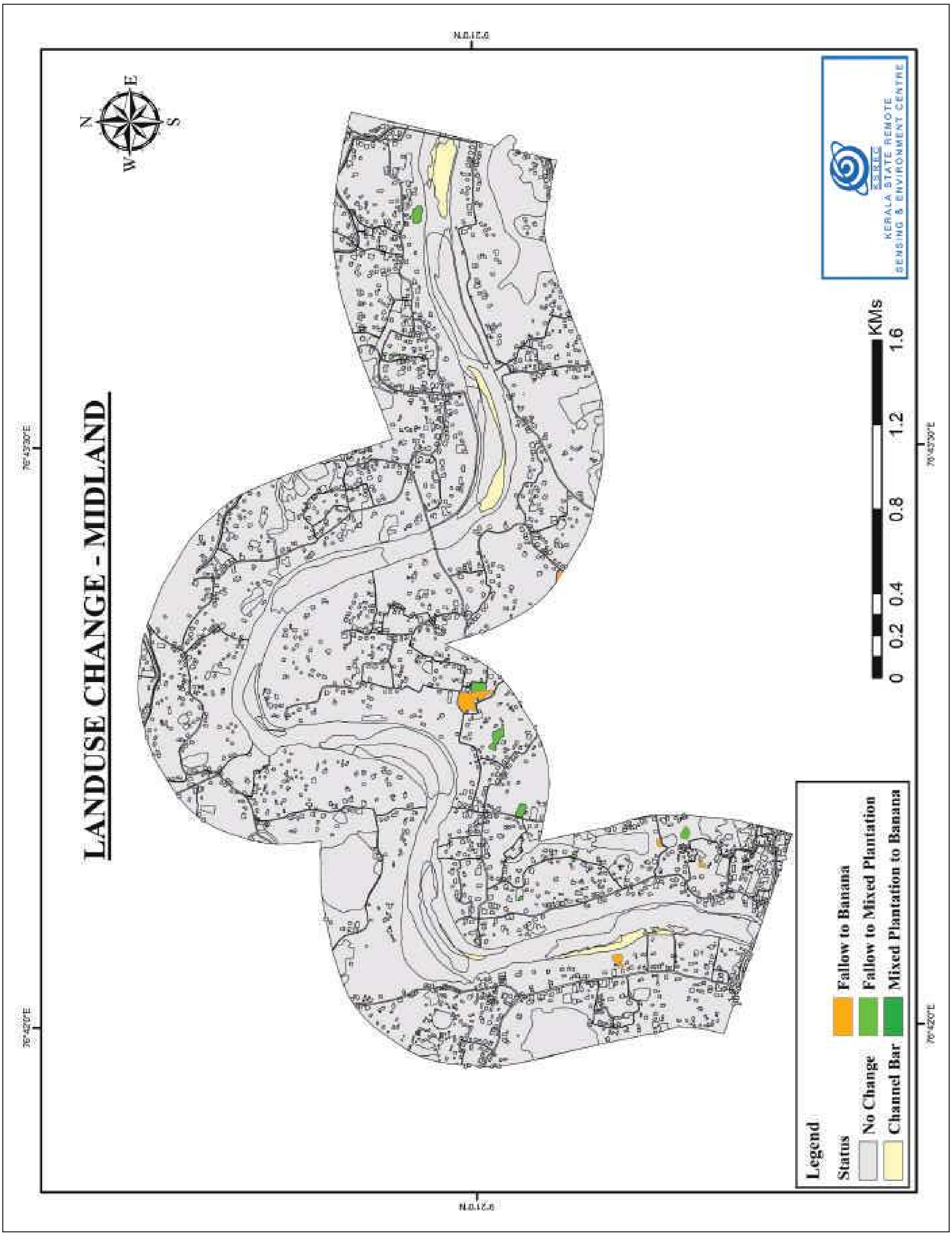


Fig: 5.6. Land Use Dynamics of Mid land

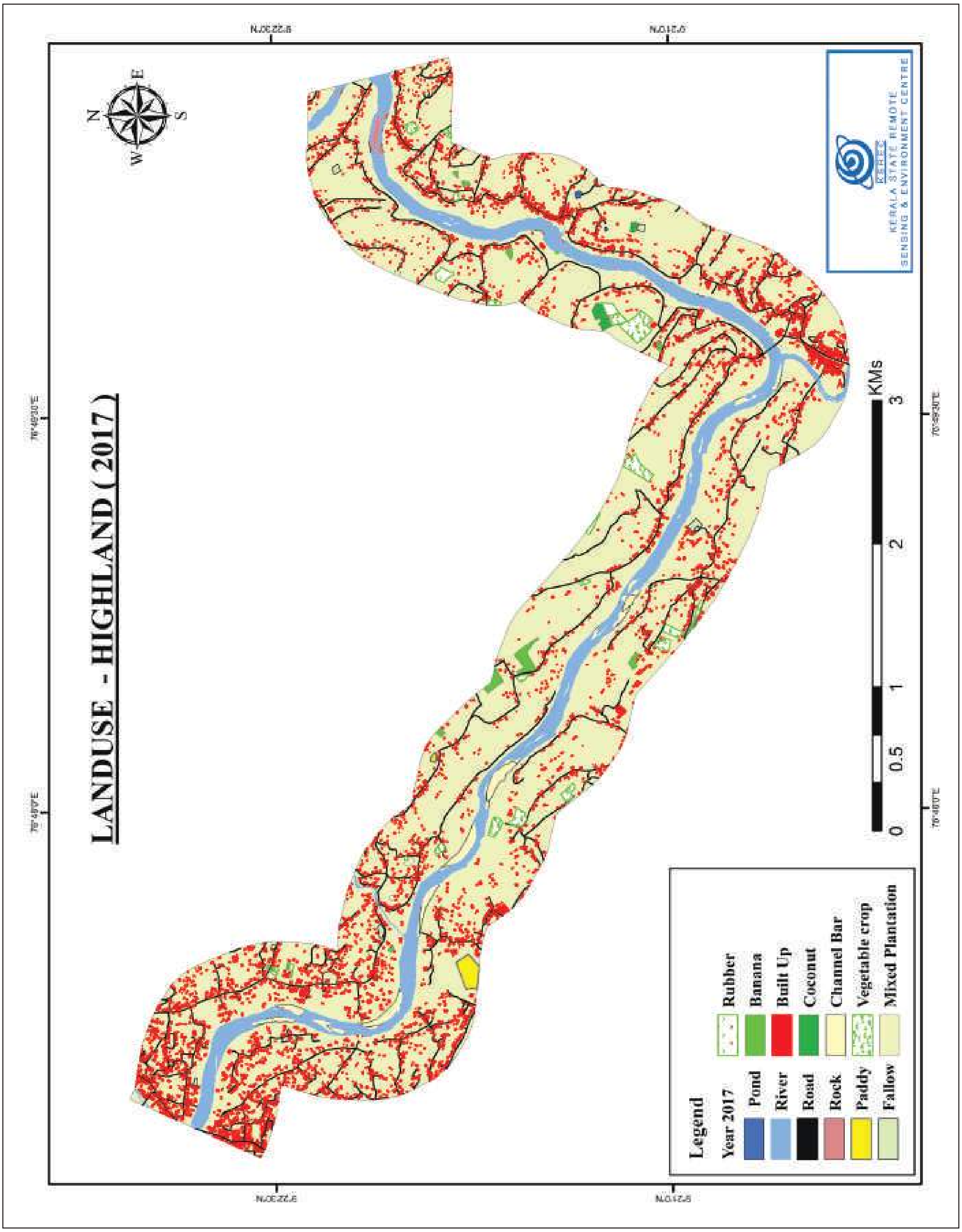


Fig: 5.7. Land Use of High land 2017 (Pre flood)

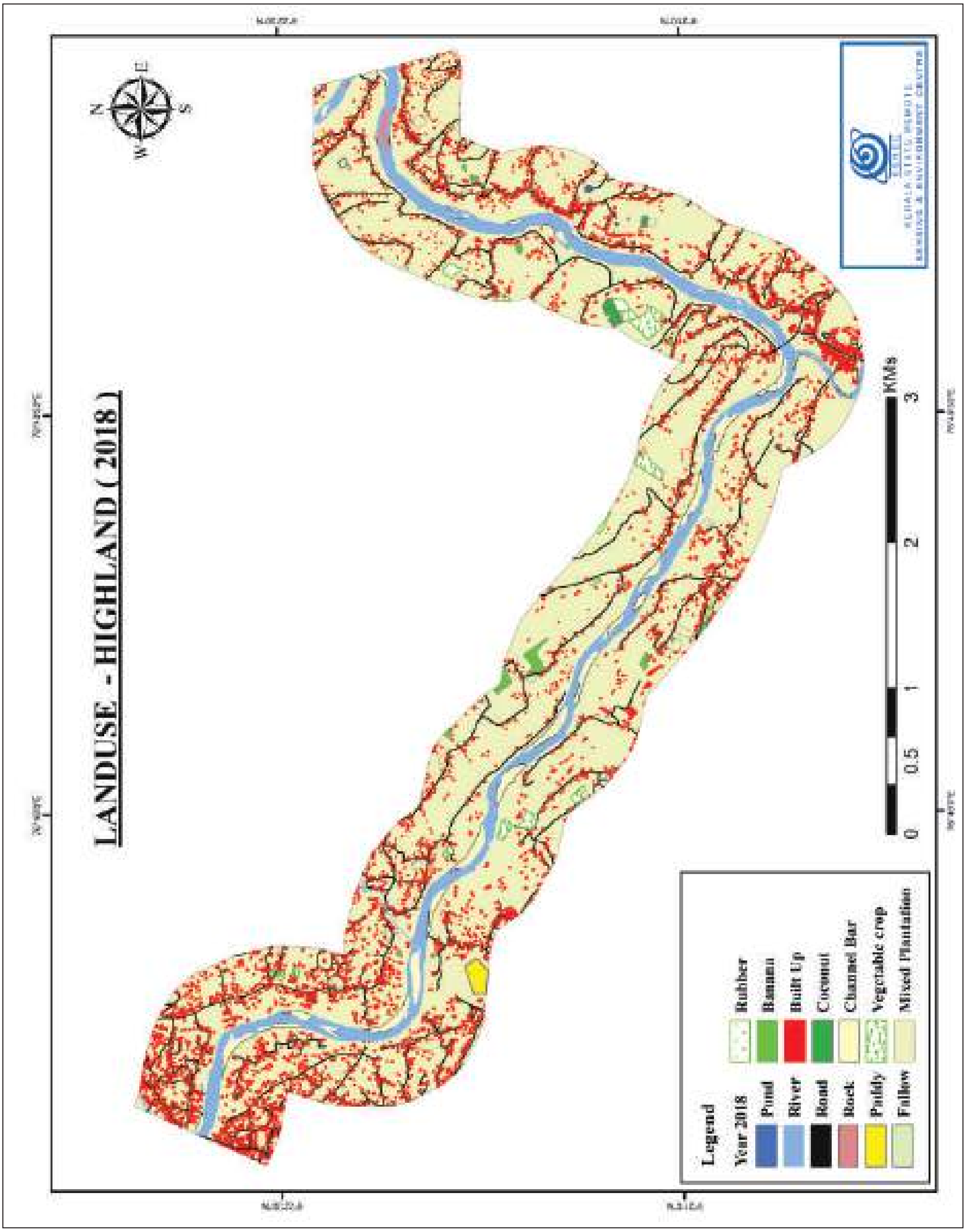


Fig: 5.8. Land Use of High land 2018 (Post flood)

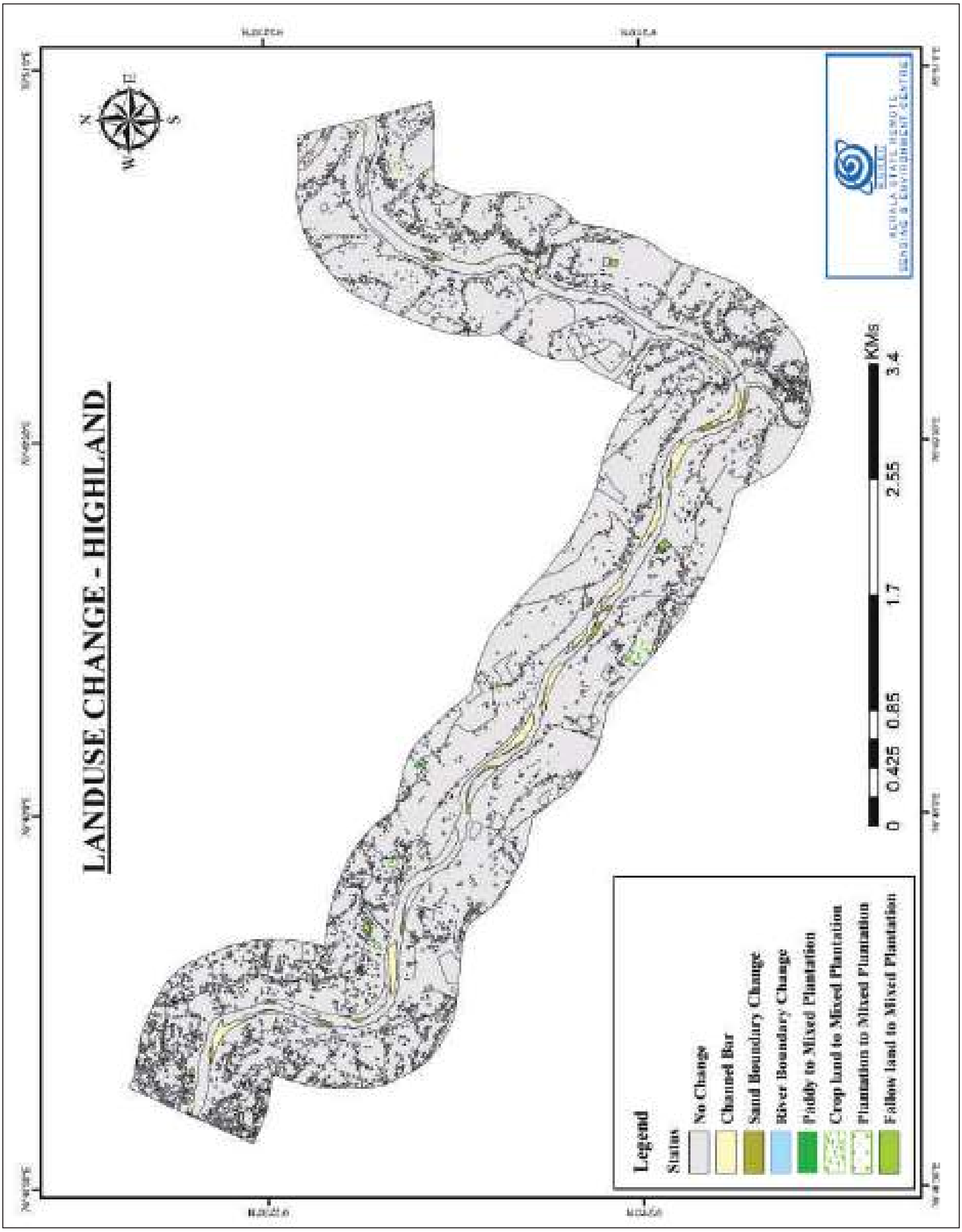


Fig: 5.9. Land Use Dynamics of High land

CHAPTER VI

GROUNDWATER DYNAMICS

6.1. Introduction

The groundwater potential of Kerala is very low as compared to that of many other states in the country. The estimated groundwater balance is 5,590 MCM. Dug wells are the major groundwater extraction structure in Kerala. The dug wells have a maximum depth of about 10 to 15 m. They have a diameter of about 1-2 m in the coastal region and of about 2-6 m in the midland and highland, including the Pamba River Basin. The open well density in Kerala, at an average of 70 to 200 wells per sq km, is perhaps the highest in the country. The groundwater withdrawal is estimated at 980 MCM and the State Groundwater Department calculated the effective recharge as 8,134 cubic metres. The groundwater level is receding drastically during the summer months and wells commonly dry up in many parts, including the Pamba River Basin. The depth of the water level in Kerala State varies from a few centimetres below ground level (bgl) to 56 m bgl and most of the area is in the range of 0-20 m bgl. The depth of the water level in the weathered crystalline of midland areas in Kerala varies from 3-16 m bgl. The midland area sustains medium capacity dug wells. Along the coastal plains, the groundwater occurs at depths ranging from less than 1 m bgl to 6 m bgl (Nick Ahrensberg et al.,2011).

The complexity of flow within aquifers may require extensive data and detailed modelling to answer development questions. Even with this, as mentioned above, accurate analysis of the water balance is often complicated by inflows and losses that are difficult to identify, monitor or interpret.

However, relatively simple data, such as specific water levels in a carefully designed network of monitoring wells, can be combined with estimates of rainfall input to provide key indications of groundwater dynamics. Long-term declines in water levels are often indicative of over abstraction conditions. Similarly, stable water levels generally indicate that inflows are in balance with outflows.

6.2. Groundwater Level comparative analysis (Pre &Post Flood)

Pre and Post flood studies were conducted to assess the changes in ground water as a result of water logging, heavy erosion and sediment deposition in the flooded areas and landslide affected highlands. In the affected areas a comparative study ofthe pre and post flood years (2017 and 2018 with available data of 2019) of groundwater level in low land, high land and mid land were done. The study was aimed to conduct detailed field survey of all the wells in the watershed area covering around 21000 wells using mobile app based survey for the post flood groundwater scenario. Due to various limitations in the field work completion by the collaborating agency could not took off and the same was abandoned. The present study is with the help of the observation wells of Groundwater department available in and around the study area.

6.2.1. January 2017, 2018 & 2019

Figure 6.1. shows groundwater level ofthe study area for the month of January 2017. The study area in general shows a groundwater level of 6.1 – 9 m below ground. Thiruvandoor panchayath region in low land shows a shallow groundwater range of 3.1-6 m and Puliyoor, Cheriyanadu and Ala region in the low land and Vechoochira region of high land is showing deeper groundwater level of 9.1-12 m.

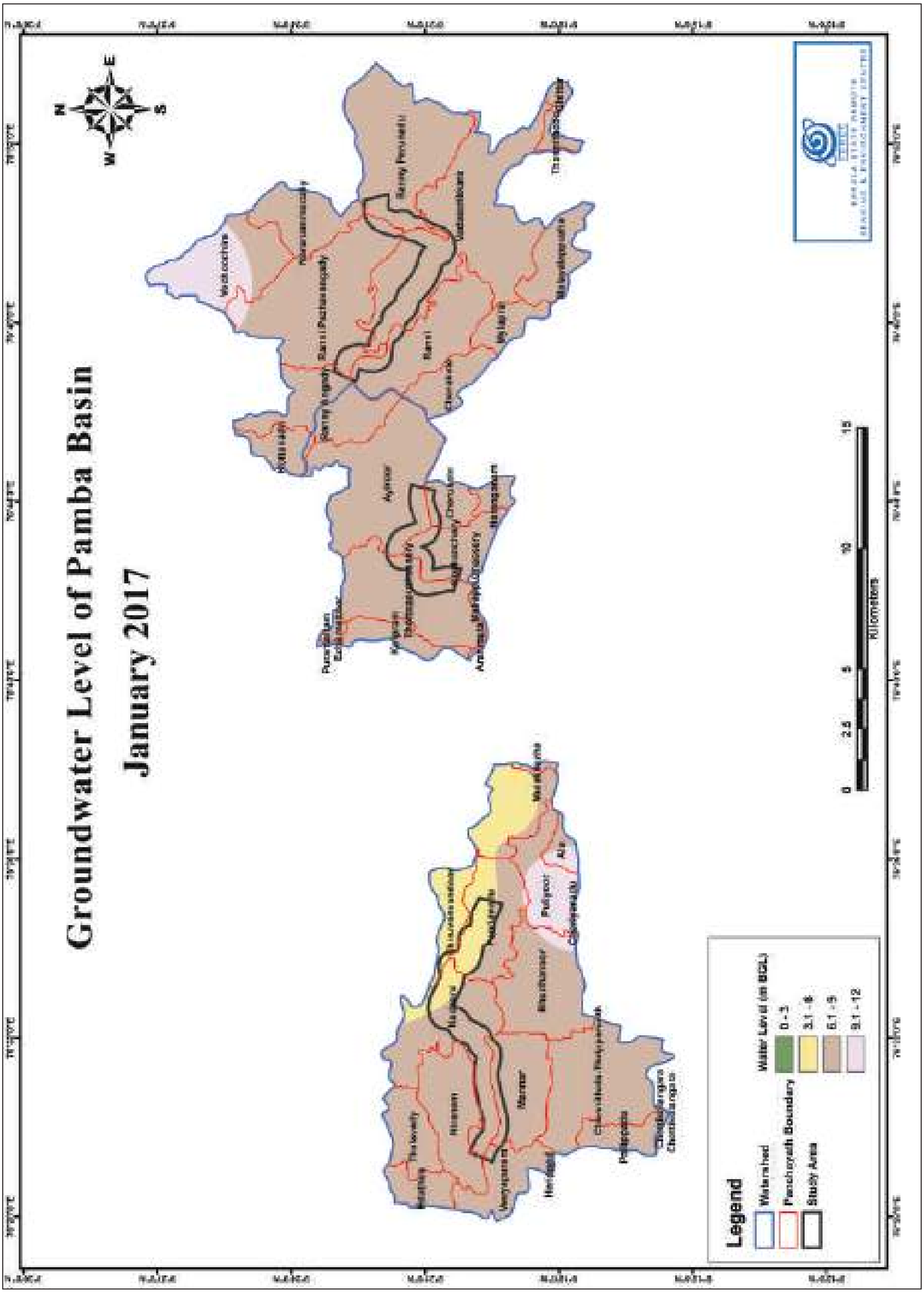


Fig:6.1. Groundwater level January 2017

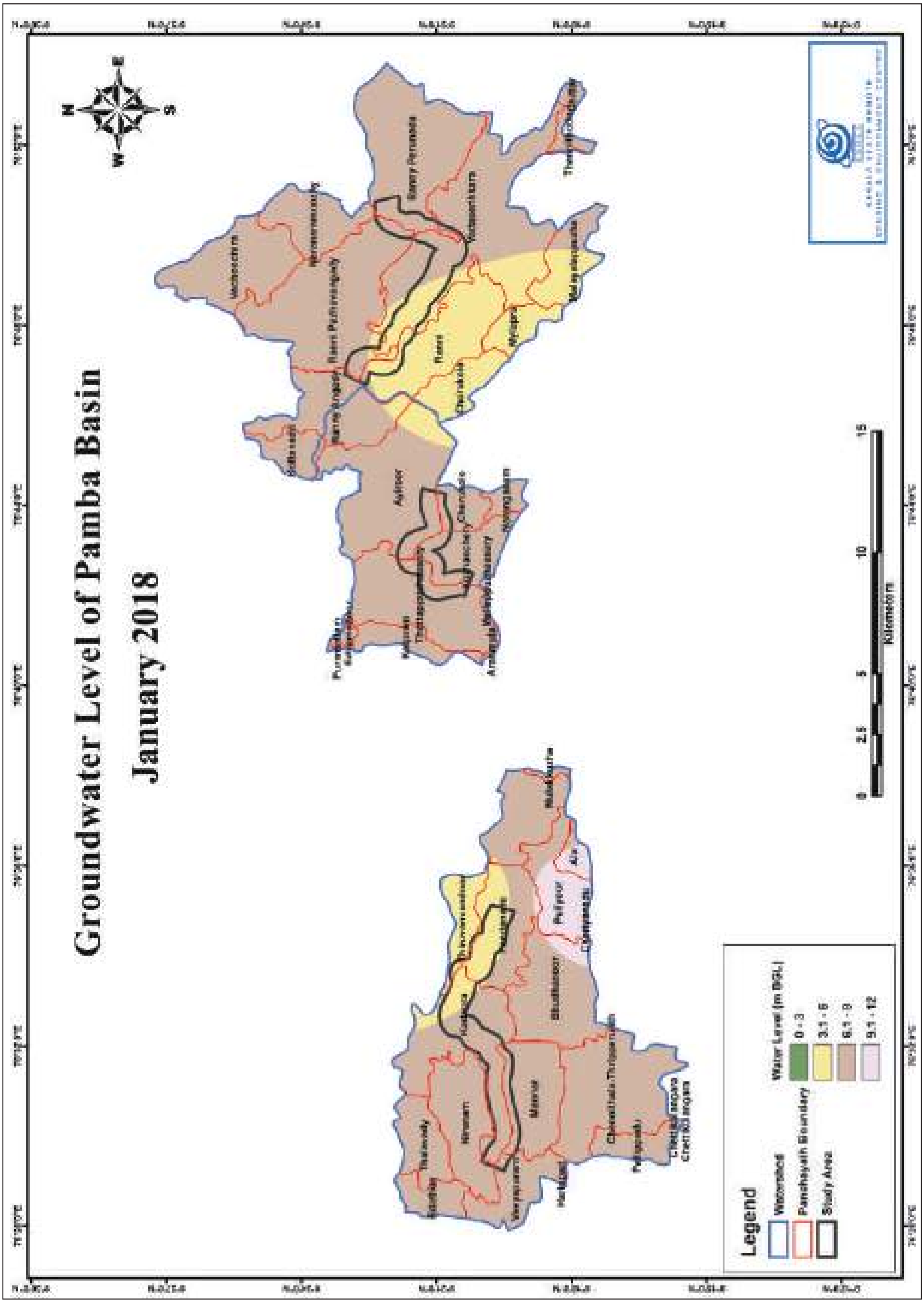


Fig: 6.2. Groundwater level January 2018

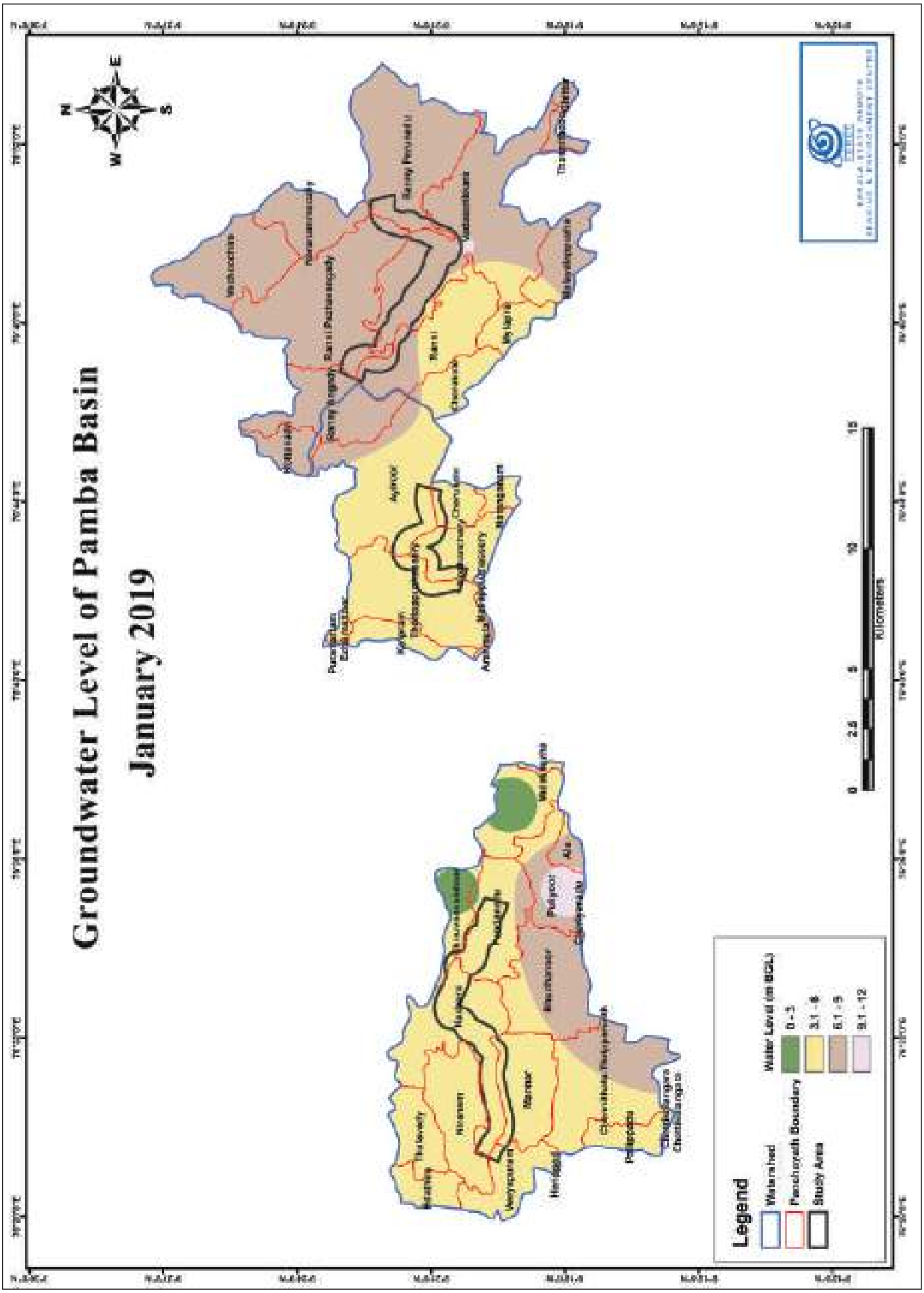


Fig: 6.3. Ground water level January 2019

The comparison of the groundwater level of January 2018 shows that there is a rise in groundwater level in the regions of Ranni, Cherukole, Mylapara and Malayalappuzha panchayaths of the high land segment (Fig.6.2), where as the groundwater level of low land and mid land remains stable.

For the case of January 2019 there seems to have a general rise in the groundwater level in the midland and low land region compared to the previous two years (Fig.6.3.). The entire mid land region and most of the low land region is showing a rise in groundwater level which is in the range of 3.1 to 6 m below ground level. In the Thiruvandoor and Mulakkuzha regions of low land the level has risen to the 0-3 m range which will be the impact after the floods of August 2018.

6.2.2. February 2017, 2018 & 2019

The figures 6.4, 6.5 & 6.6 show the depth to water level in the pre and post flood periods during the month of February 2017, 2018 and 2019. The general pattern of the three years during February is that the groundwater level is in the range of 6.1 to 9 m in most of the area. The January 2017 and February 2017 levels of low land remain stable with Thiruvandoor – Mulakuzha segment showing shallow water level of 3.1 to 6 m, compared to the average water level of 6.1 to 9 m and Puliyoor area showing deeper water levels 9.1to 12 m. In the case of high land the deeper water level segment range of 9.1 to 12 m, in the Vechoochira area has extended covering Naranamoozhy, RanniPazhavangady, RannyAngadi and Kottanada panchayaths.

In the case of low land for February 2018 (Fig.6.5) the water level is stable when compared to 2017, where as the mid land and high land region is showing an increase in the water level. In the Vechoochira panchayath and surroundings the water level has risen from the range 9.1 - 12 m to 6.1. – 9 m. The Mylapra panchayath and the surrounding area has risen from 6.1 – 9 m to 3.1 – 6 m range.

During 2019 January (Fig.6.6), the low land region is showing a groundwater level rise in the northern part, the 3.1 to 6 m range has extended to Edathua and Niranam panchayaths wheras in the Thiruvandoor panchayath area water level has risen to 0 to 3 m. The mid land and high land region is also showing a level rise. The Vechoochira and surroundings where there is the deepest water level has improved water level to 6.1 to 9 m. The Aranmula, Kolpram area of the mid land also had improved water level from 6.1 – 9 m to 3.1 – 6 m. The general increas in water level can be attributed to the August 2018 flood impact.

6.2.3. March 2017, 2018 & 2019

The groundwater level of all the study segments for March 2017 (Fig.6.7) is showing similar trend as the case of February 2017 with the low land showing three ranges of 9.1 to 12 m near Puliyoor, 3.1 to 6 m in and around Thiruvandoor and the remaining area with 6.1 to 9 m. The whole of mid land region is in the 6.1 to 9 m range. The high land shows 9.1 to 12 m range in the Vechhochira, Kottanada, RanniAngadi, Ranni Pazhavangadi and Naranamoozhy panchayath area. The remaining area is showing the range 6.1 to 9 m.

March 2018 (Fig.6.8) groundwater level of low land segment had not shown much variation compared to March 2017 except that the Mulakuzha region has deeper water level. The mid land region is stable and the high land region shows decrease in the water level for the fact that the entire region has deeper water level of 9.1 to 12 m.

March 2019 groundwater level (Fig. 6.9) shows the impact of August 2018 flood and has raised water level in all the study segments. The northern part of the lowland and most of the mid land has improved water level to 3.1 – 6 m class. The entire high land segment has raised water level compared to the 9.1 to 12 m range of the previous years.

6.2.4. April 2017, 2018 & 2019

The groundwater level of low land and mid land for April 2017 is similar to March 2017 (Fig.6.10), where as for the case of high land there is a depletion in the groundwater level to the whole of southern side. The entire high land region is showing the level range of 9.1 – 12 m.

During April 2018, the low land and mid land segment is showing similar trend to that of March 2018 (Fig.6.11), but the high land region shows a raise in the groundwater level possibly due to summer rains. It can also be noticed that the post flood April 2019 data (Fig.6.12) also shows the same trend of groundwater level in all the study segments.

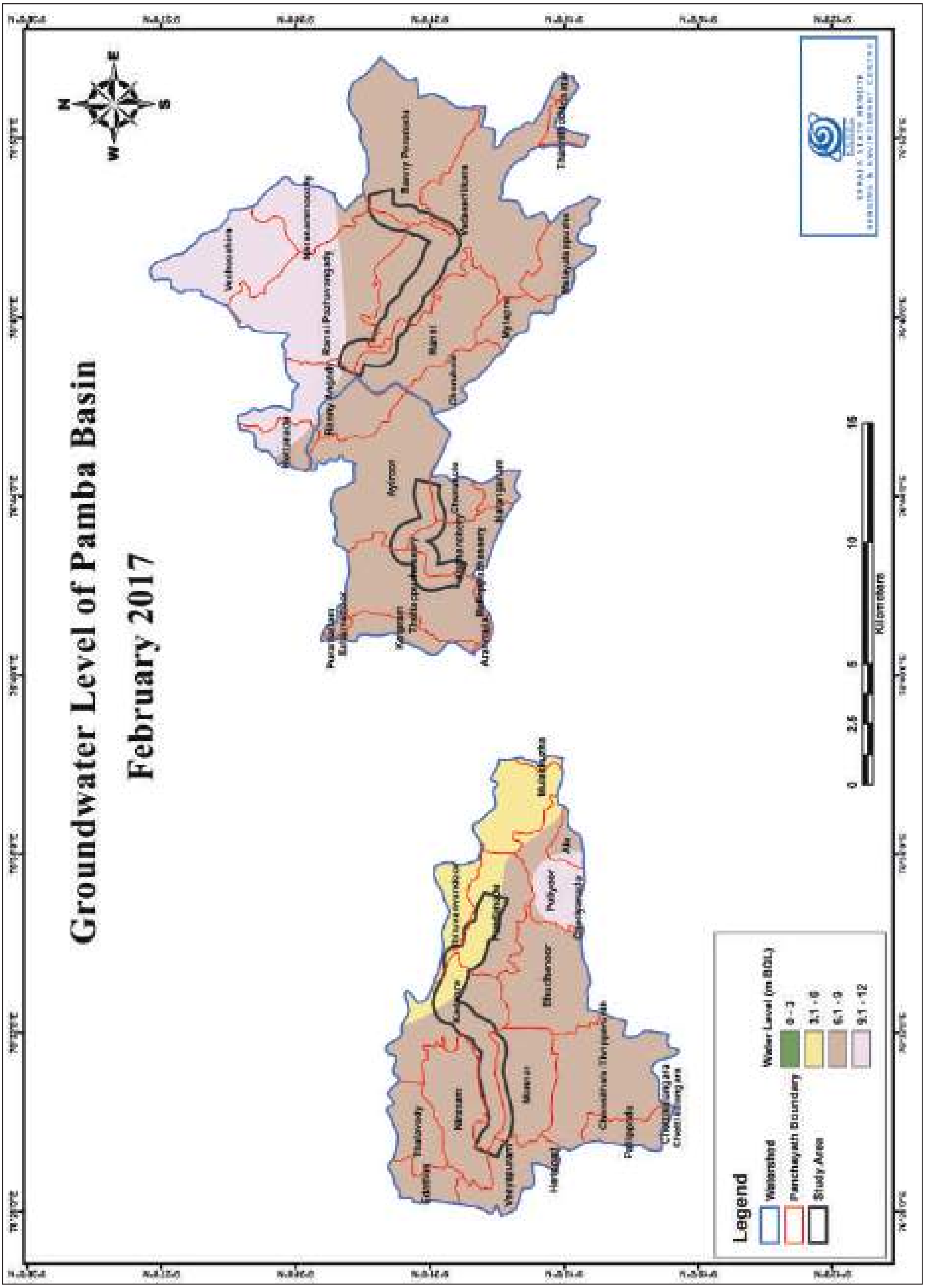


Fig: 6.4. Ground water level February 2017

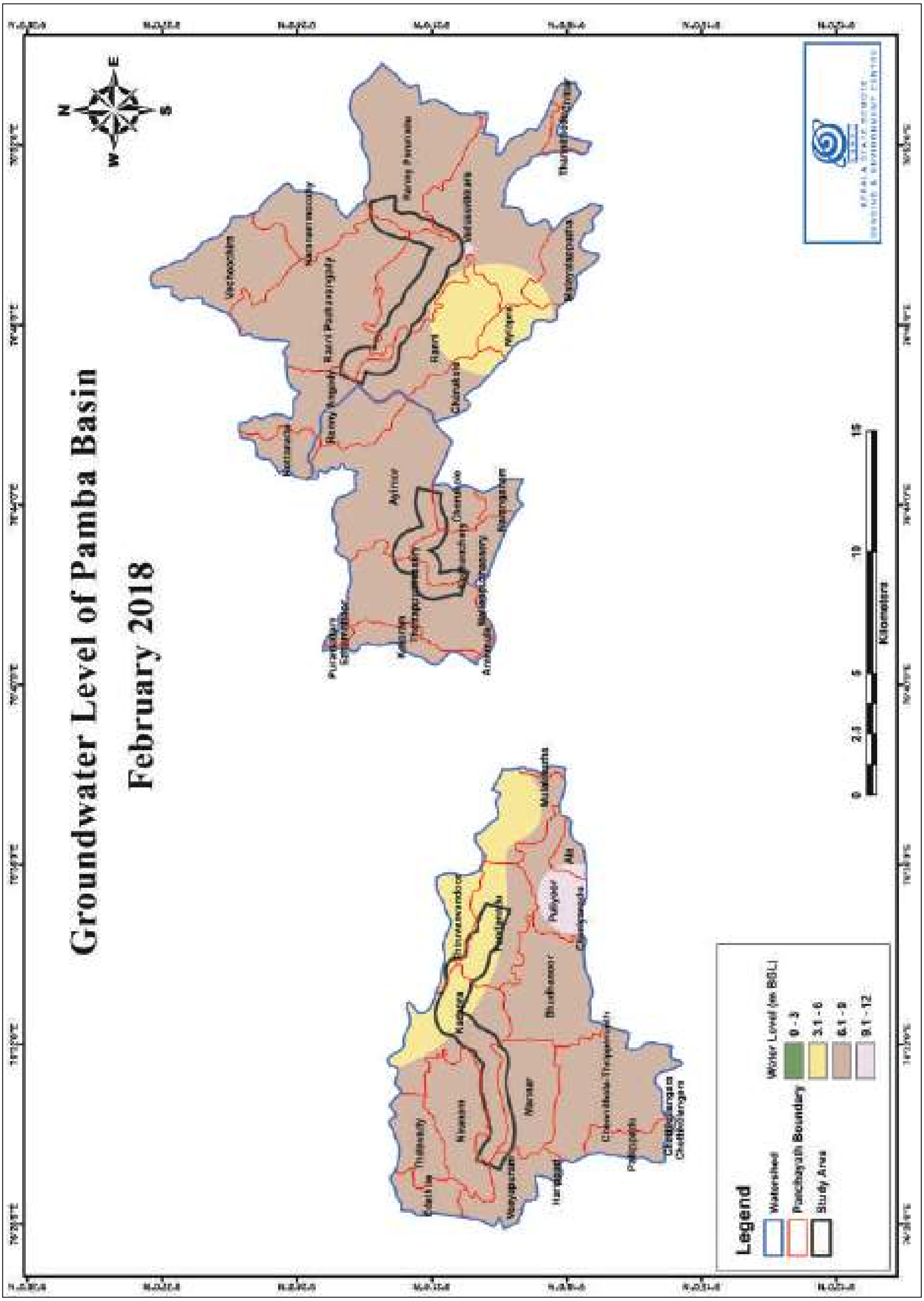


Fig: 6.5. Groundwater level February 2018

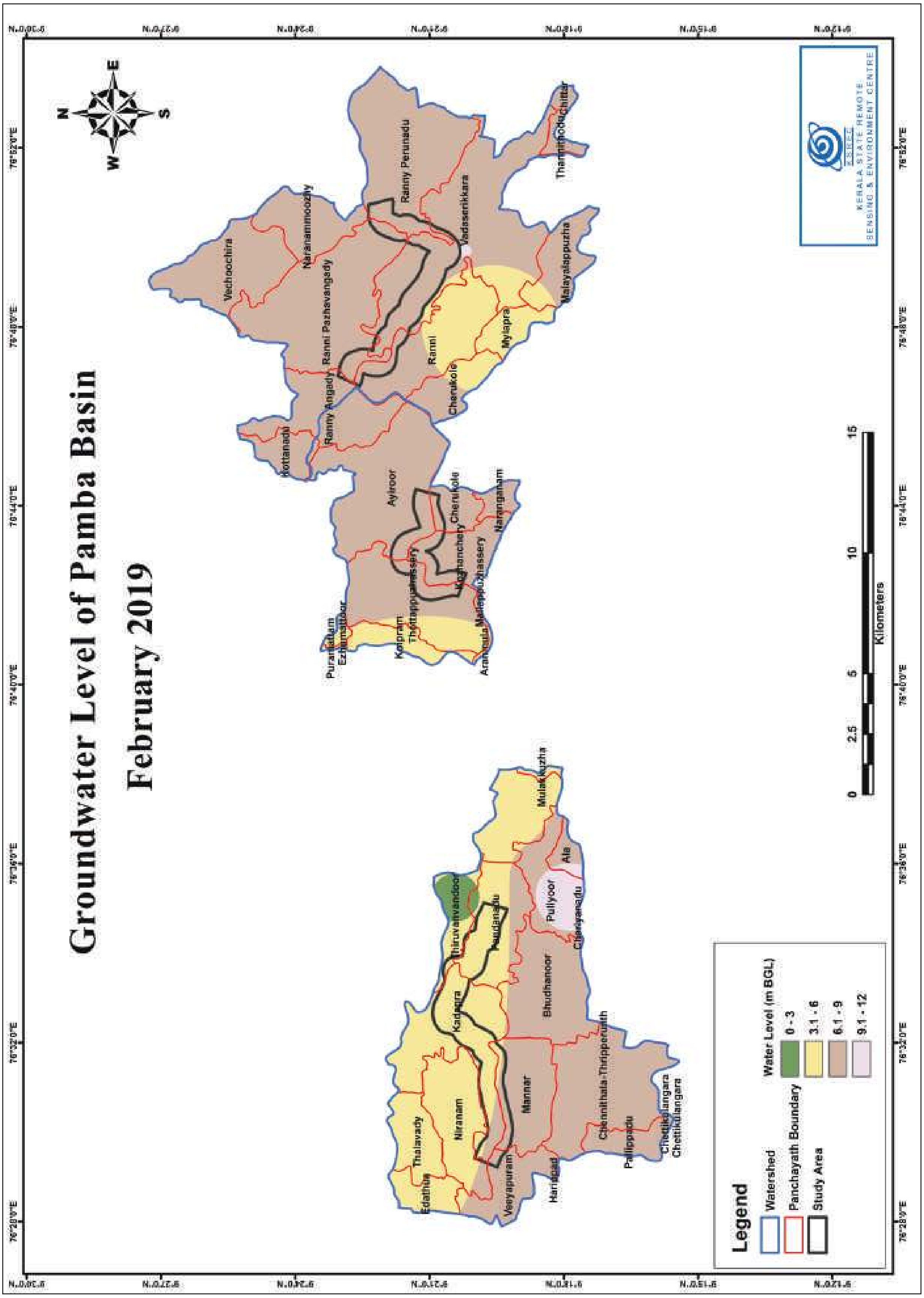


Fig:6.6. Ground water level February 2019

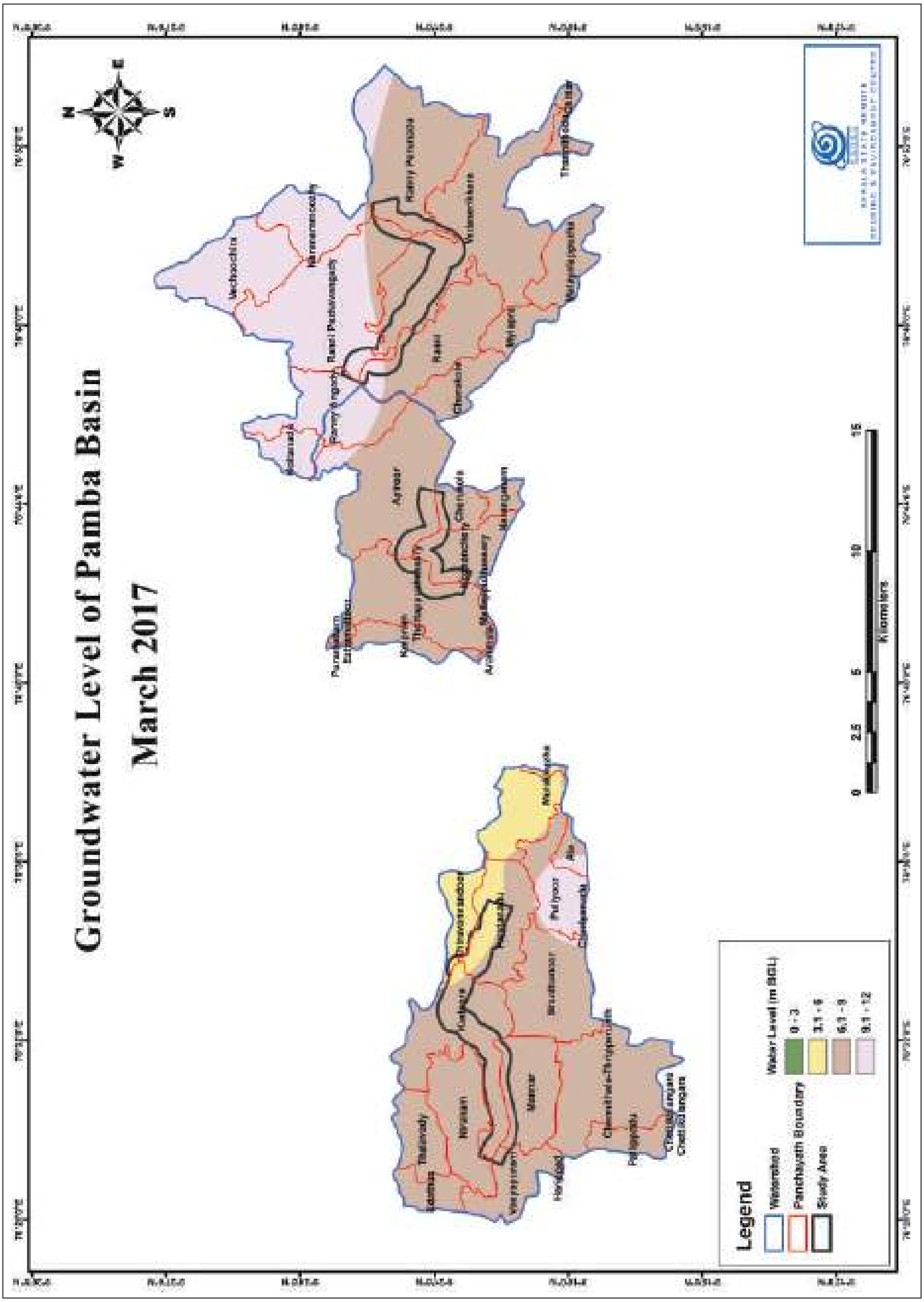


Fig: 6.7. Groundwater level March 2017

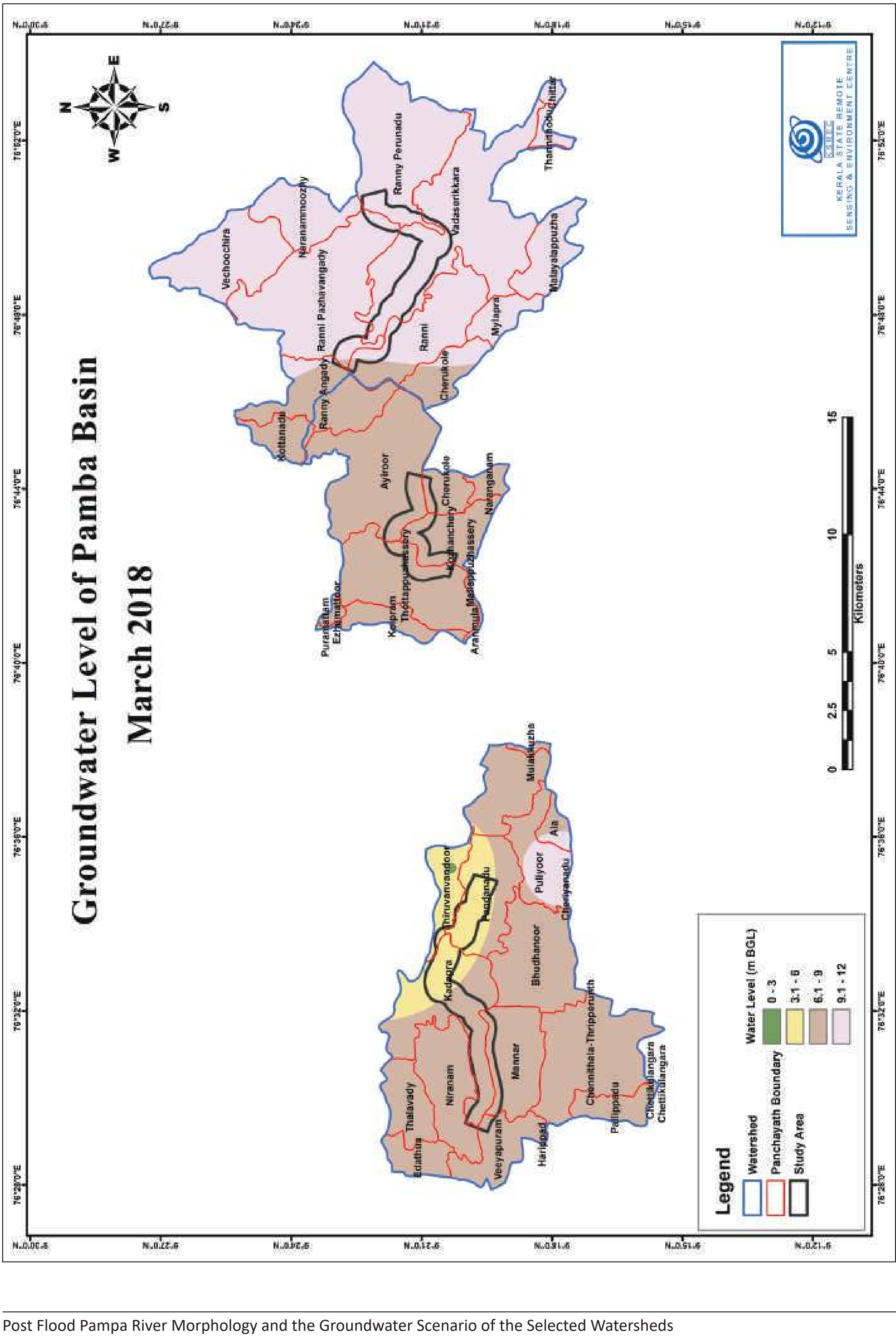


Fig: 6.8. Groundwater level March 2018

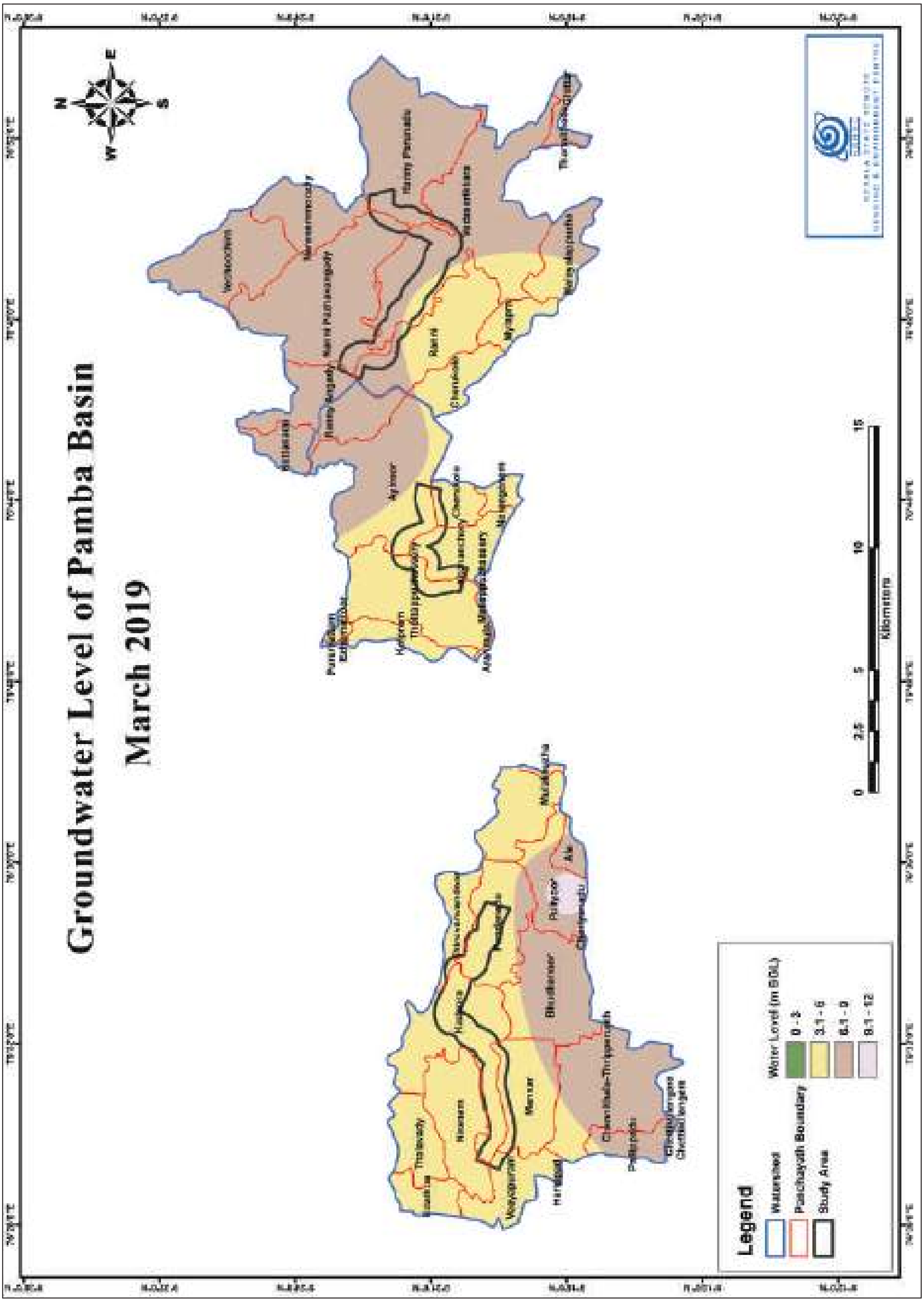


Fig: 6.9. Groundwater level March 2019

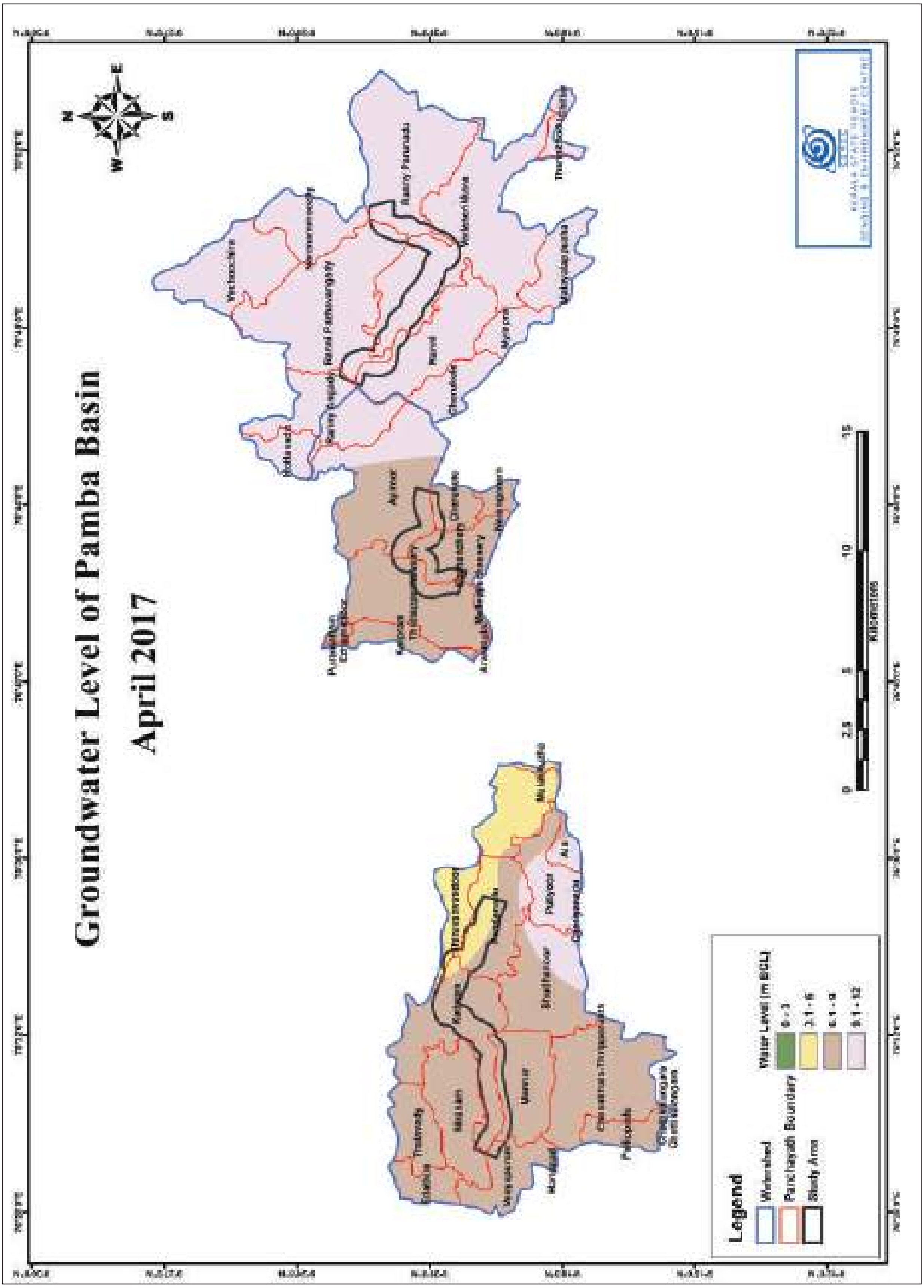


Fig: 6.10. Ground water level April 2017

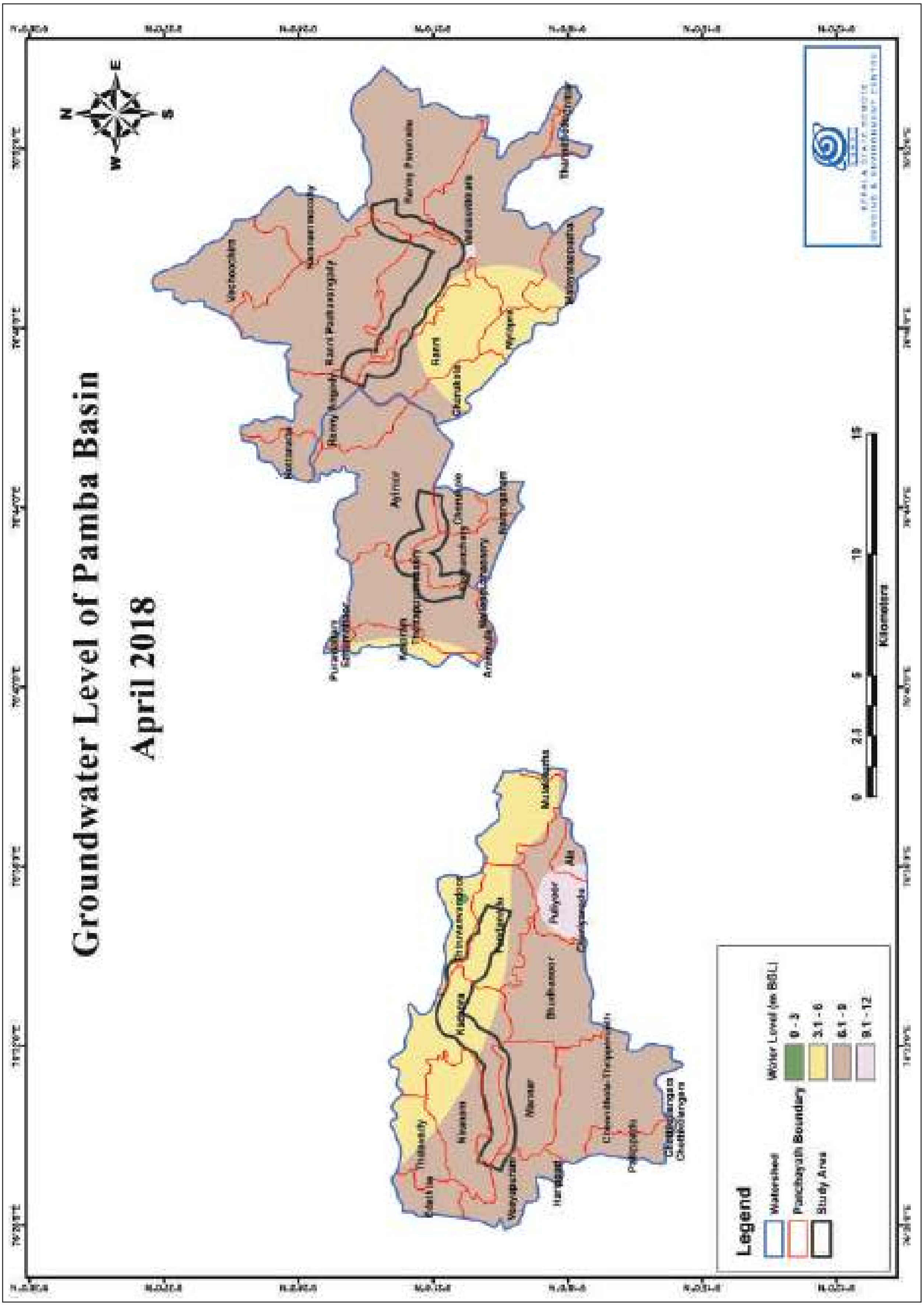


Fig: 6.11. Ground water level April 2018

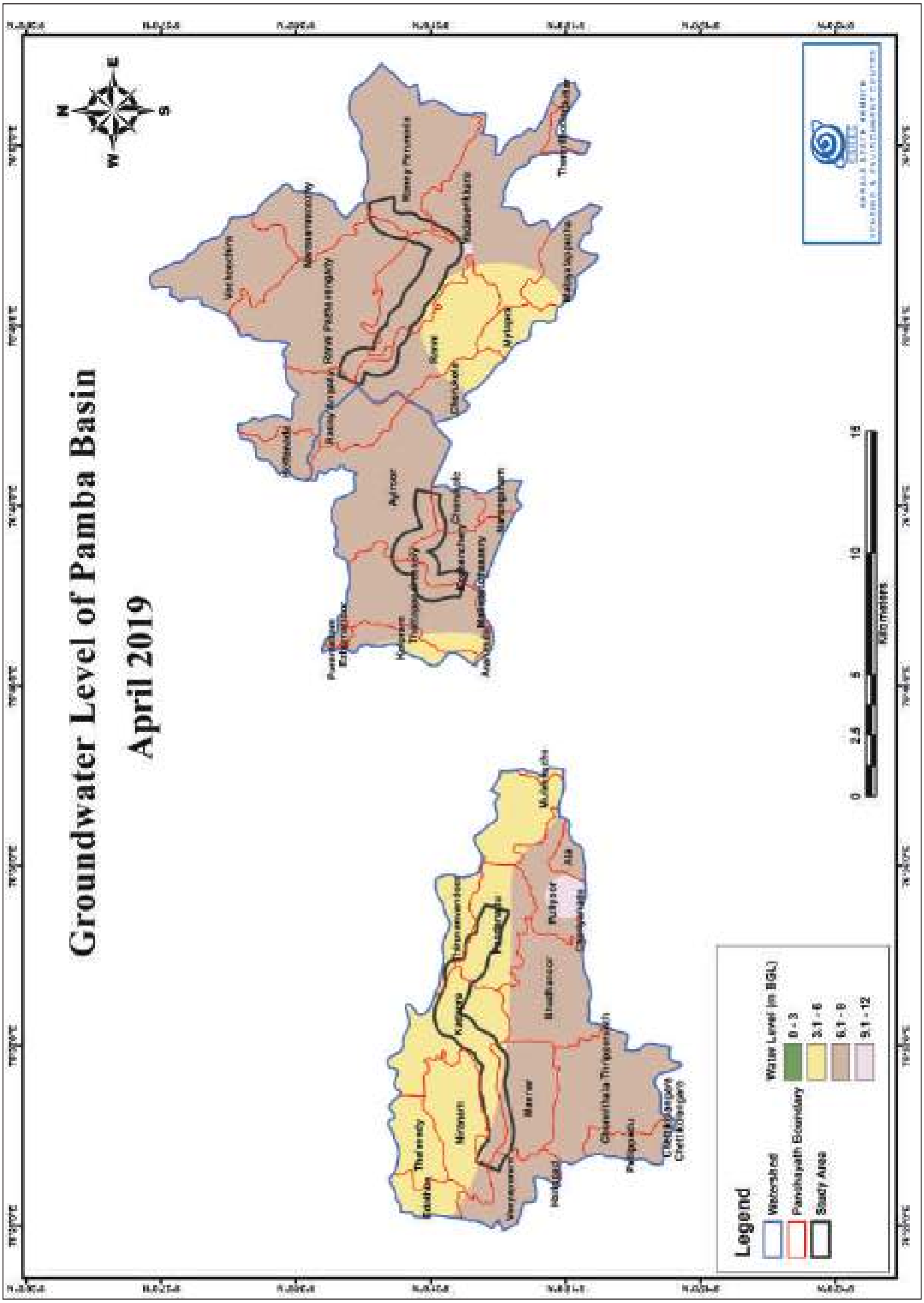


Fig: 6.12. Ground water level April 2019

6.2.5. May 2017, 2018 & 2019

Compared to the March and April 2017 groundwater level May 2017 level is comparatively elevated in most of high land region (Fig.6.13), which represents better summer rains in the catchment area. The low land and mid land is not showing much variation.

May 2018 is showing further raised groundwater level than 2017in all the segments (Fig. 6.14.). There is a gradual raise in the northern part of low land, western part of mid land and southern part of high land.

On the other hand in the post flood scenario, May 2019, the mid land region has shown raised groundwater level compared to the low land and high land segments (Fig.6.15). Low land and high land segments does not show any difference to the pre flood scenario. This represents a less impact of post flood scenario during May 2019.

In general, the Pre flood data analysis for the year 2017 shows deeper groundwater level in high land region ofVadaserikkarapanchayath. Post flood data analysis shows rise in water level in lower part of high land region (Rannipanchayath) and eastern part of midland during the year 2018 and water level rise in all of midland regions for the year 2019.

6.2.6. June 2017, 2018 & 2019

As June 2017 is the monsoon period there is a general groundwater raise in all the segments (Fig.6.16). The Vadasserikara area alone is not showing any impact of monsoon rains where the level is still in the deepest range of the study area which is 9.1 – 12 m.

In the case of June 2018, as the monsoon resulted in heavy rainfall causing the groundwater level to raise in all segments, even in Vadasserikara area of high land (Fig.6.17). The Puliyoor area in the low land region is showing a fall in the water level compared to the previous year, which shows the variation in rainfall. At the higher reaches the rainfall was comparitively heavy which has resulted in the saturation of slopes, landslides and the floods during August 2018.

During June 2019, there is a comparitive depletion in the level in the low land high land segments, where the mid land remains stable (Fig.6.18). The Vechoochira area of the high land segment and the Mannar, Veeyapuram and Cheenithal- Thripperunth segment had shown depletion compared to the previous year.

6.2.7. July 2017 & 2018

As the next phase monsoon had its overlapon the 2018 flood impact further groundwater data was not compared for 2019. The groundwater level of the study area watersheds during July 2017 is showing raised water level in the low land region compared to the June period, especially in the eastern part, Puliyoor and Thiruvandoor area, of the low land segment (Fig.6.19). The mid land and high land region is showing same water level of June period.

July 2018, further shows the raise in groundwater level in tandem with the heavy rainfall received (Fig.6.20). There is a good amount of recharge in the high land region which has resulted in the raised groundwater level,when compared to mid land and low land segments which shows similar water level of 2017.

6.2.8. August 2017 & 2018

The groundwater level for the August 2017 is similar with the July 2017 which has monsoon rainfall for the recharge and the better water level condition which has a maximum depth of only 9 mts in the high land and mid land region. The low land is also showing the same trend except for the Puliyoor region which is upto 12 mts (Fig. 6.21).

During the flood month of August 2018, it can be seen that there is general decline of groundwater level in the southern side of mid land and low land region of the study area (Fig. 6.22). The massive landslides and floods of August 2018, has resulted in the excessive outflow of surface and groundwater. The heavy rainfall for short period resulted in large scale mass movement and release of groundwater, on the one hand and the heavy runoff on the other hand could have resulted in the shift of groundwater level.

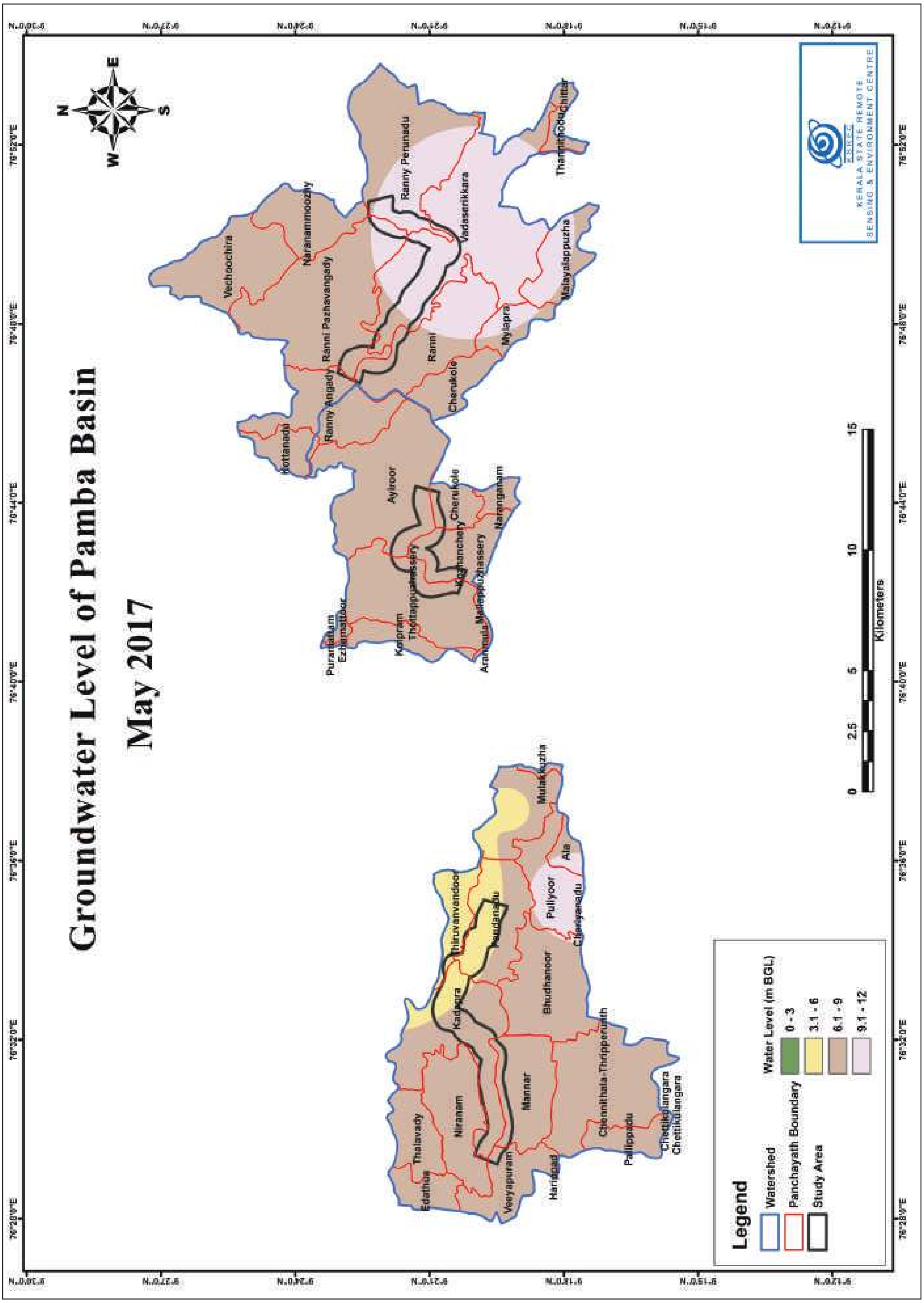


Fig: 6.13. Ground water level May 2017

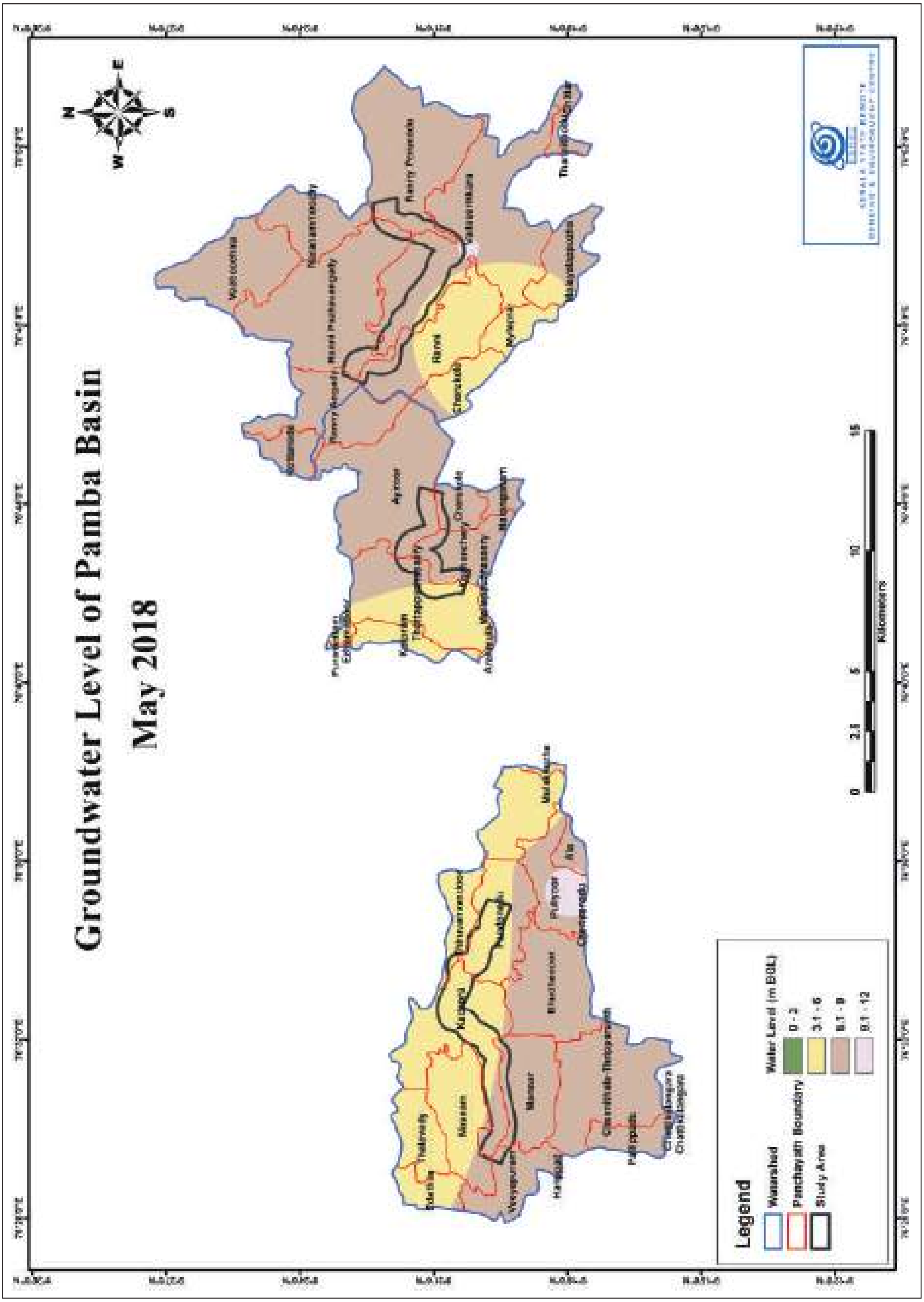


Fig: 6.14. Ground water level May 2018

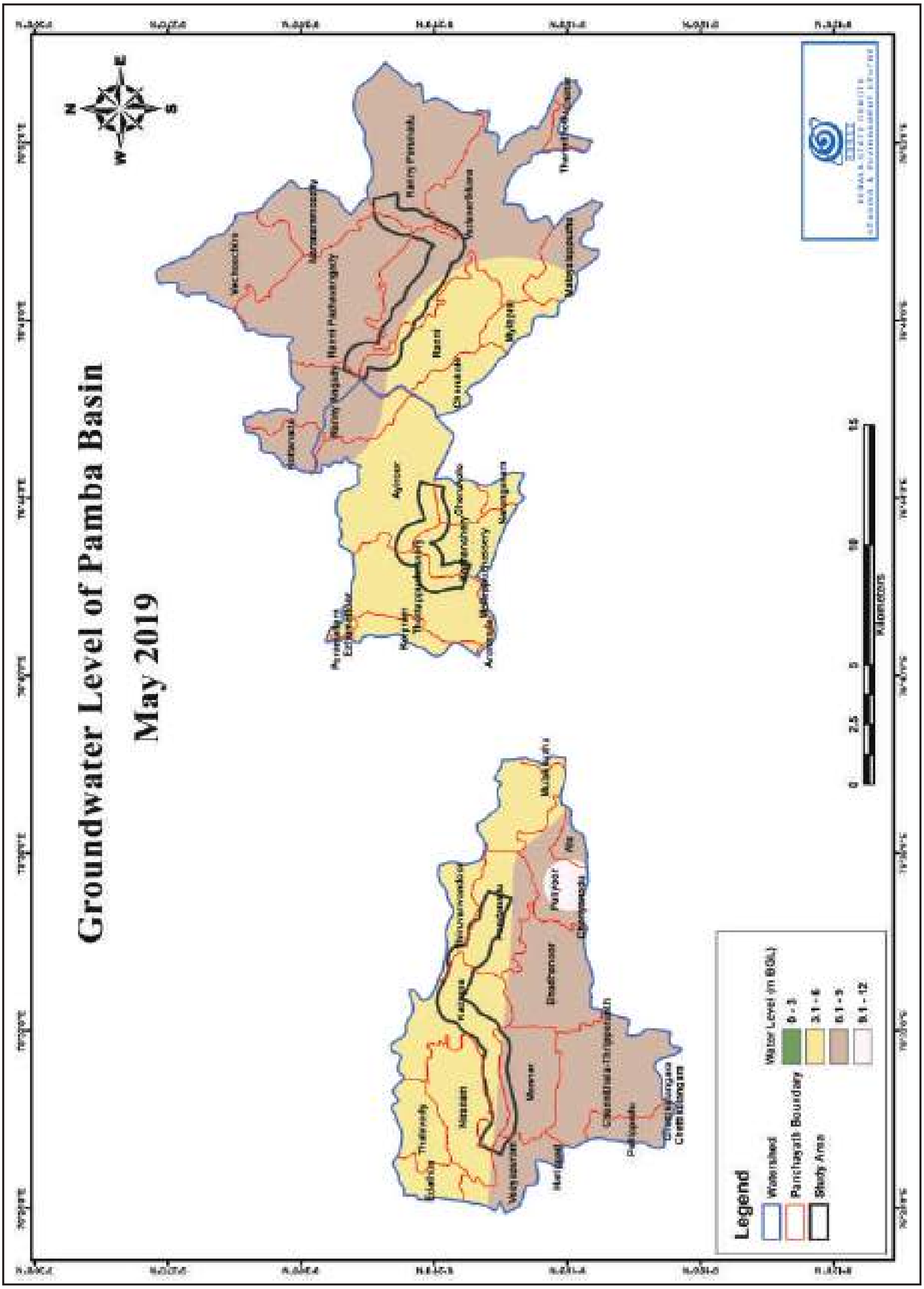


Fig: 6.15. Ground water level May 2019

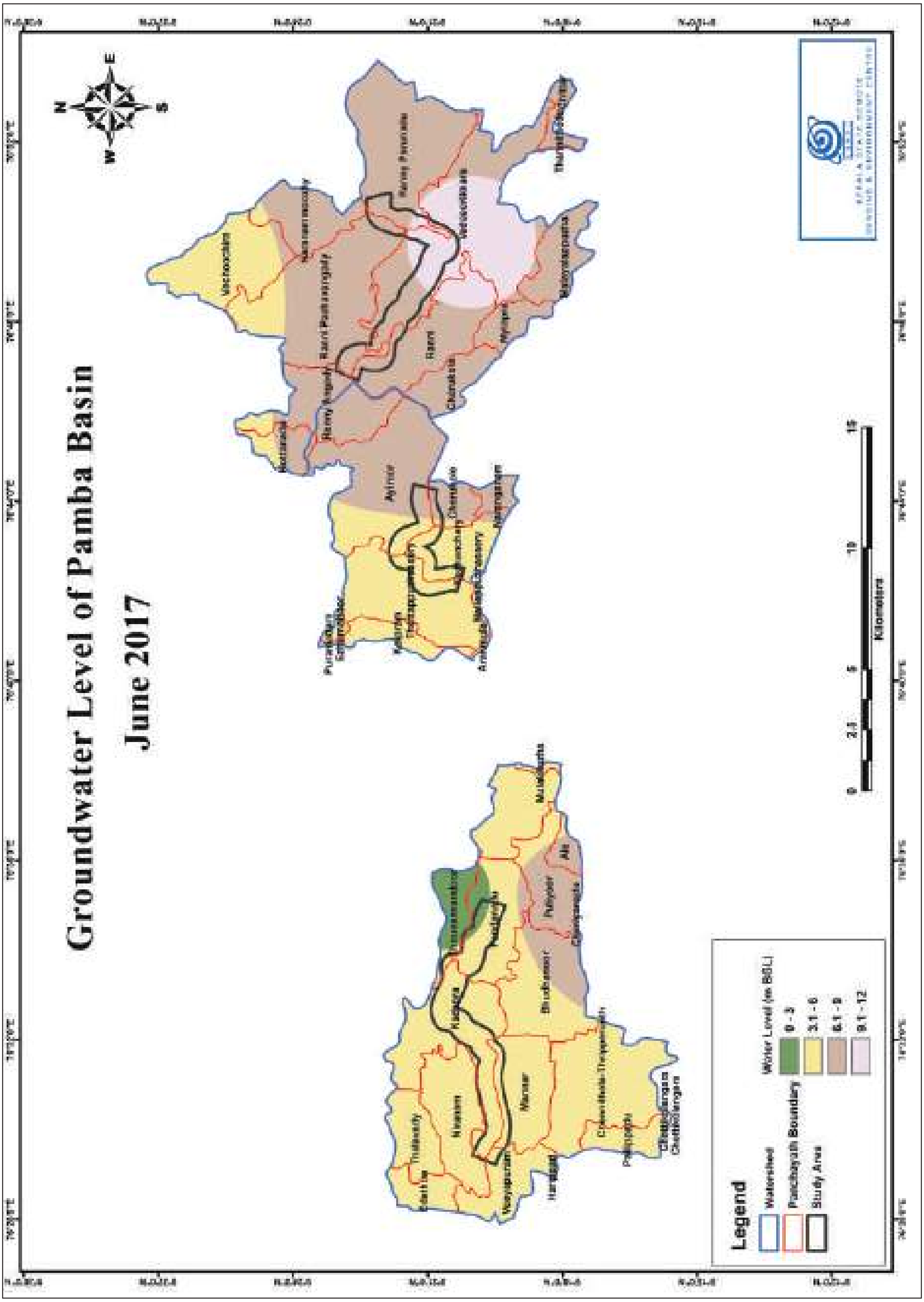


Fig: 6.16. Groundwater level June 2017

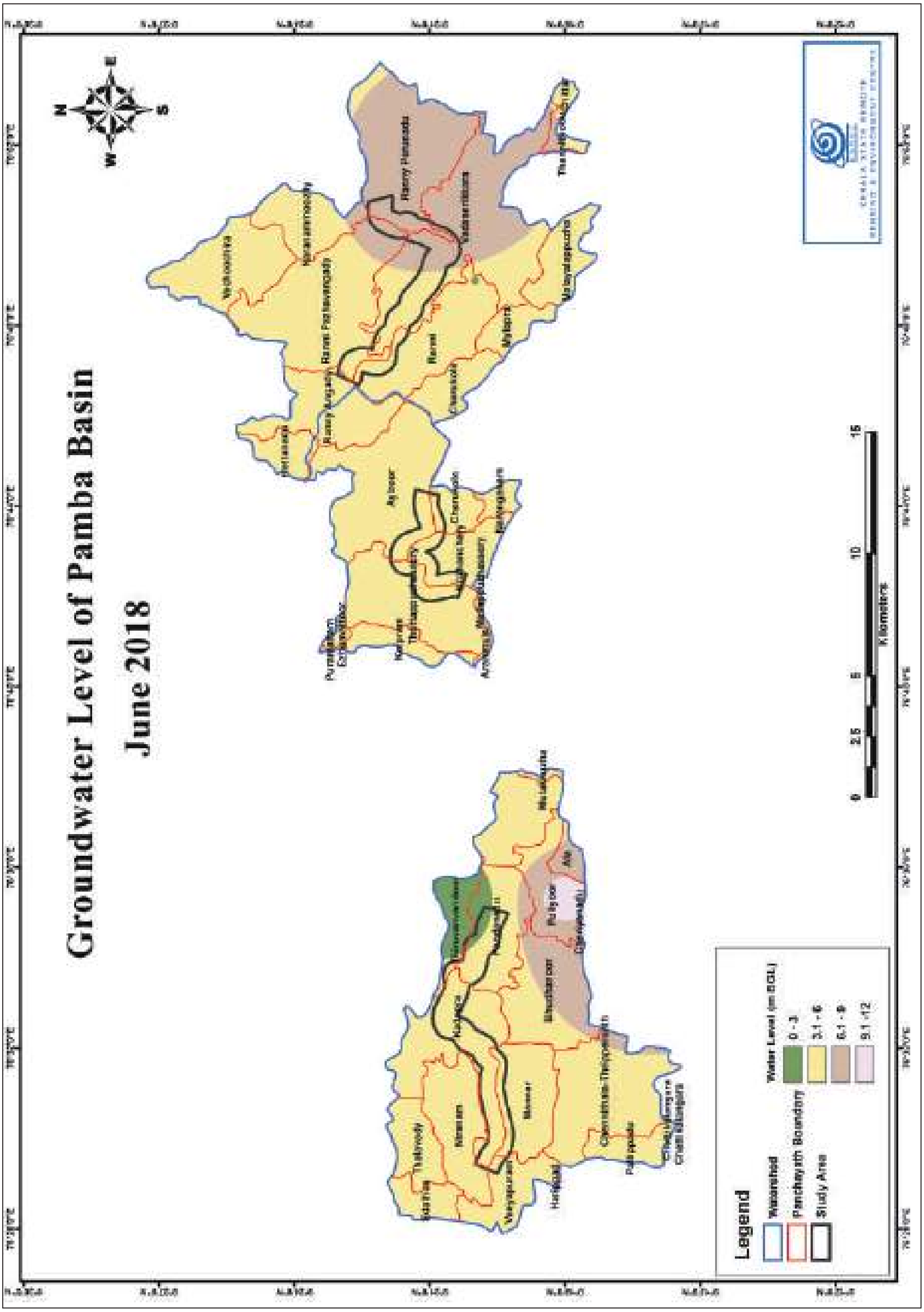


Fig: 6.17.Ground water level June 2018

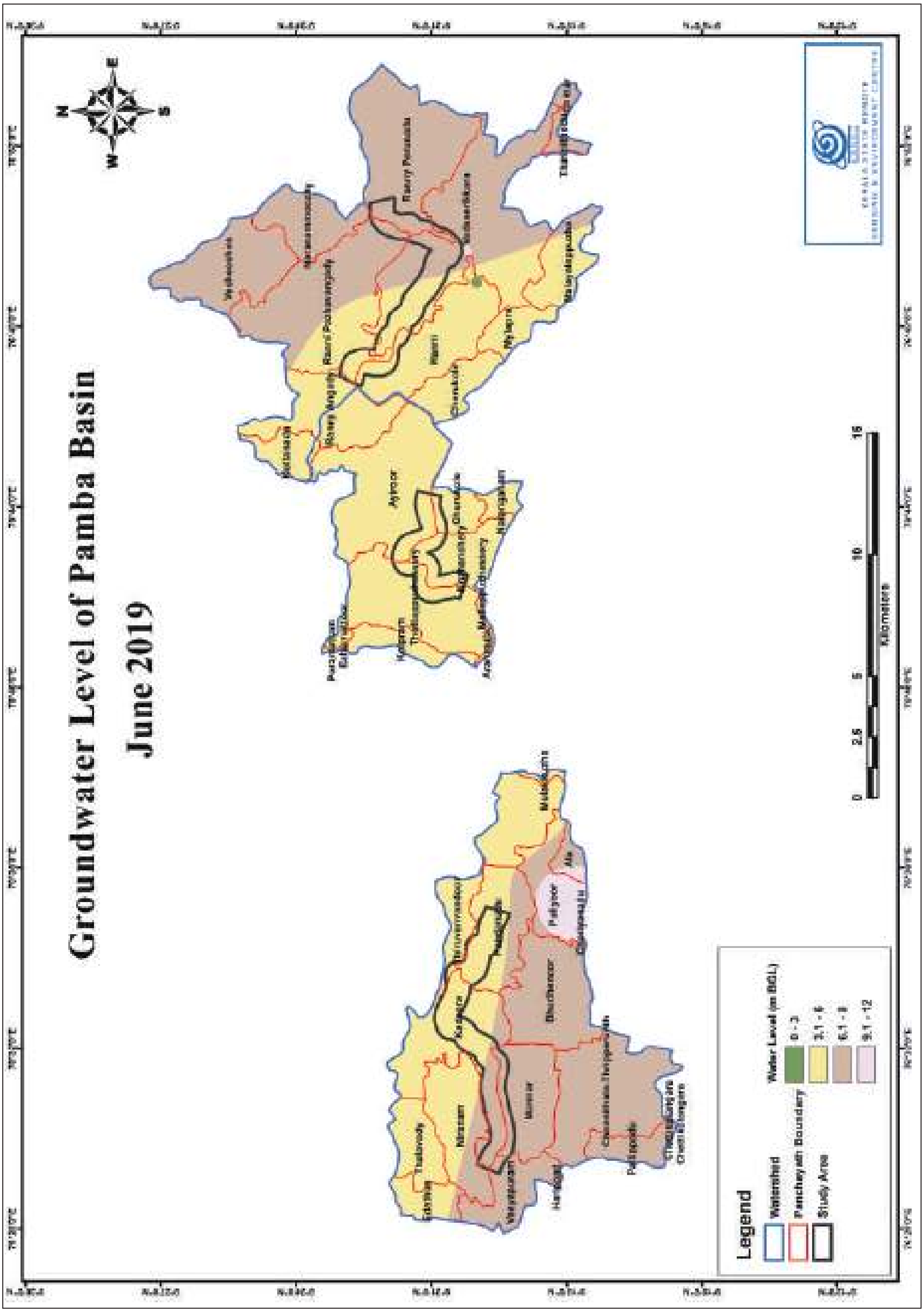


Fig: 6.18. Ground water level June 2019

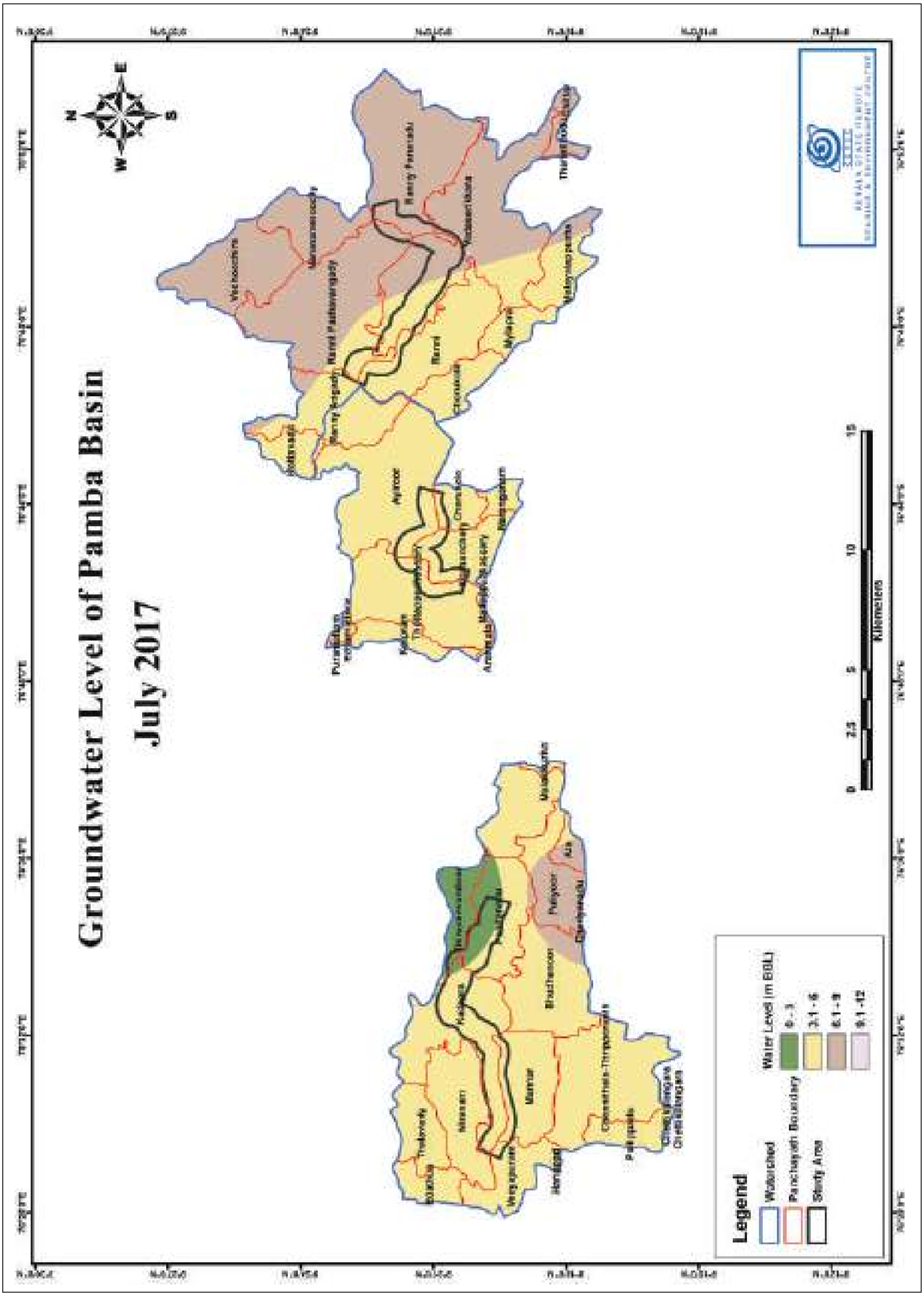


Fig: 6.19. Groundwater level July 2017

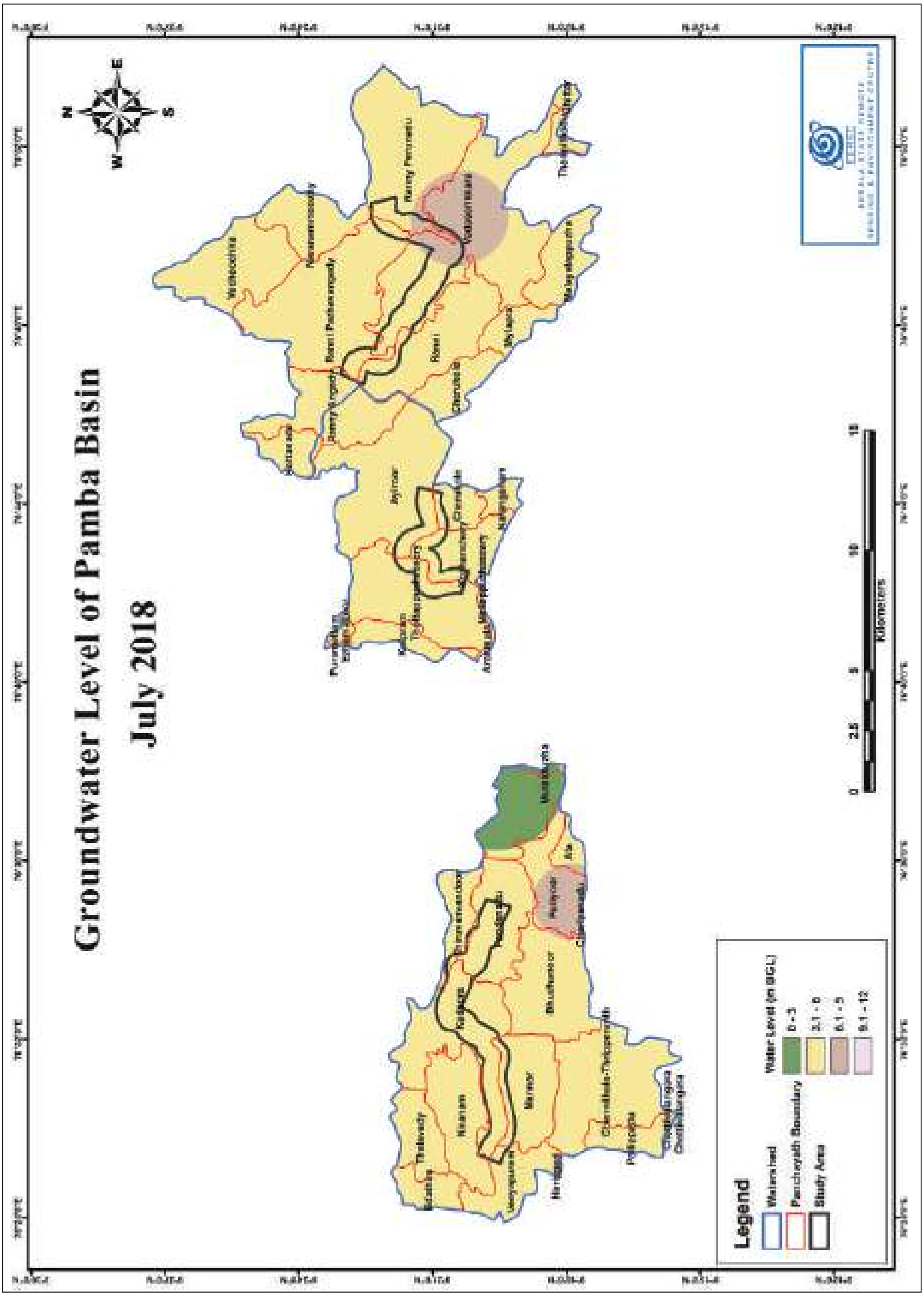


Fig: 6.20. Groundwater level July 2018

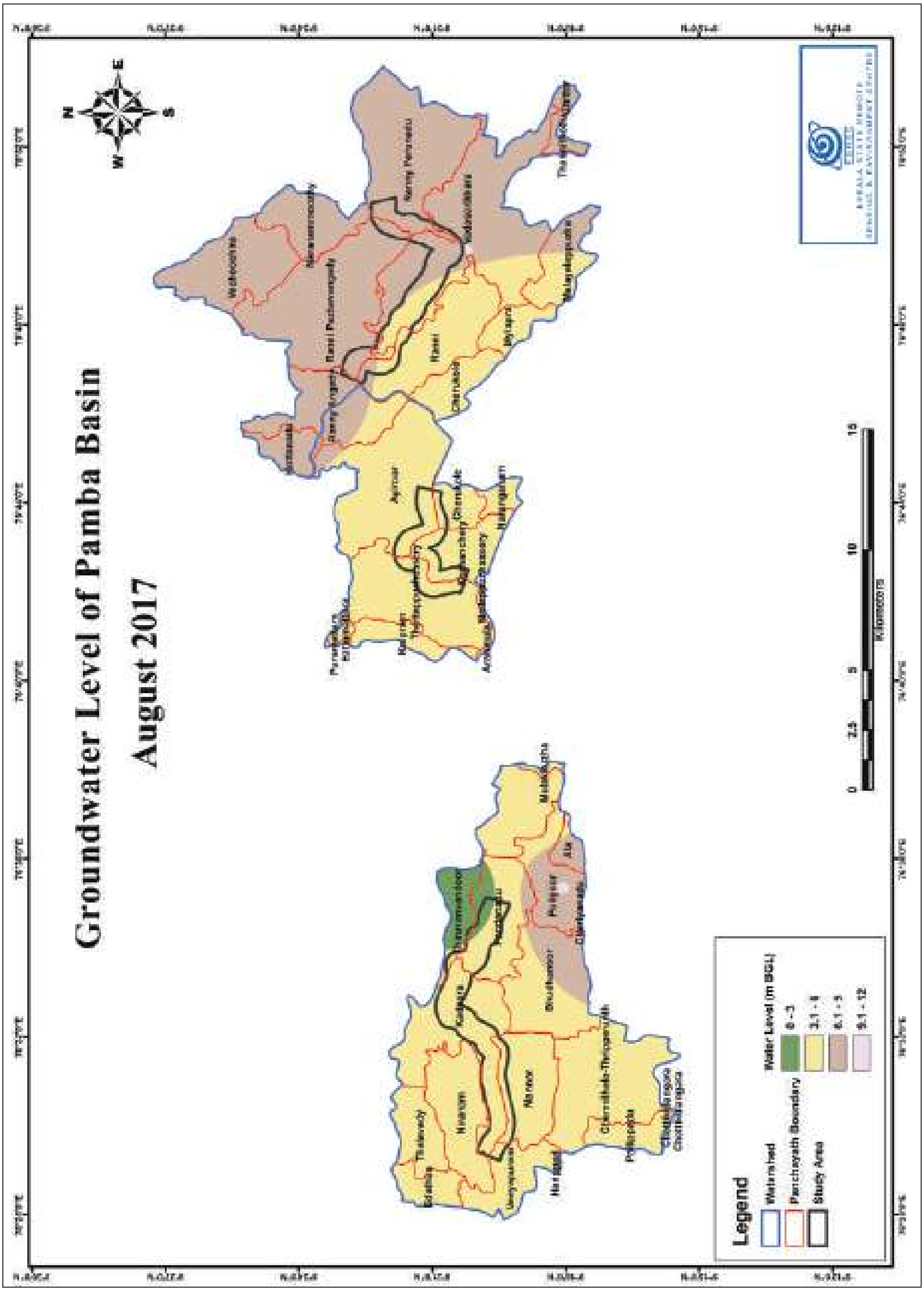


Fig: 6.21. Groundwater level August 2017

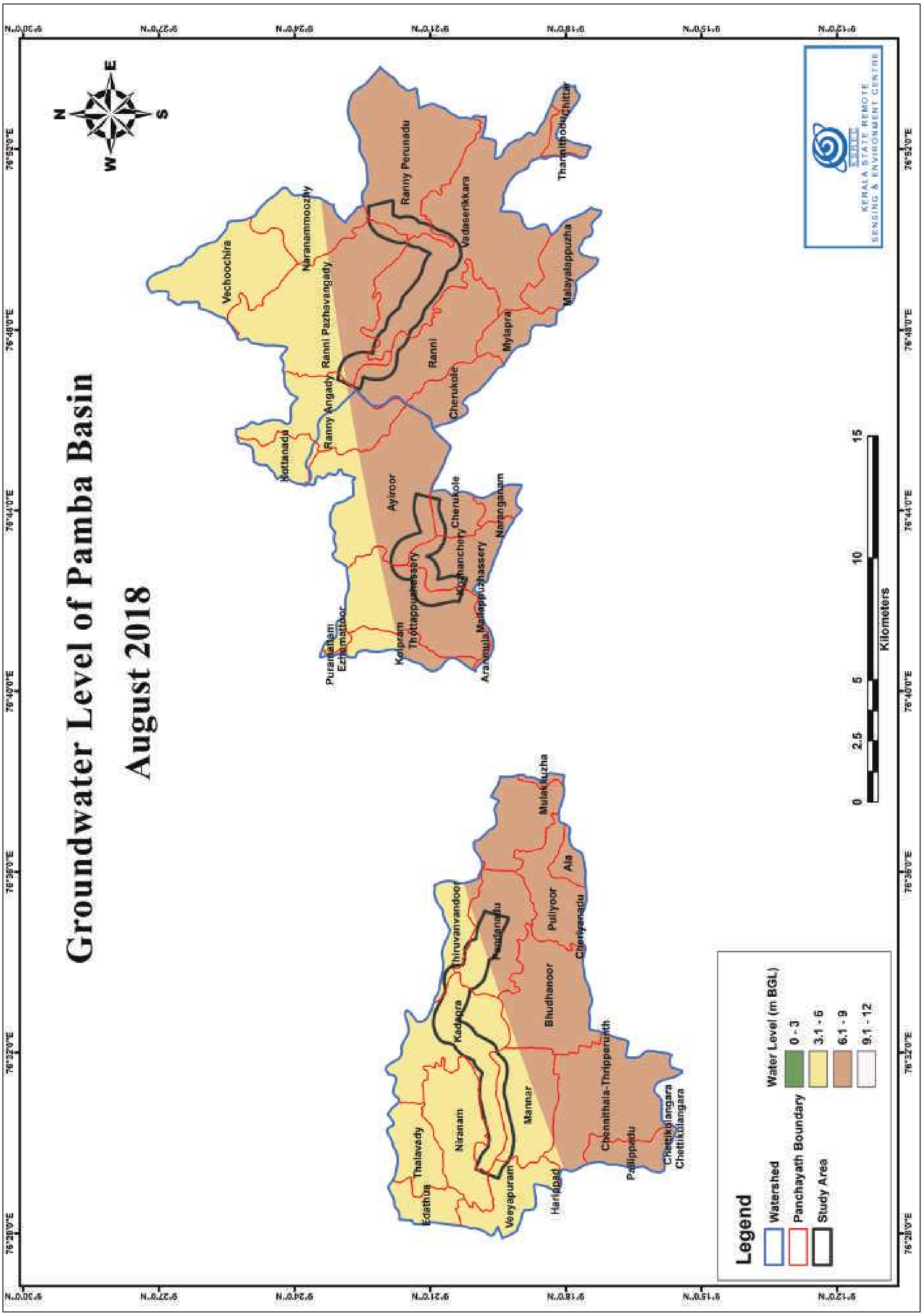


Fig: 6.22. Groundwater level August 2018

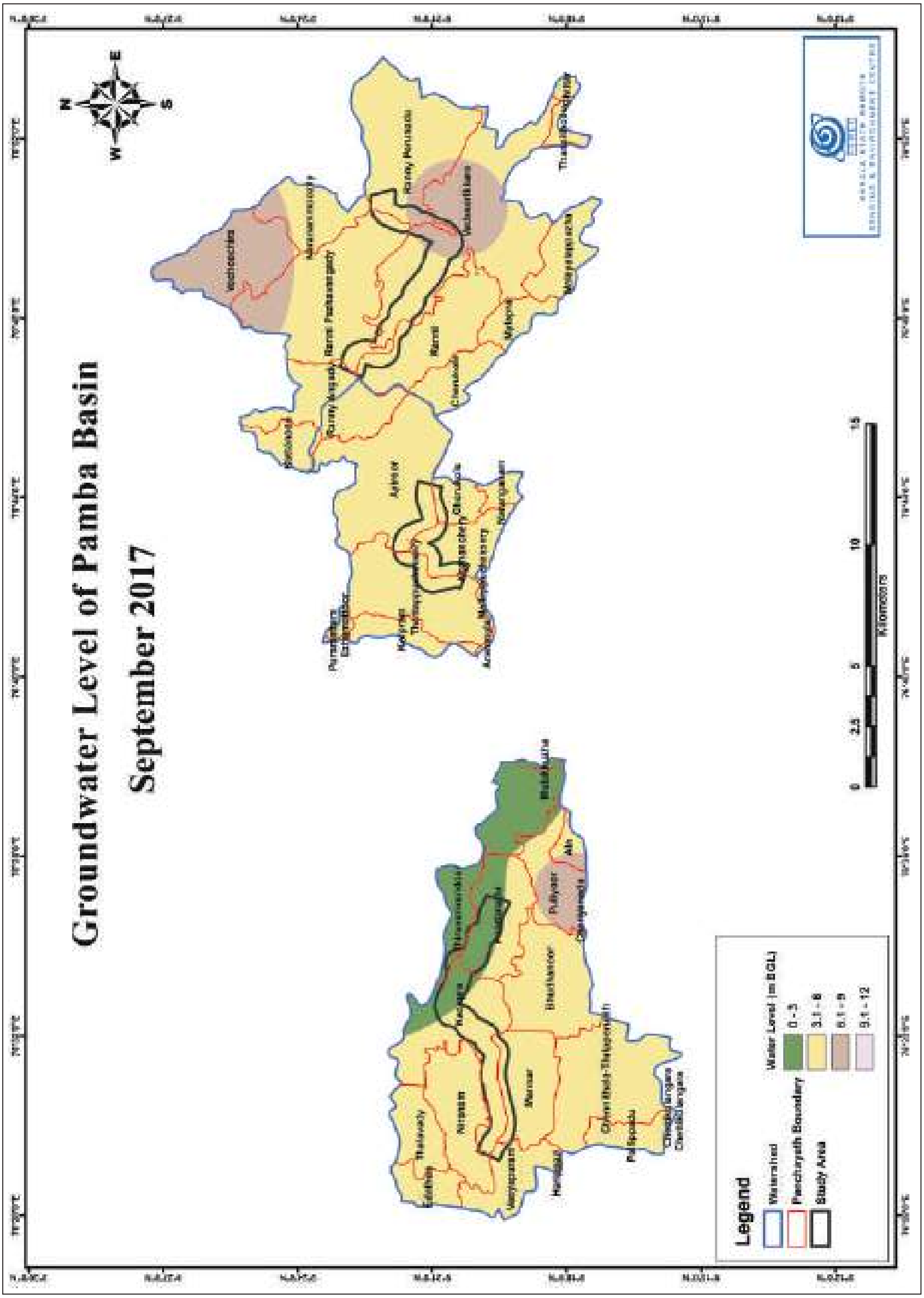


Fig: 6.23. Groundwater level September 2017

6.2.9. September 2017 & 2018

There is a further raise in the groundwater level compared to the August 2017 in September 2017. There may be continuing recharge during the monsoon which has resulted in the better groundwater level in September 2017. This is especially due to the continuing receipt of rainfall over a long period enabling the aquifer recharge. Majority of the area is showing groundwater level depth to a maximum of 6 mts., where as Thiruvandoor and Mulakuzha in the low land region has groundwater in the 3 mts. reach from the ground. Puliyoor in the low land and Vechoochira and Vadaserikkara in the high land is having groundwater level at a maximum of 9 mts from the ground surface.

The entire area of mid land and major area of low land and high land was showing the groundwater level range upto 9 mts from the ground level during September 2018 (Fig.6.24). The Vechoochira of the high land was showing better groundwater level of upto 6 mts from ground level, which was a region normaly showing low groundwater level. The Mulakuzha region of the low land segment is showing deeper groundwater level compared to the normal shallow groundwater level.There was a drastic change in the groundwater level during the August 2018 Flood and post flood September 2018 period as a result of excessive runoff and flushing of groundwater through mass movement and may also due to flood retrieval hydraulics.

6.2.10. October 2017 & 2018

During the October 2017 the groundwater in the low land has shallow level, even the Puliyoor region has groundwater range upto a maximum of 9 mts, which normaly has deeper groundwater levels. In the case of mid land there is a slight decrease in the water level especially in the Ayiroor – Cherukole segment. The high land region is showing shallow water level in general.

October 2018 shows a recovery of groundwater level and the low land segment matches with the level of October 2017 (Fig. 6.26). In the case of mid land and high land the level has further gained and the general depth is below 6 mts from the ground except for the Vadasserikkara – RanniPerunadu region where the depth is upto 9 mts.

6.2.11. November 2017 & 2018

During November 2017, the groundwater level is similar in line with the conditions of October 2017 for all the three segments (Fig.6.27). In the case of November 2018 the Puliyoor in the low land has gone back to the 12 mts depth range, but the mid land and high land has recently stable groundwater level (Fig.6.28) with draining of groundwater level from the higher elevation of high land.

6.2.12. December 2017 & 2018

The level of groundwater is showing a depleting trend in all the three study segments during December 2017. The low land has all the four classes of groundwater level which is upto 12 mts below ground level. In the case of mid land and high land there are only two classes ranging between 3 to 9mts.

During December 2018 the low and and high land are showing the deepest waterlevel locations especially in the Puliyoor in low land and Vadasserikkara in High land showing that water level is receding as the draft is substantial (Fig. 6.30). All the three study segments are showing the receding trend in the groundwater level.

6.3. Conclusion

The groundwater level of the study segments of the Pamba basin has the deepest groundwater level upto 12 mts in the Puliyur area of Low land and Vadasserikkara area of High land, where as in the mid land region the deepest level is upto 9 mts only. The region is normally showing a groundwater level depending on the monsoon rain availability. The study was focusing on the impact of August 2018 flood in the groundwater dynamics,which reveals that during the flood period of August and September 2018 there was depletion in groundwater availability. The depletion can be attributed to the excessive runoff and flushing of groundwater through mass movements and may also due to flood retrieval hydraulics.

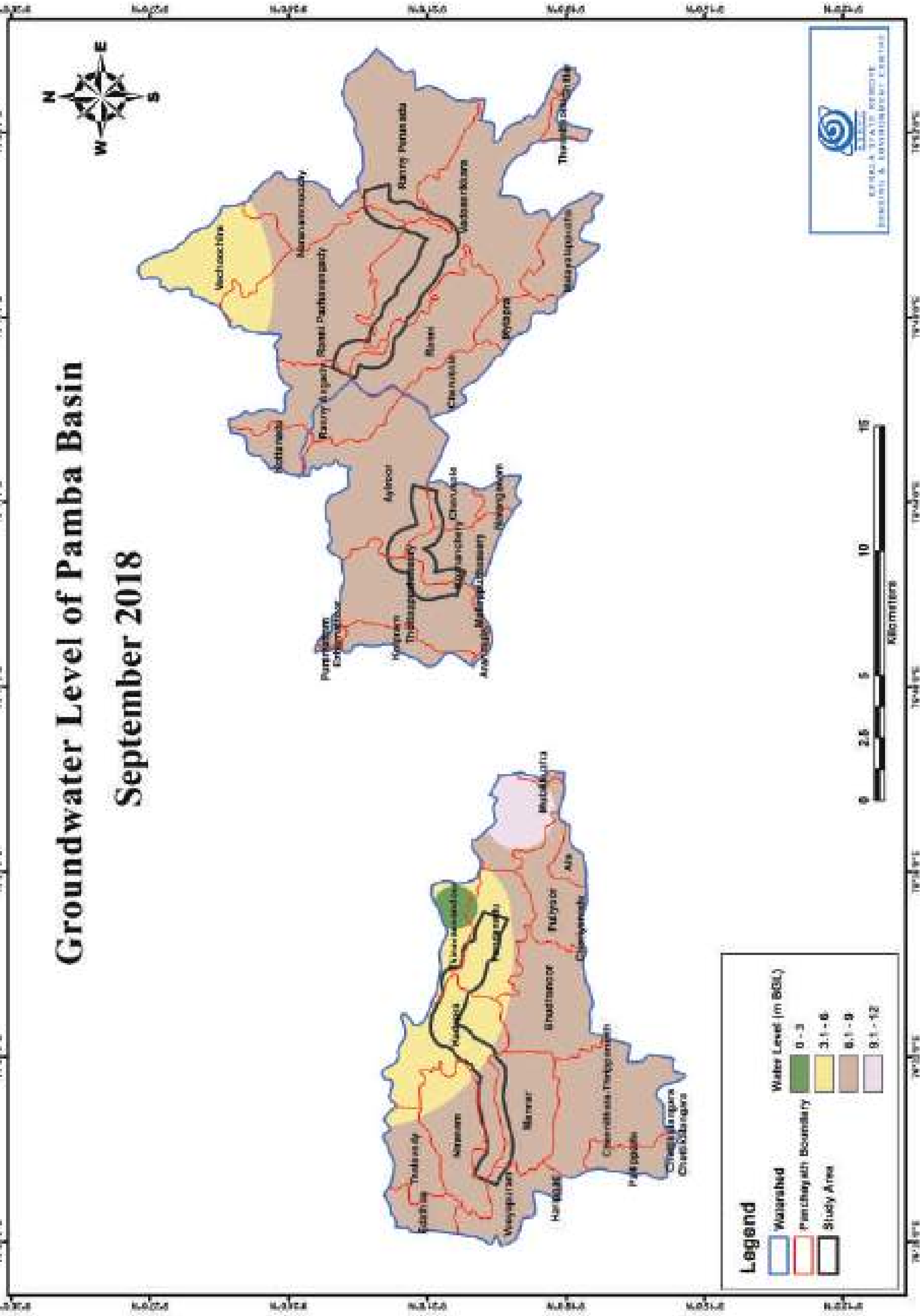


Fig: 6.24. Groundwater level September 2018

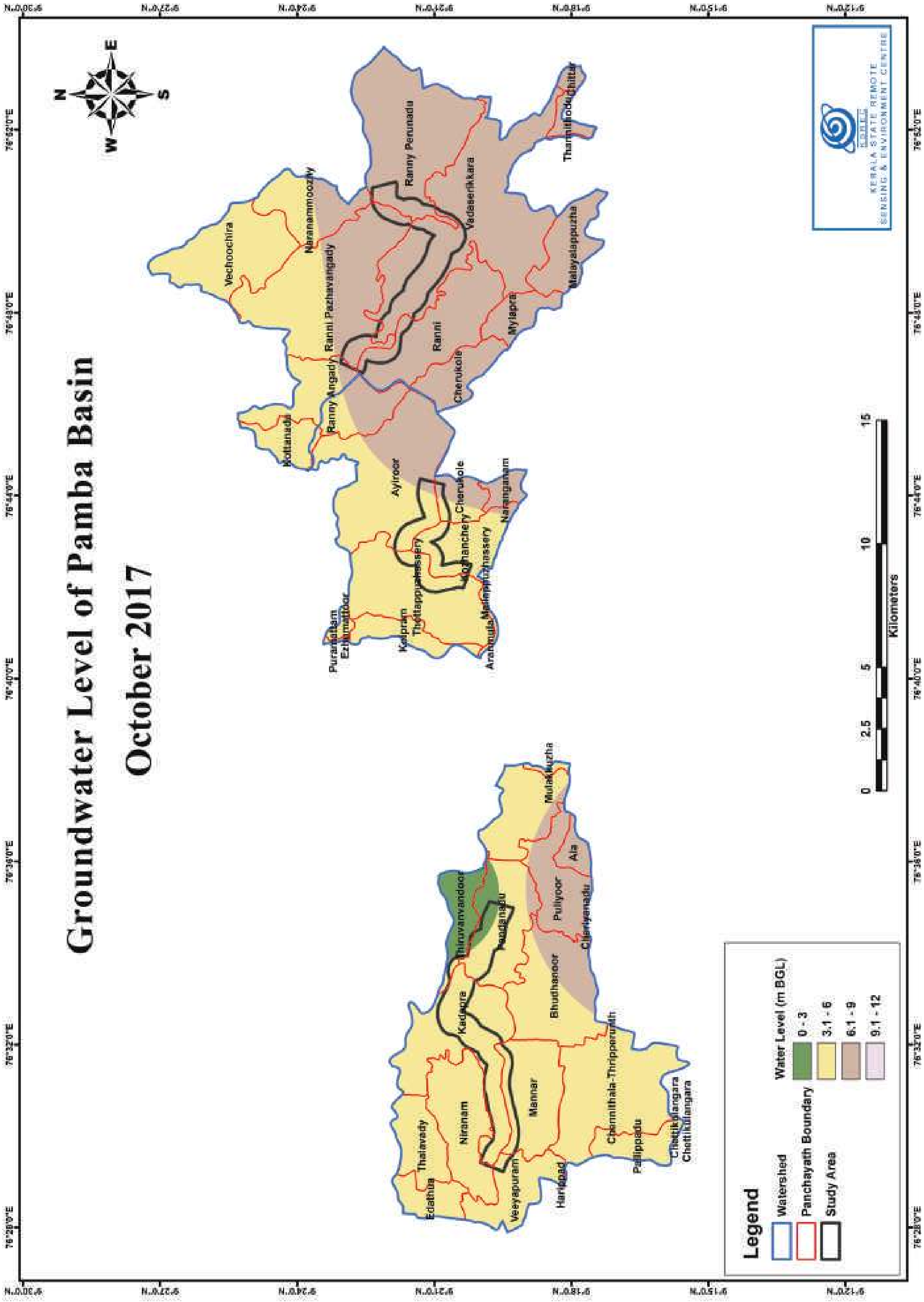


Fig: 6.25. Groundwater level October 2017

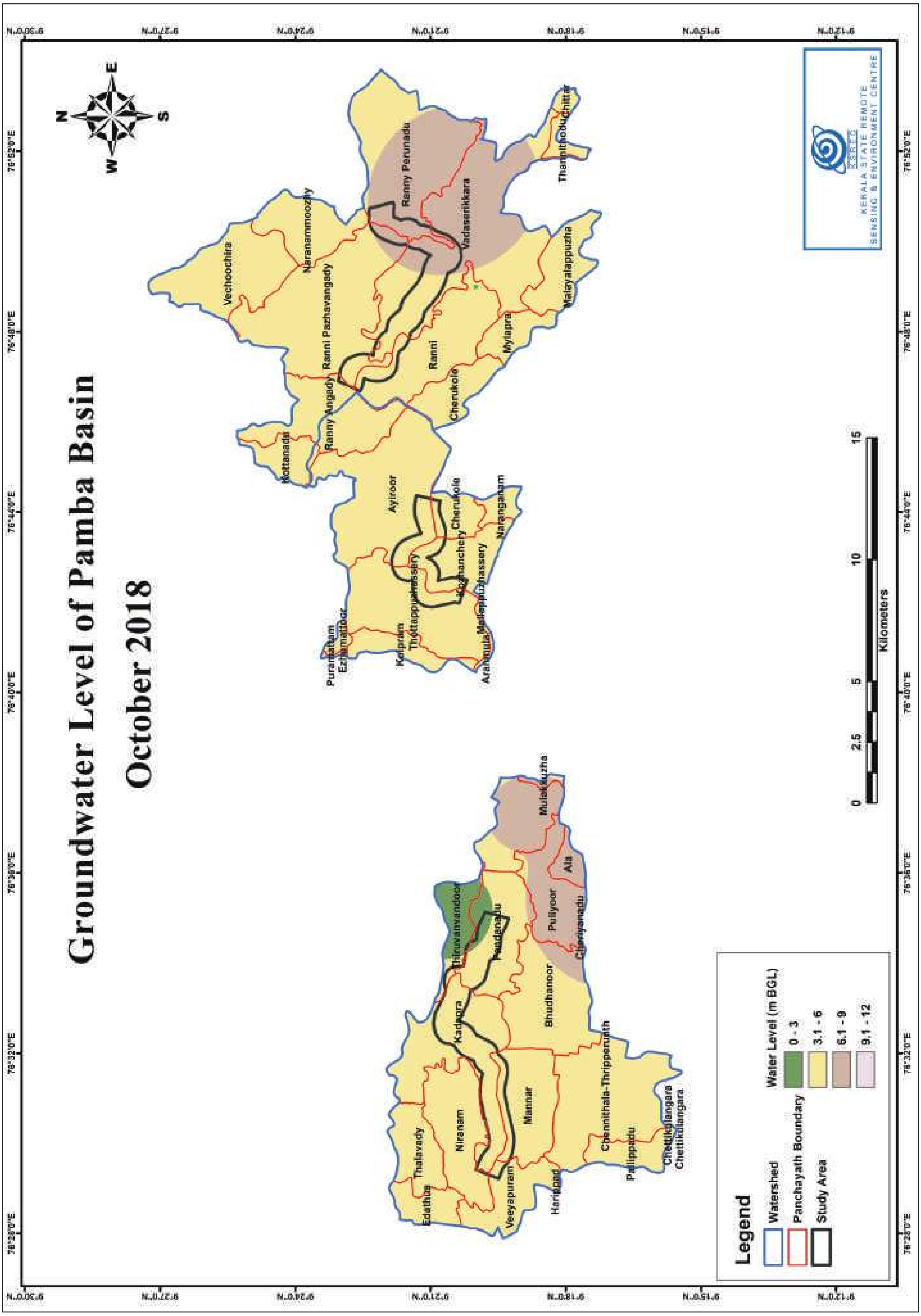


Fig: 6.26. Groundwater level October 2018

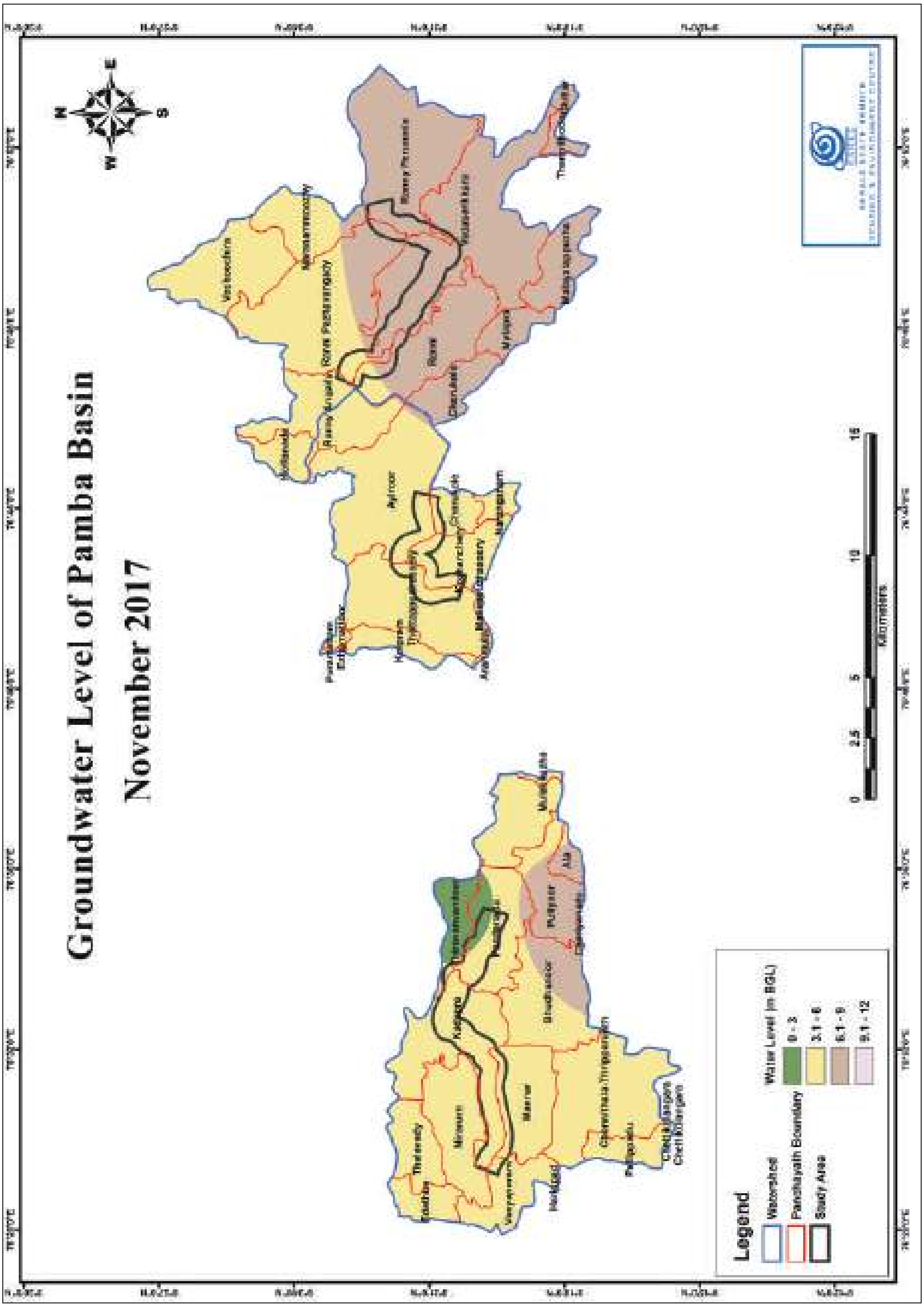


Fig: 6.27. Groundwater level November 2018

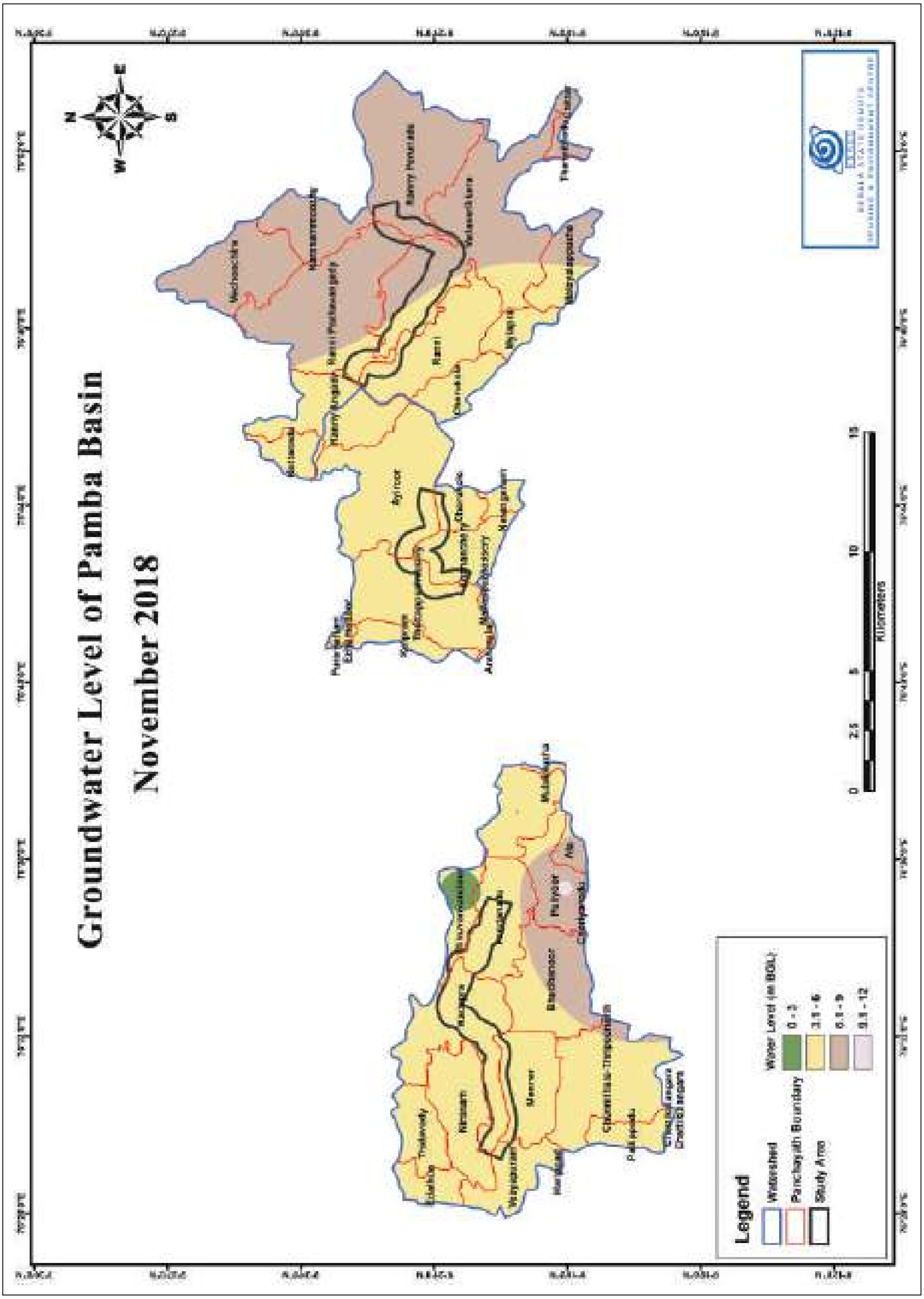


Fig: 6.28. Groundwater level November 2018

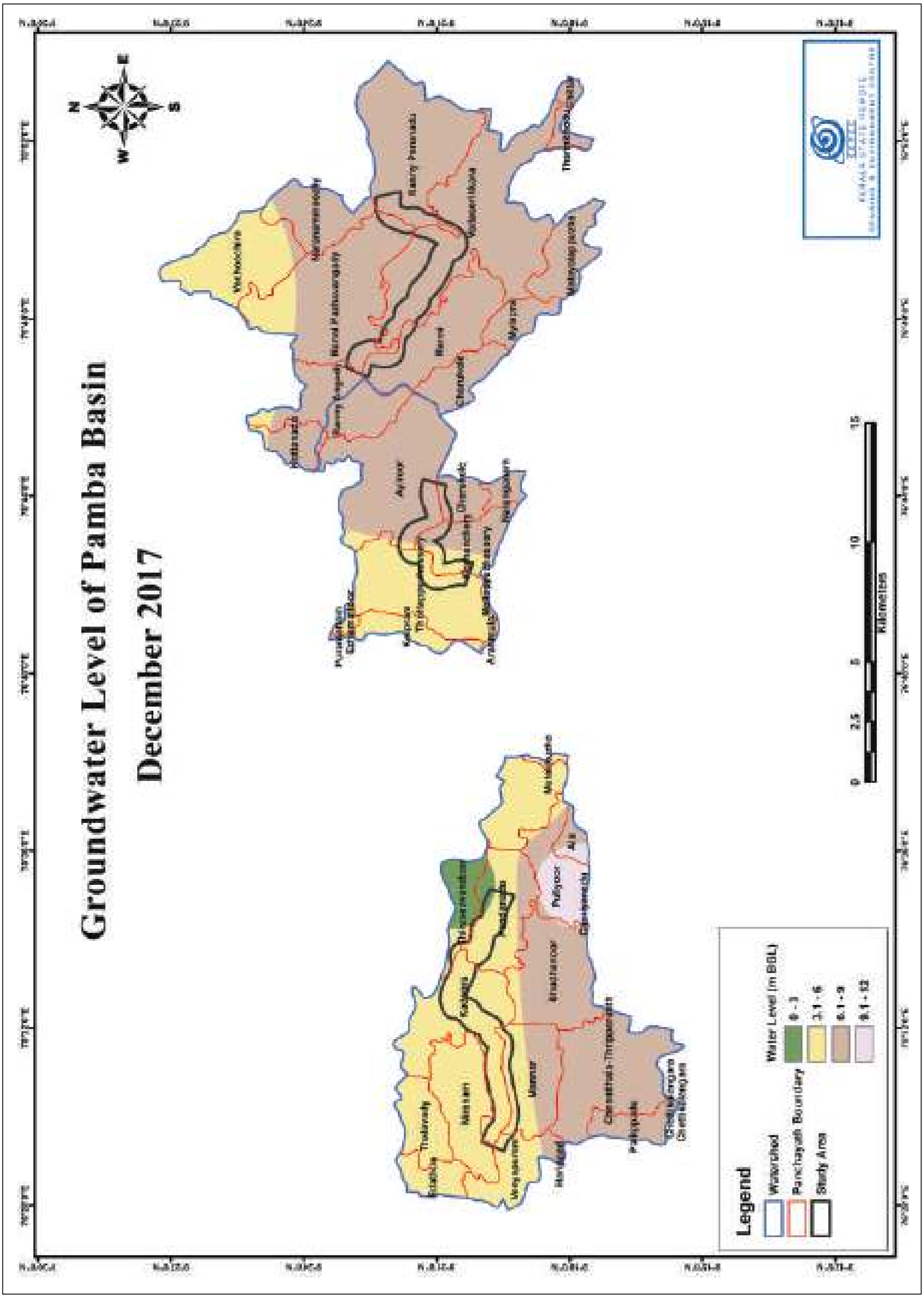


Fig: 6.29. Groundwater level December 2017

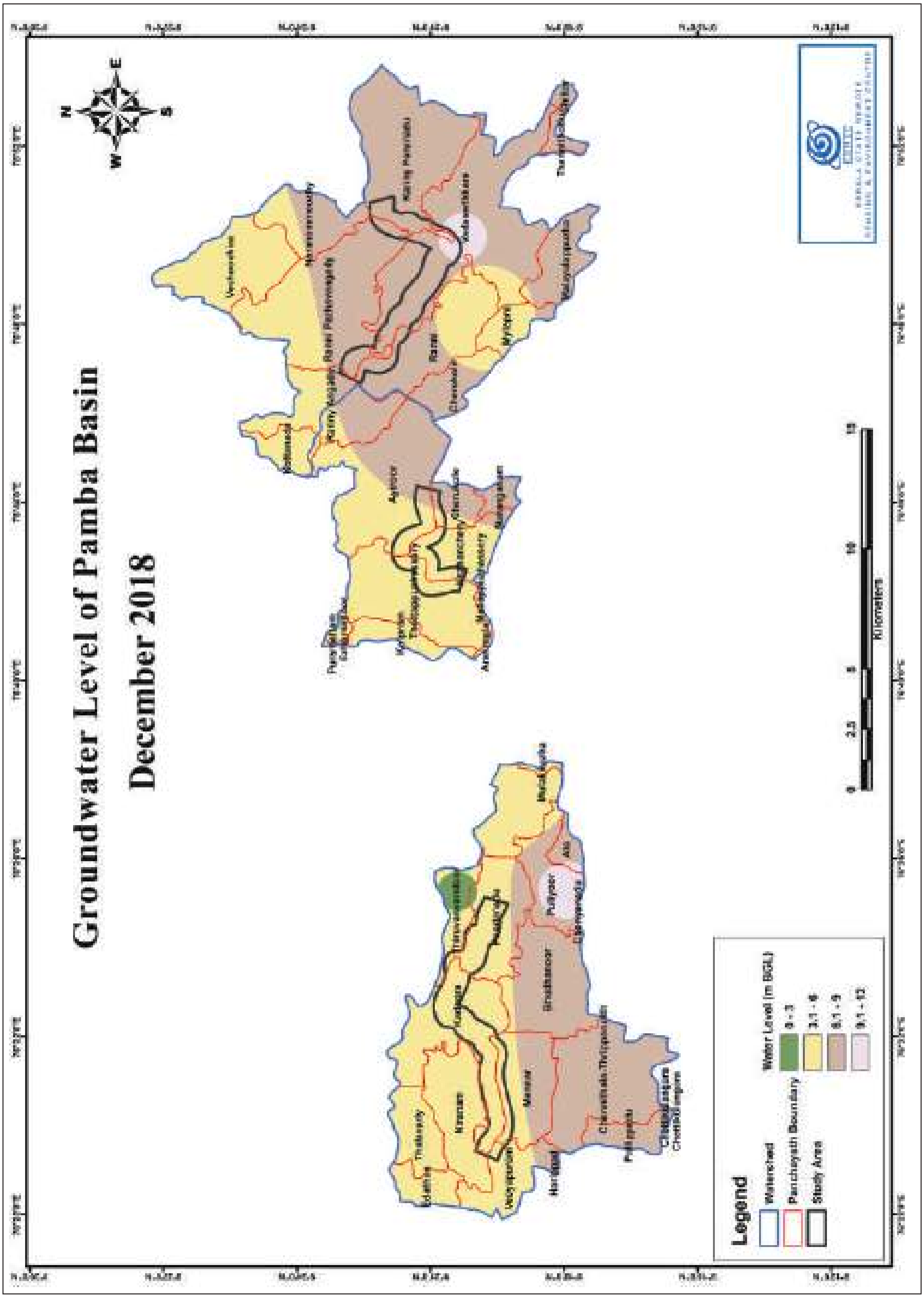


Fig: 6.30. Groundwater level December 2018

CHAPTER VII

RIVER PROFILE CHARACTERISTICS

7.1. Introduction

The course a river in Kerala terrain takes its split into three stages, the upper, middle and lower stage. These three stages are found in the high land mid land and low land region of the terrain. In the upper stage, the river is close to its source and high above its base level (the lowest point the river can erode to). In the lower stage the river is far away from its source, close to the mouth and not far above its base level. In the middle stage, it's somewhere in between.

The total energy that a river possesses varies from one stage to another because of changes in the river's height, gradient and speed. In the upper course of high land, the gradient of the river is steep and the river is high above sea level giving it a large amount of gravitational potential energy that can be converted to kinetic energy later on. In the middle course of mid land, the river's gravitational potential energy gets converted to kinetic energy and the gradient begins to level out resulting in the river's velocity increasing. By the time the river reaches its lower stage in the low land, it has next to no gravitational potential energy but lots of kinetic energy resulting in a high velocity (Alex, 2014).

7.2. River Processes

7.2.1. Processes in the high land

In the upper course of high land, the river has a lot of gravitational potential energy so it has a lot of energy to erode vertically. The bed of the river is eroded greatly while the banks aren't eroded as much. The river mainly transports large pieces of angular rock and does so by traction because it doesn't have enough kinetic energy to move the load in any other way. This increases erosion of the bed by corrasion as a result of the load being dragged along the bed of the river. Vertical erosion is further increased by the rough nature of the channel in the upper course which increases the water's turbulence and its ability to erode. Erosion and transportation only takes place in large quantities in the upper course when the river's discharge is high after periods of heavy precipitation. When the river's discharge falls the river stops transporting the large boulders and deposits them(Alex, 2014).

7.2.2. Processes in the Mid land

In the middle course of mid land, the river has less gravitational potential energy and more kinetic energy so erosion shifts from vertical to lateral erosion. Corrasion is still the main erosive process as large particles are transported by saltation(Alex, 2014). The average load size has decreased in the middle course, so more load is being transported in suspension. In the middle course, the river can flood and in doing so, it deposits gravel and sand sized particles onto its flood plain.

7.2.3. Processes in the Low land

In the lower course of low land, the river has decreased gravitational potential energy so erosion is almost exclusively lateral. There isn't much erosion though because the channel is smoother resulting in less turbulent flow. The main place where erosion takes place is where the river meanders. The average particle size is very small now, another reason for the reduction in erosion. The river's load is mainly composed of silts and clays and it is transported in suspension or even solution(Alex, 2014). Like in the middle course, when the river floods it deposits its load but deposition now also takes place at the mouth of the river where the river meets the sea.

7.3. River Cross Profiles

River cross profiles show you a cross-section of a river's channel and valley at certain points in the river's course. The cross profile of a river changes as it moves from the upper to lower course as a result of changes in the river's energy and the processes that the river carries out.

In the high land, the valley and channel are narrow and deep as a result of the large amount of vertical erosion and little lateral erosion. The sides of a river's valley in the upper course are very steep earning these valleys the nickname "V-Shaped Valley" since they look like a letter V. The river's valley can be anything from a few meters to a few hundred metres in width depending on the lithology but the channel rarely will be more than 5m or 6m wide.

In the mid land, the valley has increased in width due to the increase in lateral erosion but its depth has not changed significantly because vertical erosion has slowed down. Similarly, the channel's width has increased but it's still roughly the same depth. The land to either side of the channel in the valley is now the river's floodplain and the valley's sides are much gentler.

7.4. River Profile Characterization

A study on the river profile and cross sections were conducted with the help of field survey using Differential Geographic Positioning System (DGPS). The survey was intended to measure the river cross sectional values, mapping of the river along the cross sectional segments for its characteristics and landuse during the pre flood period 2013. Further the cross sectional values were again measured and mapped during the post flood survey of 2018 at the same locations.

7.5. River Profile Characteristics

Pre and Post flood river profile variation assessment has been done in lowland, midland and high land. The change occurred in the river profile is analyzed to identify the impact of flood on the river channel.

7.5.1. Low Landsegment - long profile

The low land segment long profile for the pre and post flood were mapped with the help of elevation values along the study stretch. The values were plotted and analyzed in the GIS platform and profiles derived against water level and length of the segment from the lowest to highest elevation. Profiles were generated with the help of values from 2013 study and also from the 2018 study for the case of post flood (Fig.7.1). The comparative analysis shows that there is impact due to the flood within the 3 to 9 km stretch. Even though the variations in the profile are not easily discernible, the variations are mainly due to the depositional and erosional characteristics developed by the river stretch during the flood scenario. The depositional characteristic is less in the post flood as represented in the figure 7.2. The erosional characteristic is dominant (Fig.7.3) when compared to the depositions. River bank erosion is the post flood characteristic of the low land segment which is also shown in the study using Drone based Remote Sensing techniques as shown in chapter 3. Even though the low land area is predominantly showing erosional characteristic in the 2013 survey compared to its depositional units, the trend got aggravated in the post flood scenario. The broken erosional patches of the 2013 survey have become continuous stretches in the post flood 2018 scenario.

7.5.2. Mid Land segment - long profile

The long profile of the mid land segment also shows flood impact all through the study segment. The profile graph is showing variations due to the depositional trend of the region (Fig.7.4). The flood impact of the region is depicted as the deposition of channel bars and erosion also at specific locations. It is also found that there is substantial increase in the number of channel bars and braid bars in the mid land segment with erosion along the meander bends. The field survey erosional features could not be depicted, but the same is

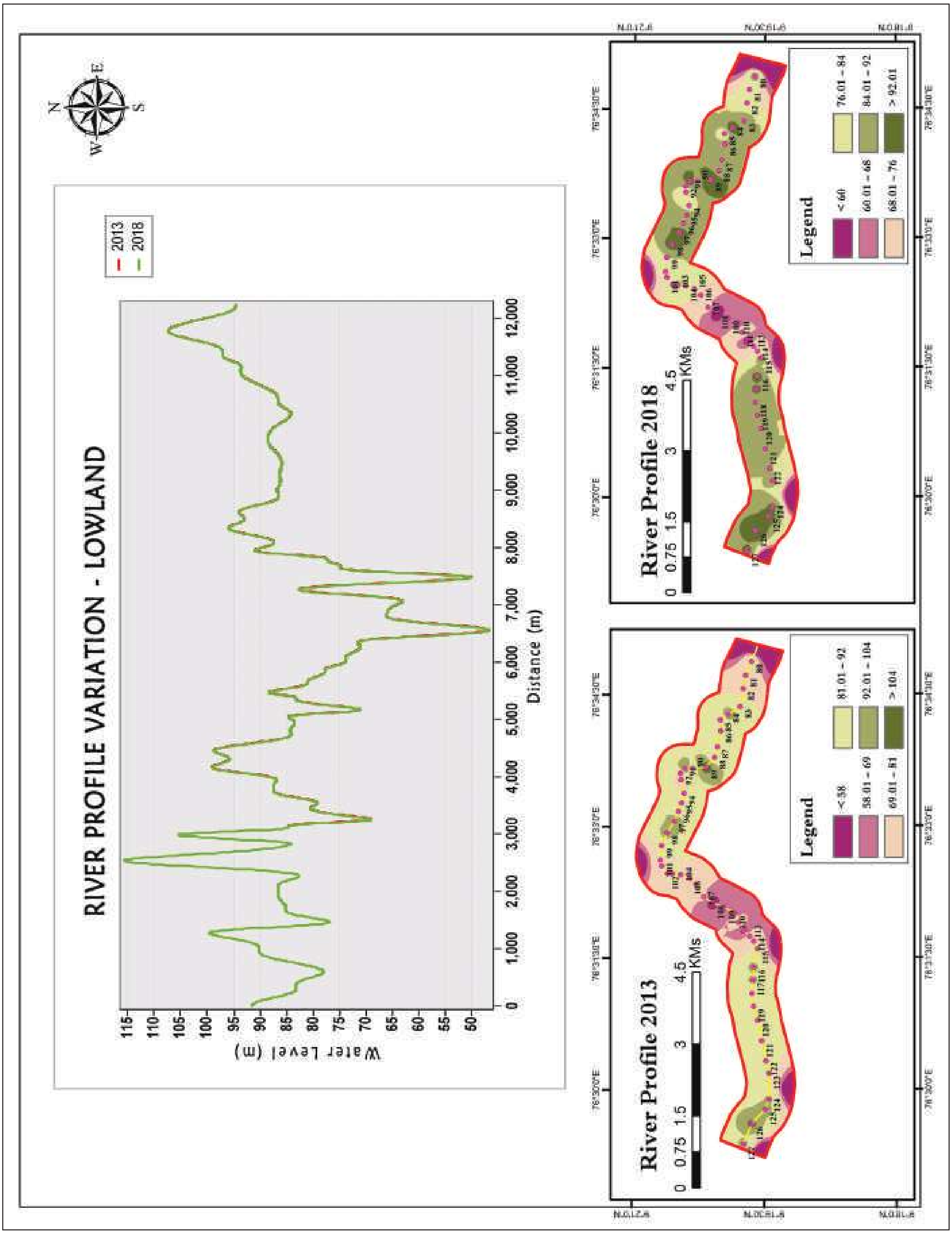


Fig:7.1.River profile variation - Low land

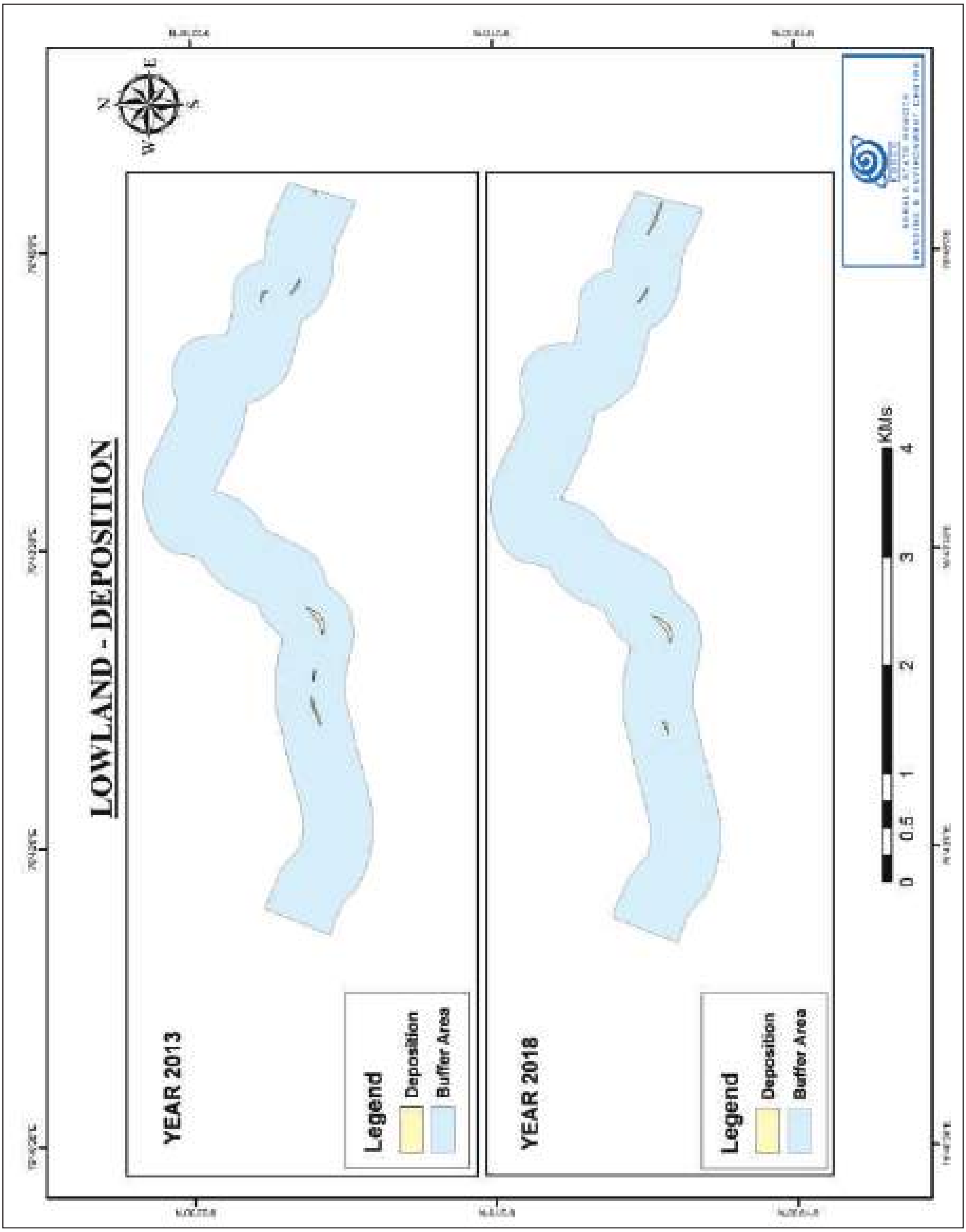


Fig:7.2.Deposition features - Low land field survey

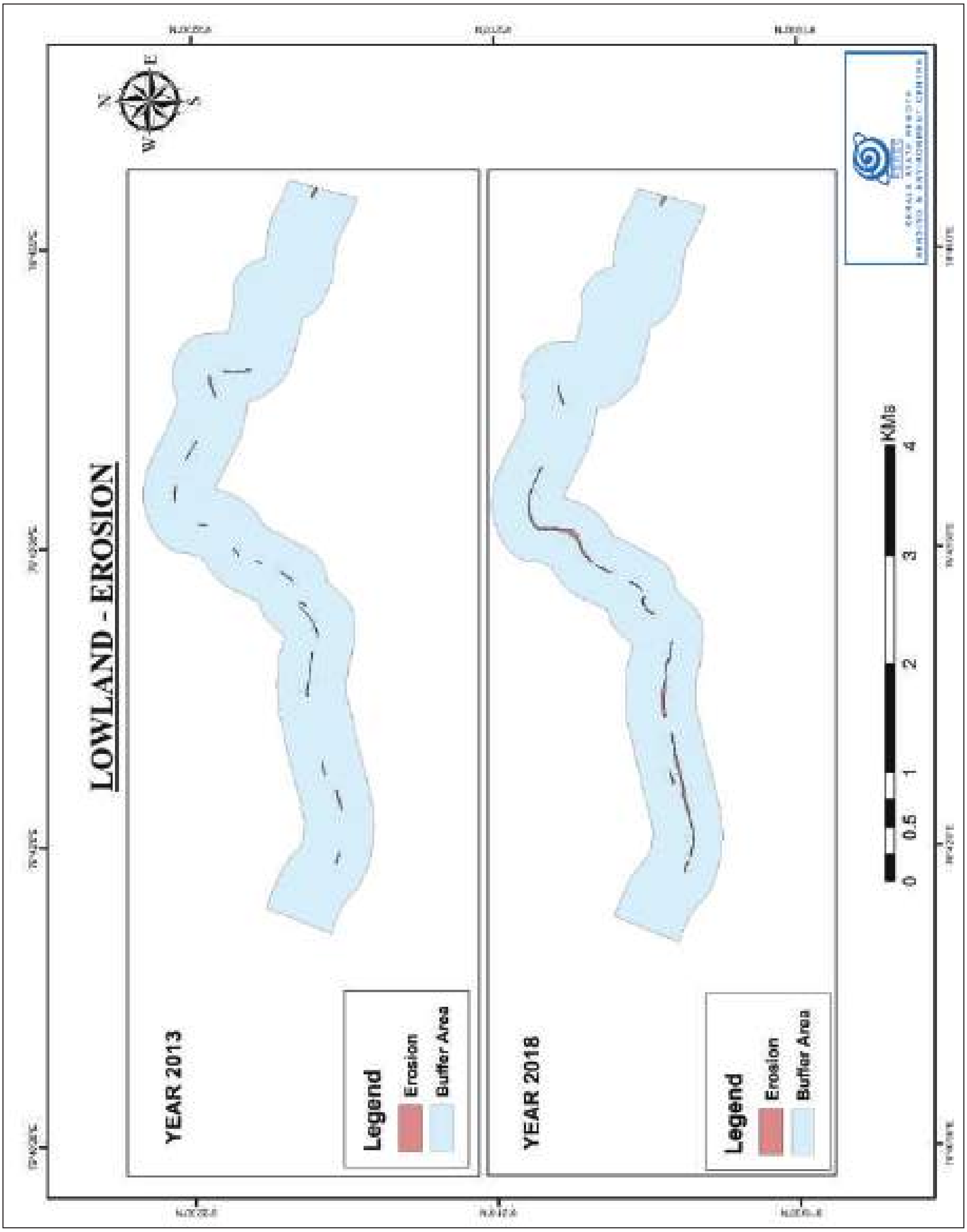


Fig:7.3.Erosional features - Low land field survey

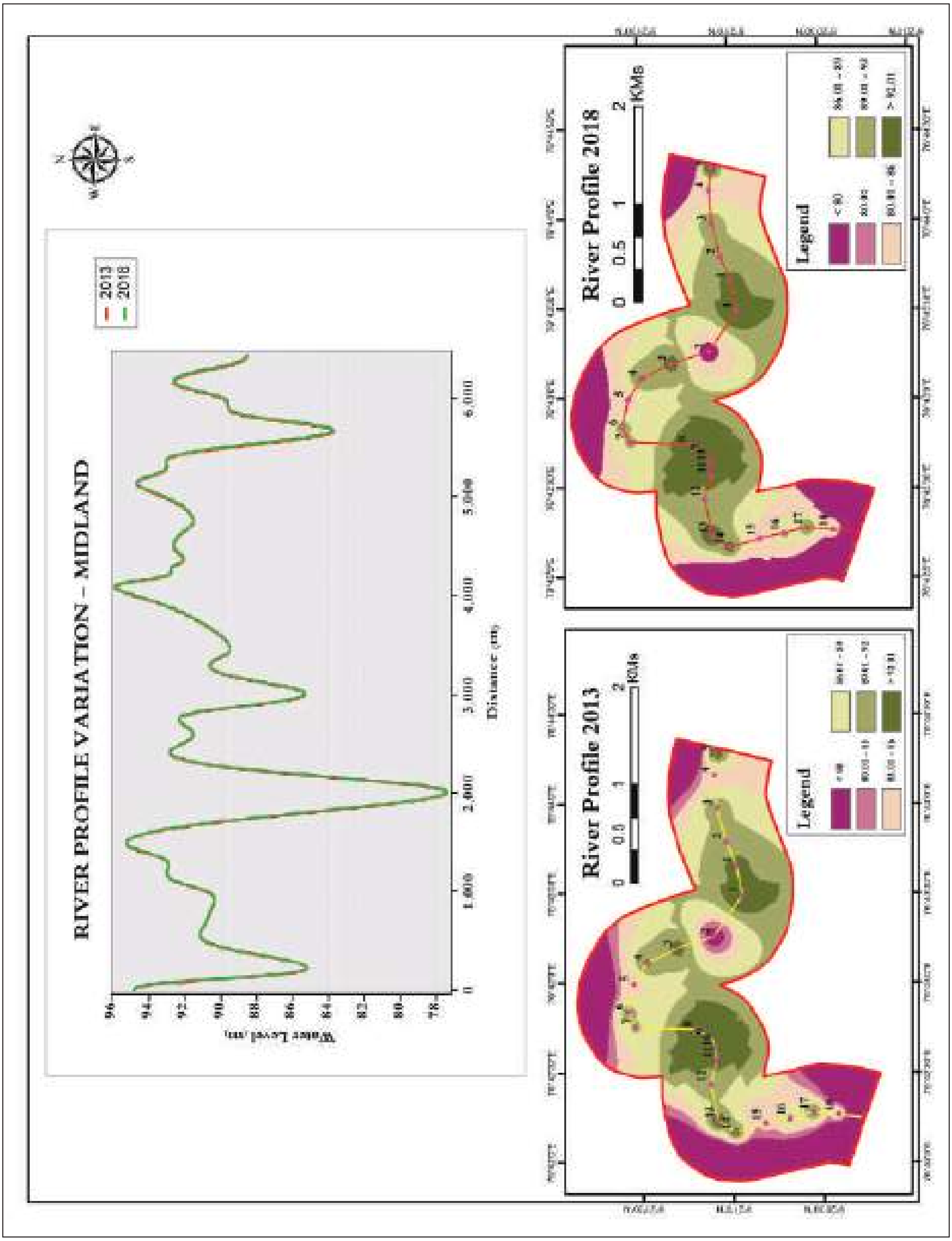


Fig: 7.4.River profile variation - Mid land

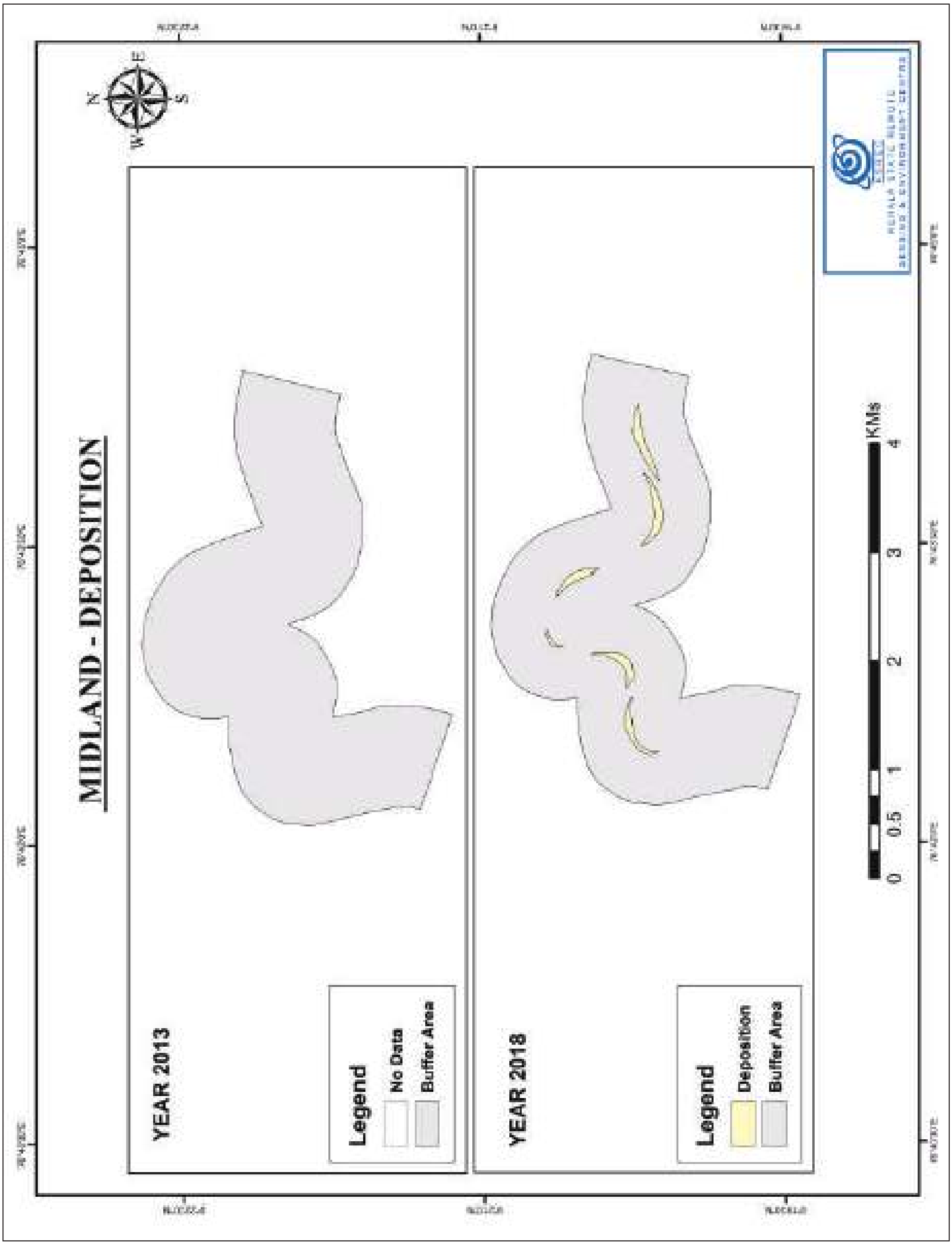


Fig:7.5.Deposition features -Mid land field survey depicted in the Drone based remote sensing study for the River morphology and Land Use classes explained in chapter 3. The 2013 field survey has not shown any depositional features where as the field survey of 2018 post flood has shown depositional units all along the stretch (Fig. 7.5).

7.5.3. High Land segment - long profile

The long profile of the high land segment also shows flood impact all through the study segment. The profile graph is showing variations due to the post flood depositional trend of the region (Fig.7.3). The flood impact of the region is depicted as the deposition of channel bars and erosion also at specific locations. It is also found that there is substantial increase in the number of channel bars and braid bars in the high land segment with erosion along the river banks and channel bars. In the field survey erosional features could not be depicted, but the same is depicted in the Drone based remote sensing study for the River morphology and Land Use classes explained in chapter 3. The 2013 field survey has not shown any depositional features where as the field survey of 2018, post flood has shown depositional units especially to the lower stretches (Fig. 7.7).

7.6. River stretch Characterization

The study stretch for the low land, mid land and high land is characterized within 50 mts buffer with the help of the field survey data for the case of river channel, survey numbers, plot level land use, protection wall for the river bank, riparian vegetation, detailed road connectivity etc.

7.6.1. River channel and survey plots

The river channel mapping along with the cadastral plots on either sides of the river within 500mts were mapped during both the study period of 2013 and 2018. All the survey plots around were mapped for the case of low land (Fig.7.8), mid land (Fig.7.9) and high land (Fig.7.10). This will help in implementing management plans for the river with the knowledge of the stakeholders around and their participation.

7.6.2. Land Use

Plot level land use mapping for the 50 mts buffer on either side of the river was done along with the profile survey which has given detailed land use classes plot level. For the case of low land, mid land and high land the land use mapped during the 2013 were 22 classes (Fig. 7.11, 7.12 & 7.13), while the classes had reduced to 18 classes during 2018. The 2013 classes like paddy, Tuber crops, Cultivable waste land and paddy converted cocconut were changed to other classes in the 2018 land use for all the thre segments. The loss of paddy area, tuber crops and paddy converted area to perenial crops will result in the reduced water holding capacity, reduced recharge and the groundwater availability and also will result in increased runoff and floods. The loss of cultivable waste land to built up and other crops is a positive change which is beneficial for the society.

7.6.3. Riparian Vegetation

A riparian zone or riparian area is the interface between land and a river or stream. Riparian vegetation grows along banks of a waterway extending to the edge of the floodplain (also known as fringing vegetation). This includes the emergent aquatic plants growing at the edge of the waterway channel and the ground cover plants, shrubs and trees within the riparian zone.

Riparian areas supply food, cover, and water for a large diversity of animals and serve as migration routes and stopping points between habitats for a variety of wildlife. Trees and grasses in riparian areas stabilize streambanks and reduce floodwater velocity, resulting in reduced downstream flood peaks.

By acting as buffers between upland areas and open water, they help filter pollutants such as nutrients and sediment. Healthy riparian vegetation helps to reduce stream bank erosion and maintain stable stream channel geomorphology. Vegetation also provides shade, which works to lower water temperatures.

7.6.3.1. Low land Riparian Vegetation

The low land riparian vegetation seems to have not much impacted by the flood. The figure 7.14 shows that the riparian vegetation on the 2013 and 2018 survey remains almost the same. The riparian vegetation might have played an important role in reducing the bank erosion. The low land was highly eroded as per the land use and morphology mapping. If not for the riparian vegetation the situation would have been much worse.

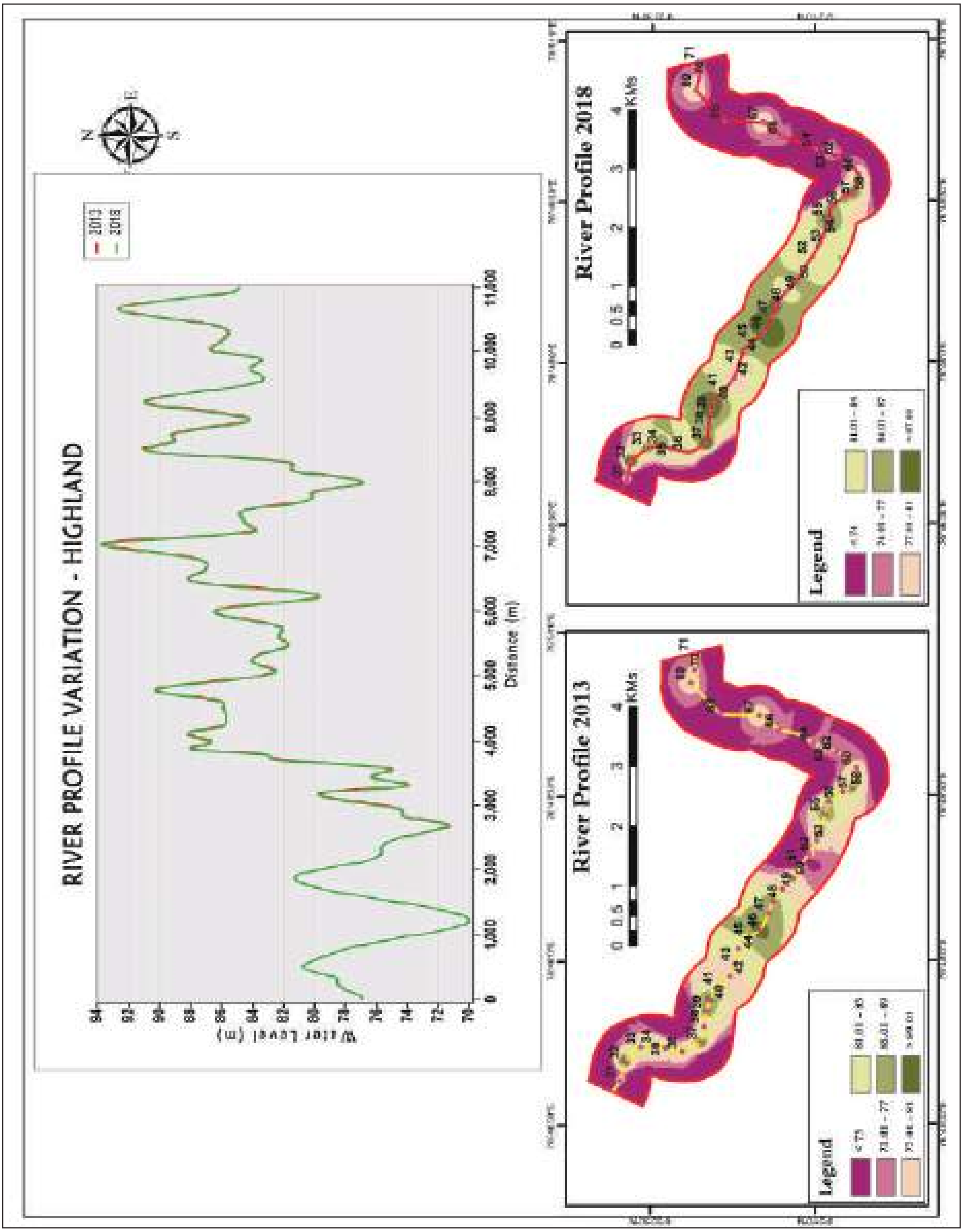


Fig: 7.6. River profile variation - High land

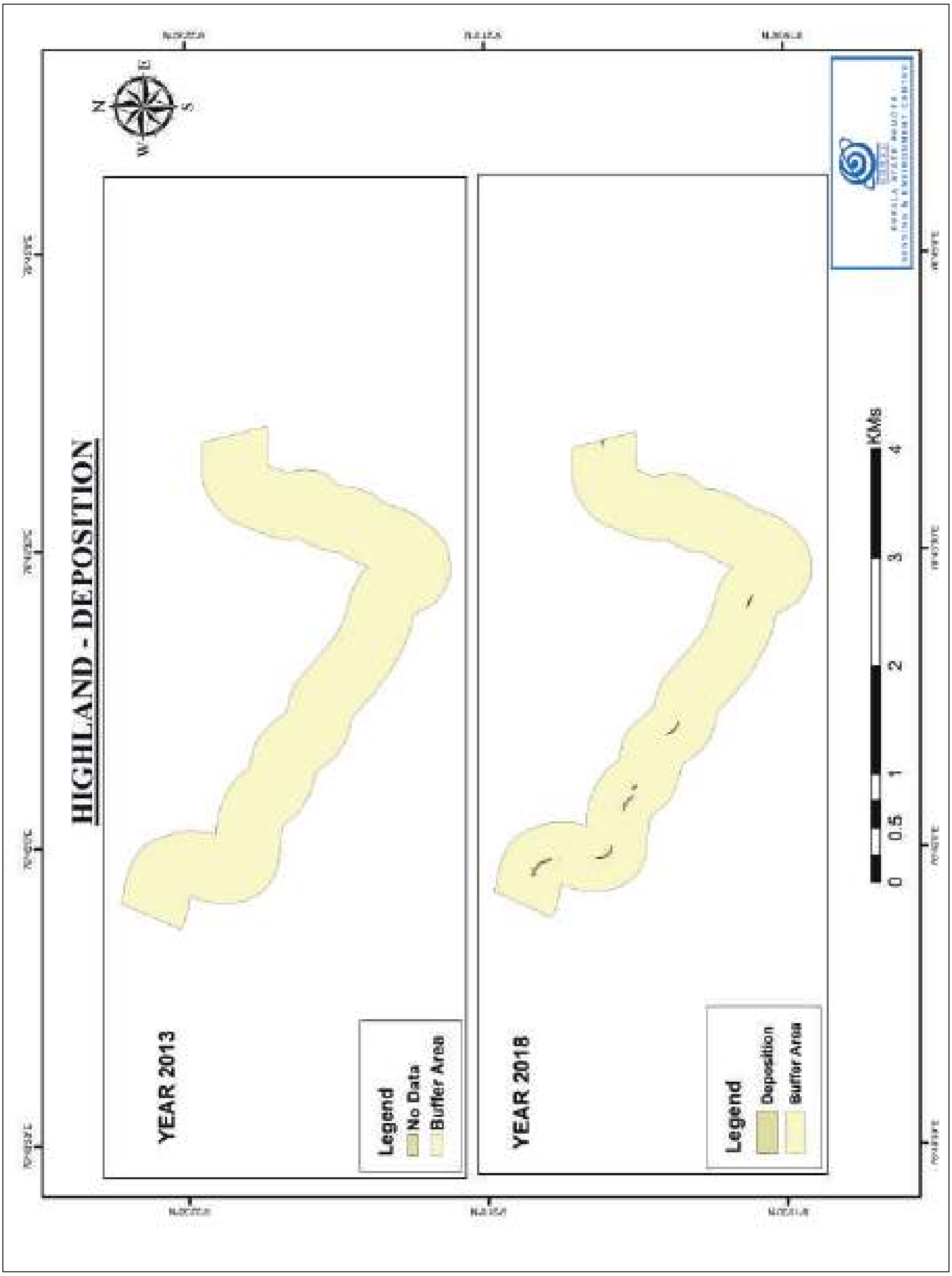


Fig:7.7.Deposition features -High land field survey

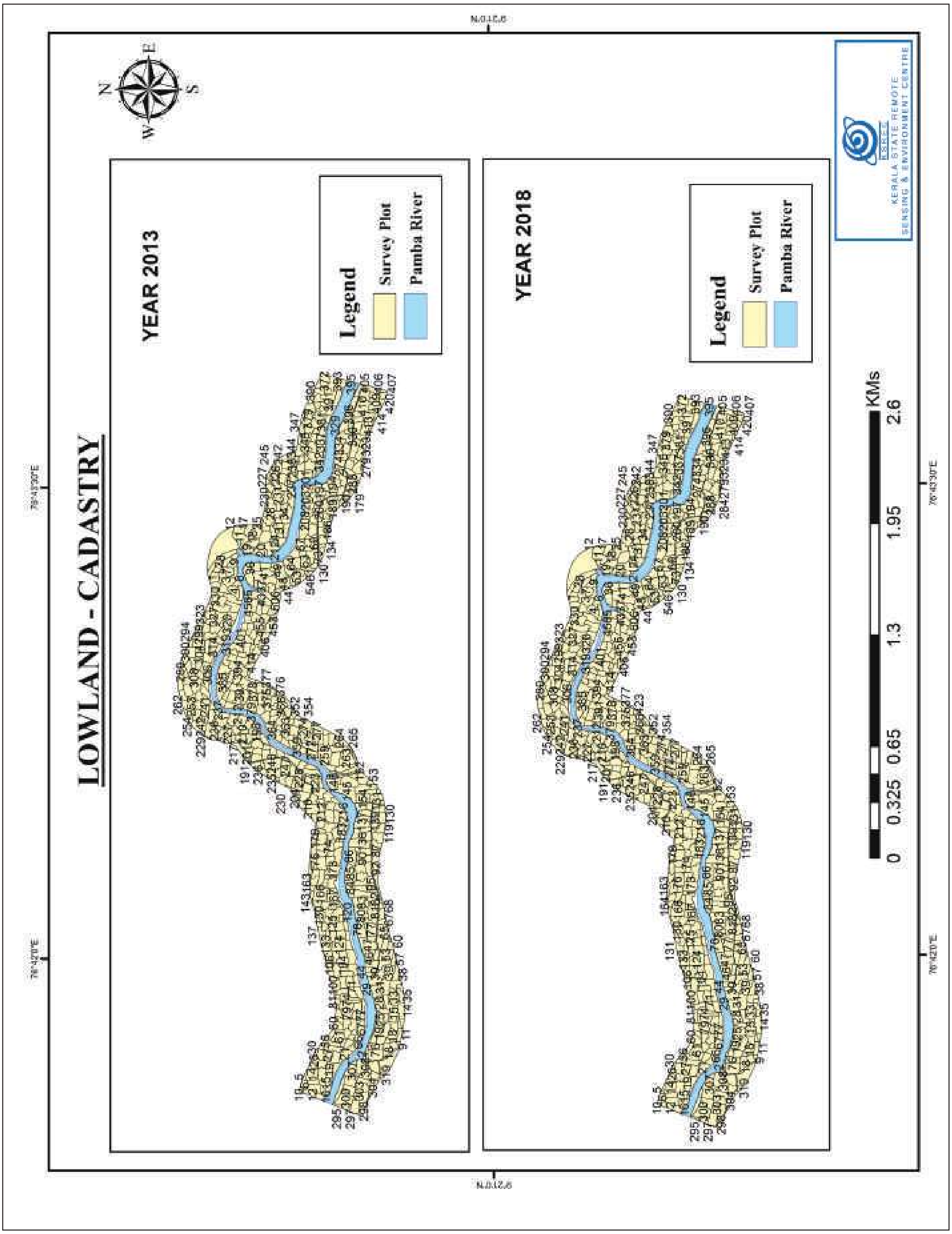


Fig: 7.8. Cadastry of Low land

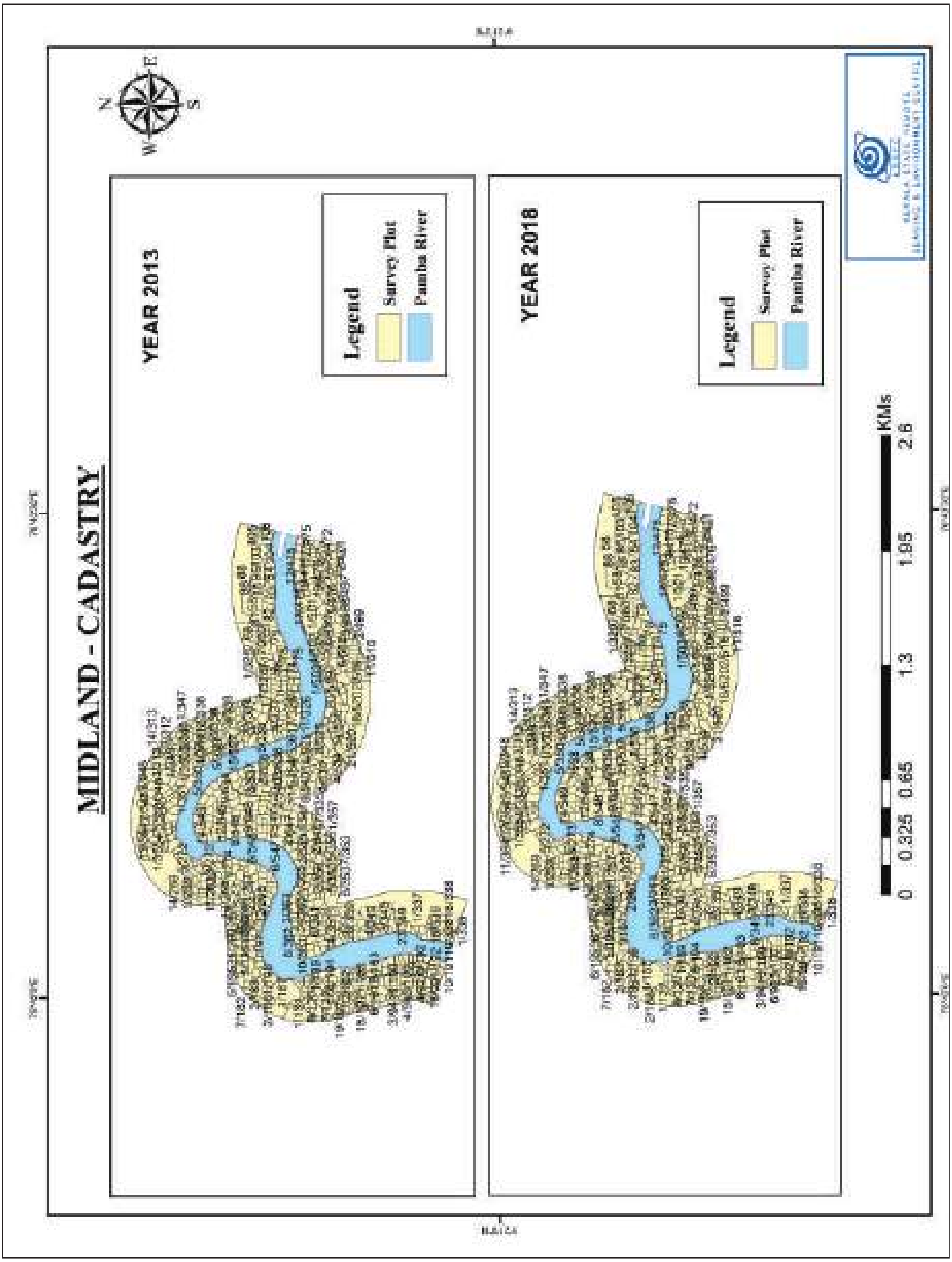


Fig: 7.9. Cadastry of Mid land

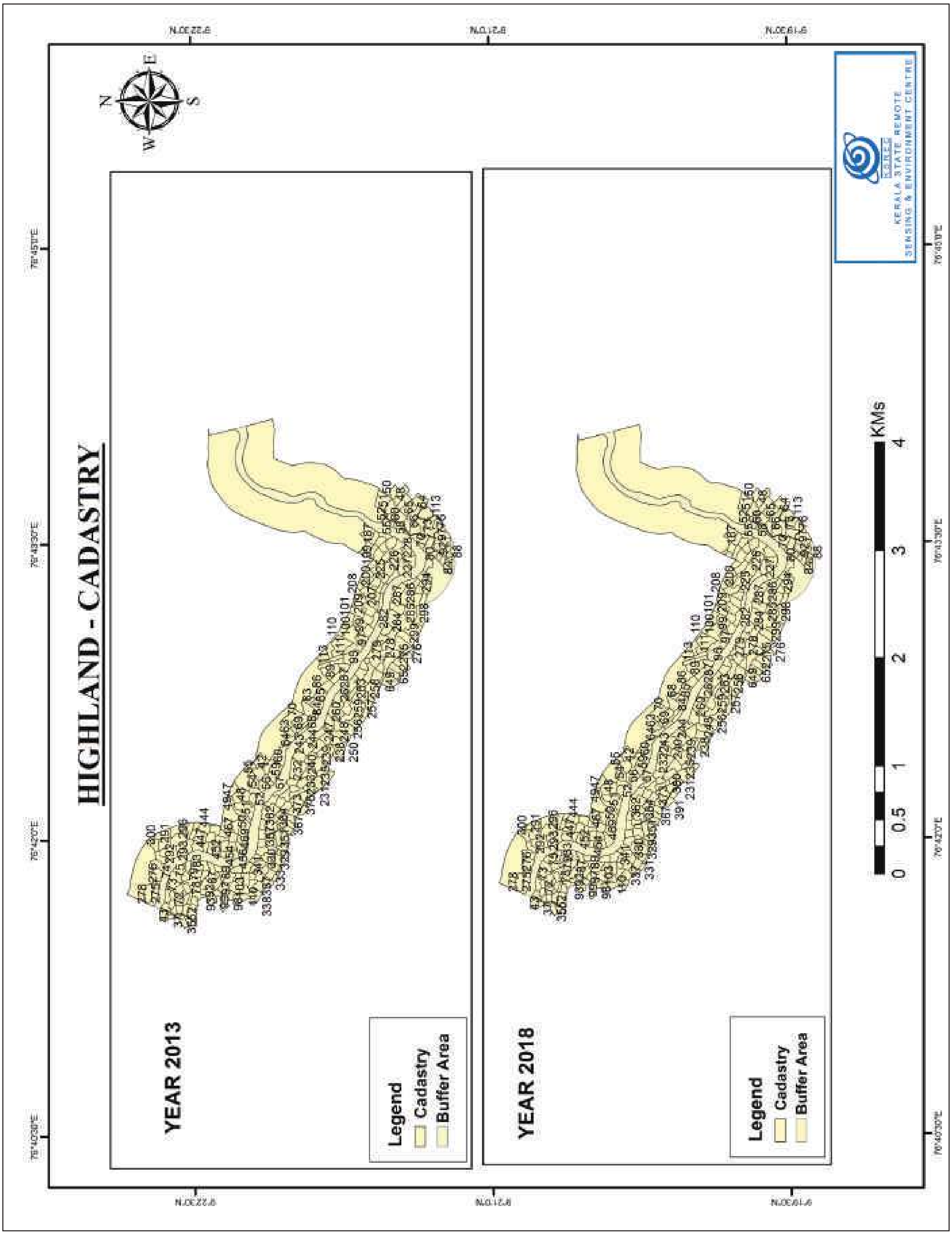


Fig: 7.10.Cadastry of High land

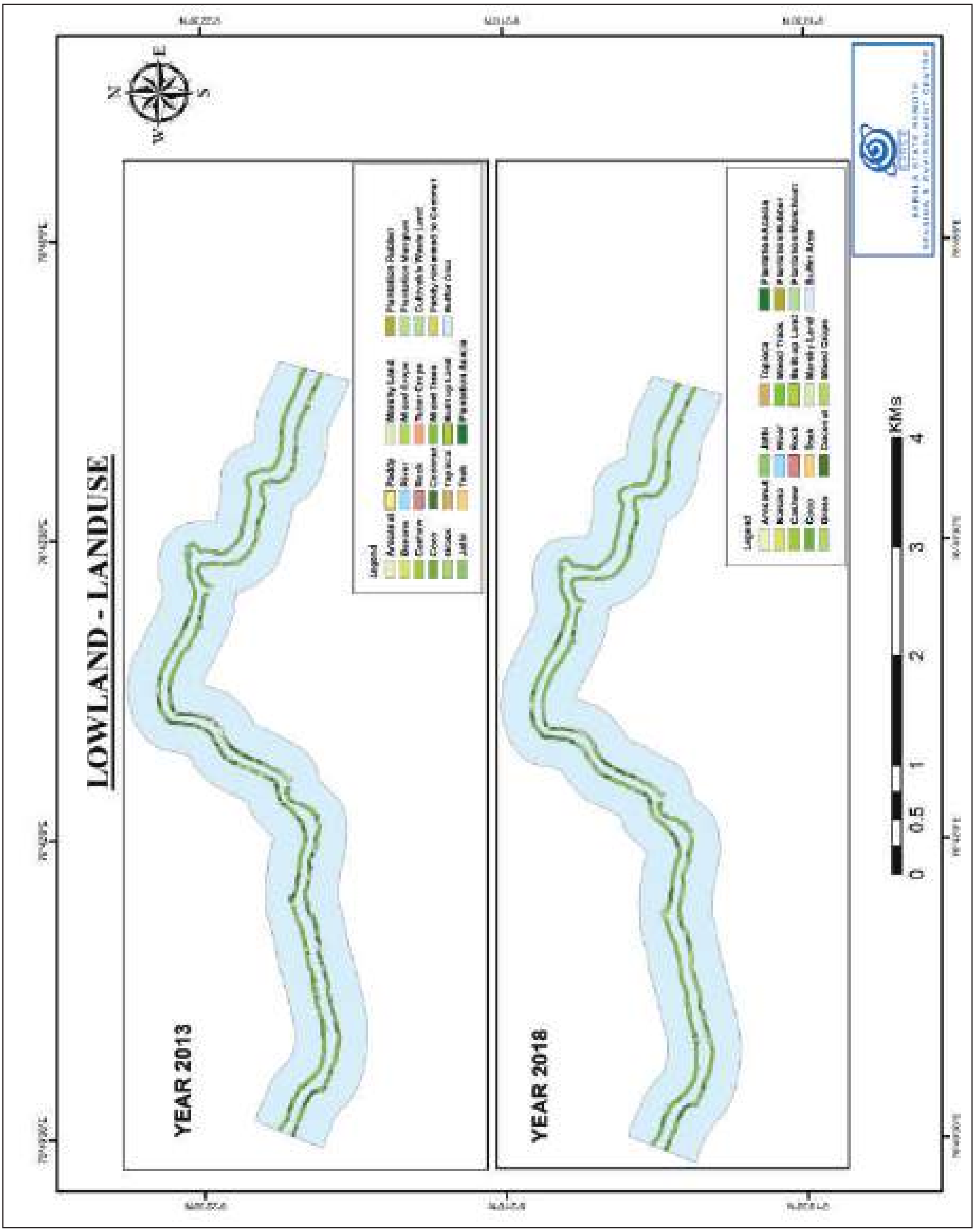


Fig. 7.11. Plot level Land Use – Low land field survey

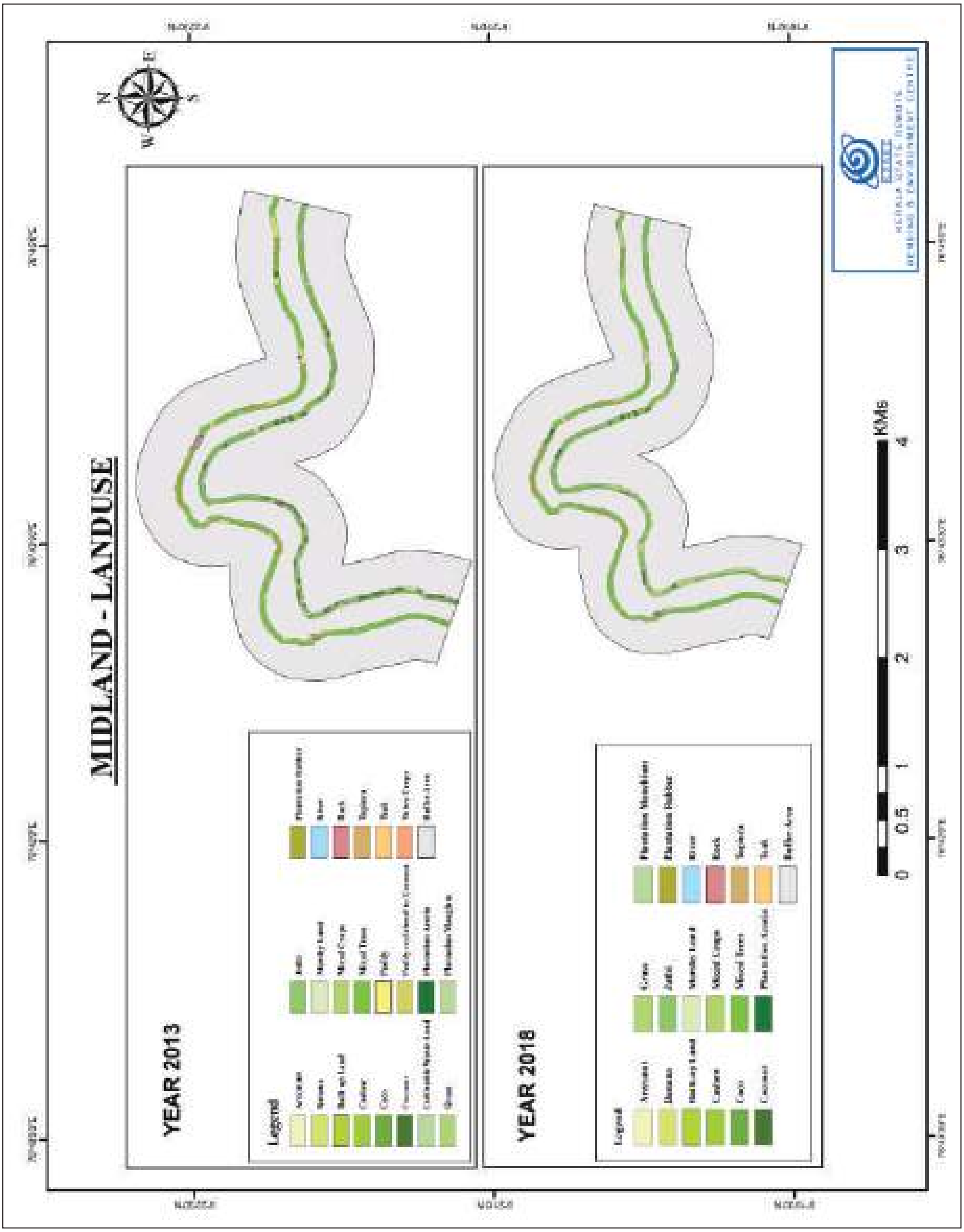


Fig. 7.12. Plot level Land Use – Mid land field survey

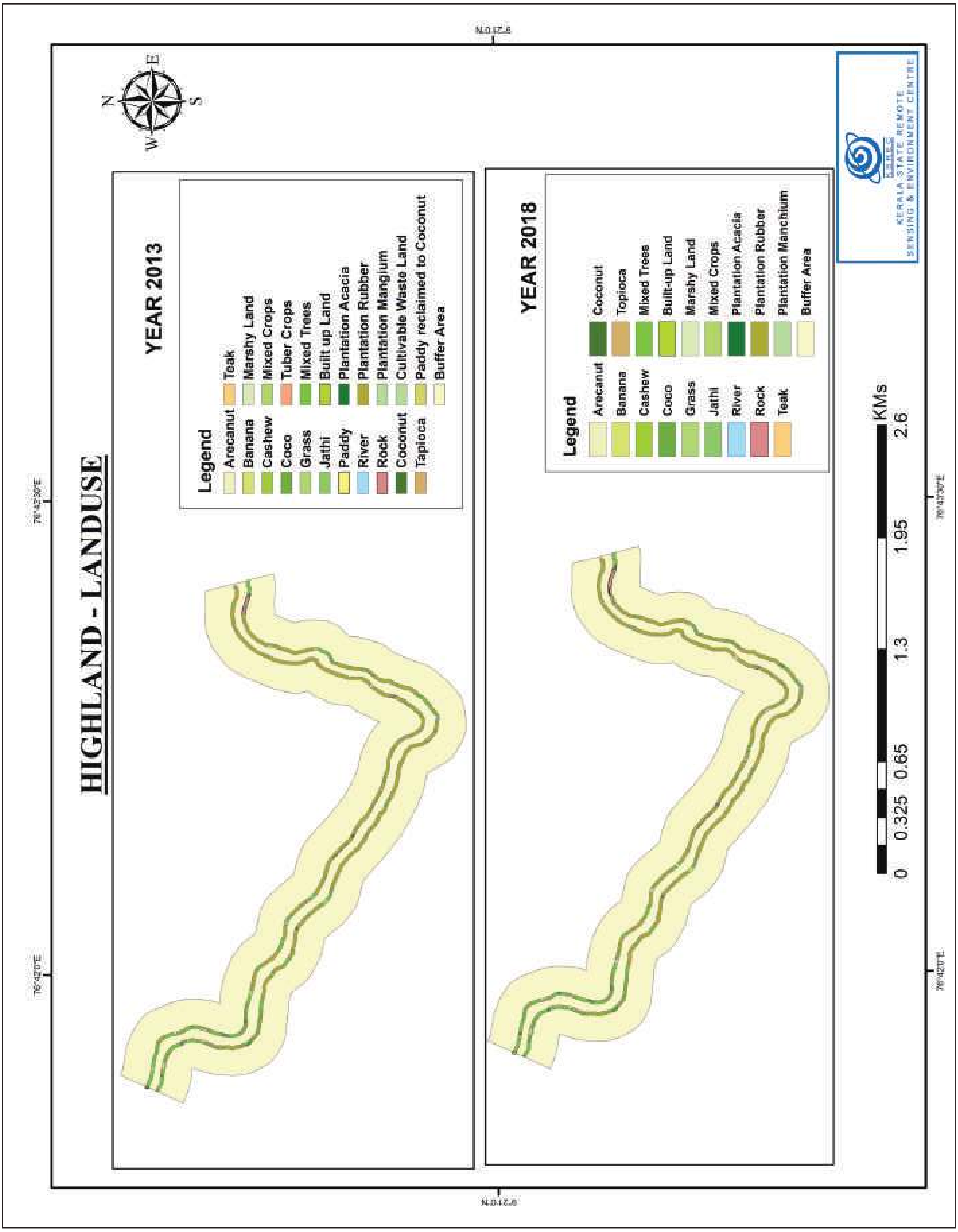


Fig. 7.13. Plot level Land Use – High land field survey

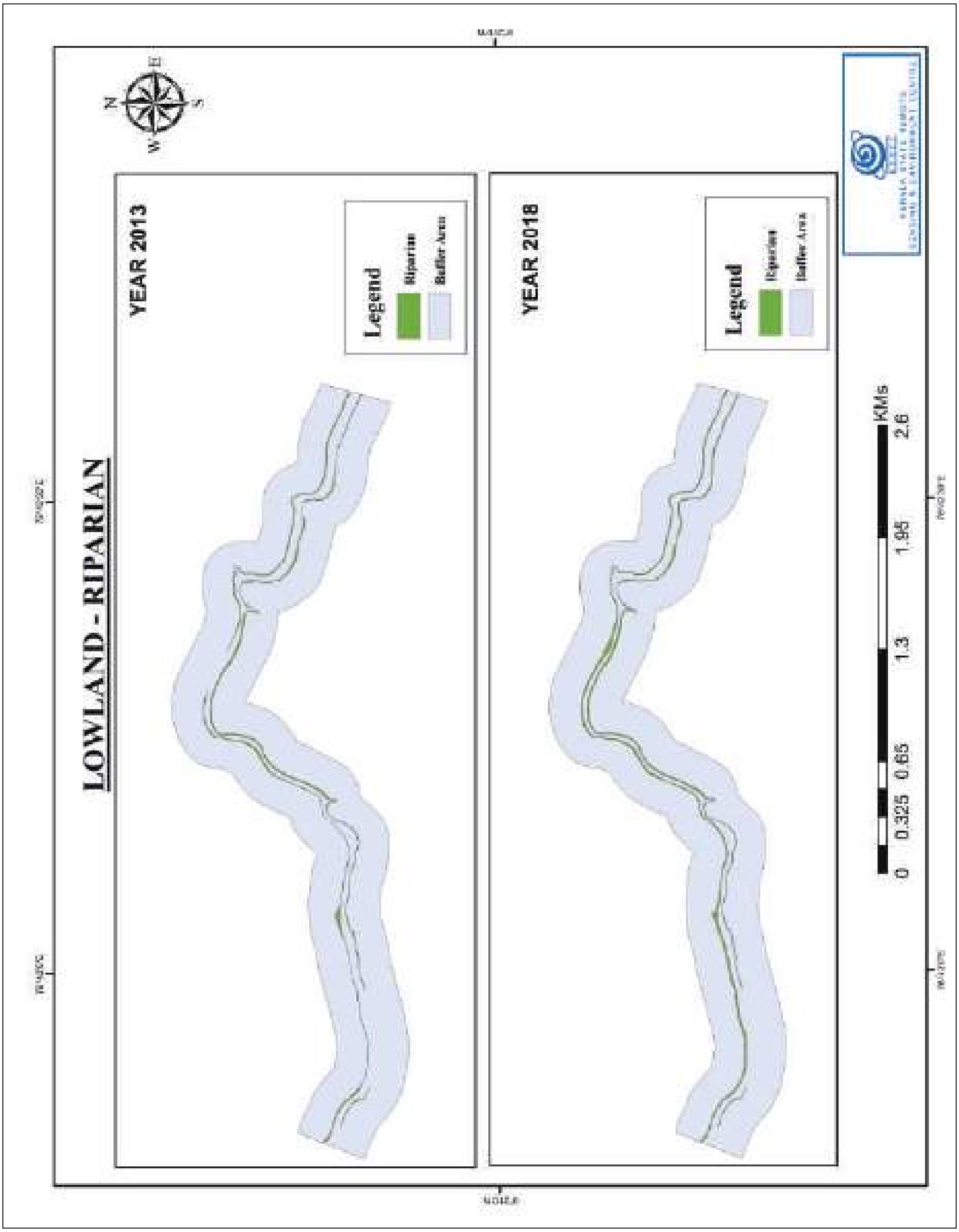


Fig. 7.14. Riparian vegetation – low land

7.6.3.2. Mid land Riparian Vegetation

The dynamics of the riparian vegetation in the midland is that the entire vegetation stretch found on either side of the mid land has been cleared by the flood (Fig. 7.15). 2013 survey had identified the healthy and strong vegetation on either side of the river stretch in this segment, which is totally vanished in the 2018 survey. This can be attributed to the flood impact.

7.6.3.3. High land Riparian Vegetation

The high land riparian vegetation seems unaffected by the flood as the 2013 and 2018 field level mapping represents the vegetation in similar manner (Fig.7.16). The high land is found to be predominantly depositional in trend in the post flood scenario. The maintenance of the riparian can be attributed to the depositional trend of high land.

7.6.4. Protection wall

The river bank protection walls are constructed along the river stretches at various places which had been mapped during the field survey in both the cases of 2013 and 2018. For the three segments the protection walls remains the same for the two periods of survey (Fig. 7.17, 7.18 & 7.19).

7.6.5. Road Network

The road network associated with the river which may not be discernible in the remote sensing techniques due to the heavy canopy cover and the narrowness of the roads was mapped during the survey for 2013 and 2018. It can be seen that there is enough human intervention within the 50 mt buffer region of the river and had created impervious layers during 2013 itself. SO it can be found that further addition of roads may not be much possible in this vulnerable zones for want of land and density of population and hence the development from there is not found in the three segments during 2018 (Fig.7.20, 7.21 & 7.22).

7.6.6. River Cross profiles

The river cross profiles were taken for the entire stretch of 30 km in the three segments. A total of 114 profile values were taken with the help of DGPS and dumby levels etc. The cross profiles of 2018 post flood survey were taken at the same location of the cross profiles taken during the 2013 survey. The map showing the locations of the cross section values taken are given in the figures 7. 23, 7.24 & 7.25.

7.6.6.1. Pre and post flood Cross profiles comparison for High land

The cross profiles of the high land region shows the erosional characteristics as described earlier in the study. Some sample profiles of the high land region for comparing the river bed characteristics is shown below. Figure 7.26 and 7.27 represents the profile sections of Ranni and Pazhayangadi panchayats for the period 2013 and 2018 respectively. The profiles remains the same in both cases except for the case that the water level is high in the 2018 period. The sand deposits remains same in both the sections below water level reamins same. In the Ranni and Vadasserikkara sections (Fig.7.28 and Fig.7.29) there is an increase in the water level during 2018 and also there is river bed depositional trend below the water level in the 2018 post flood scenario. In the case of cross sections of Vadasserikkara panchayat during 2013 and 2018 (Fig.7.30 and Fig.7.31) it shows there is no water level variation and no sand deposit in the river bed for the cross section 59. The cross section 58 shows sand deposit towards the right bank of the river.

7.6.6.2. Pre and post flood Cross profiles comparison for Mid land

The cross sections of Kozhenchery and Thottapuzhasseri Panchayat shows same water level for both the pre and post flood scenario. The sand deposition is towards the right bank and does not seem to have altered (Fig.7.32 and Fig. 7.33). In the case of Kozhenchery and Thottapuzhassery Panchayats cross sections 15 (Fig.34 and Fig. 35), there is no sand deposition and there is slight increase in the water level during the post flood scenario.

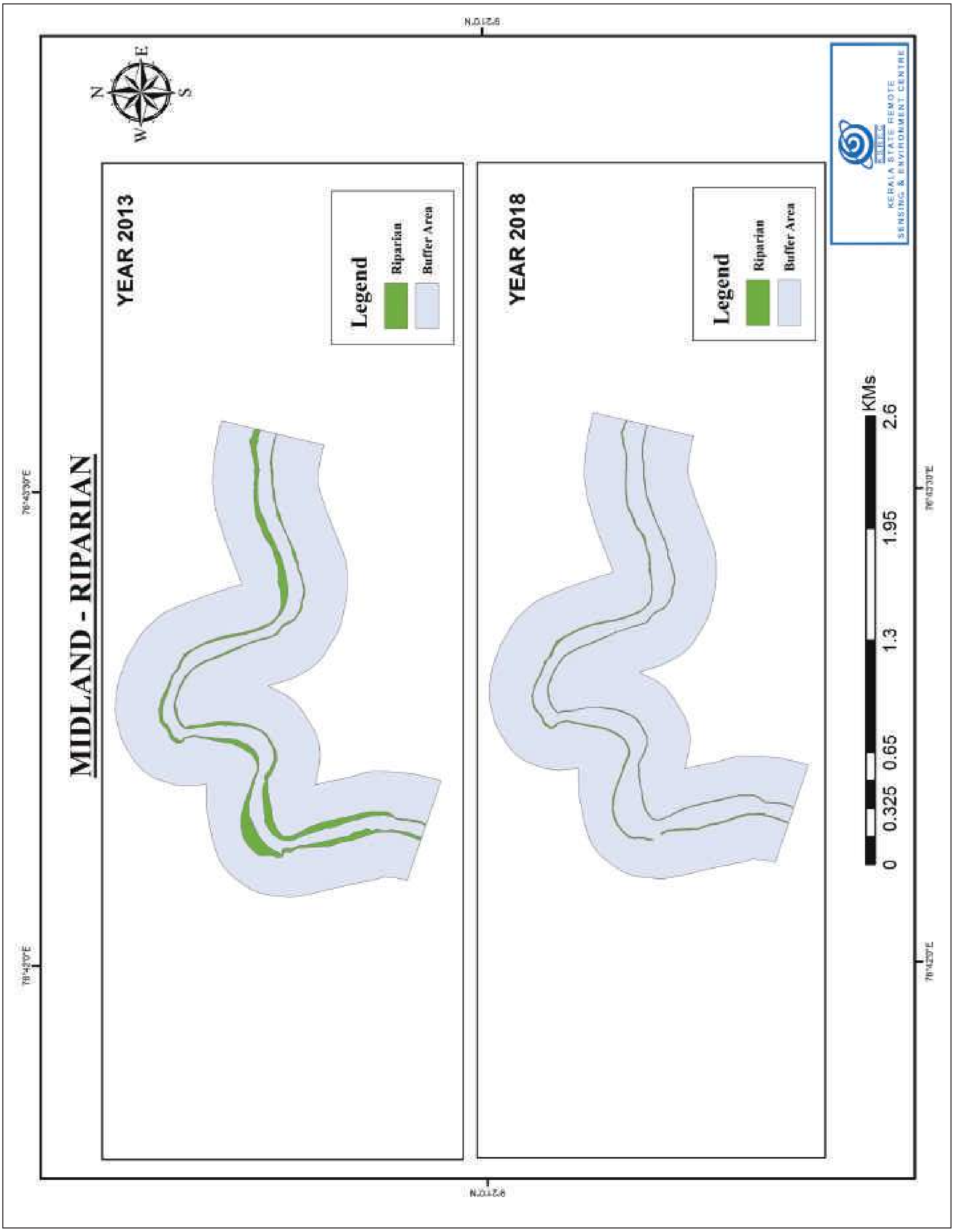


Fig. 7.15. Riparian vegetation –mid land

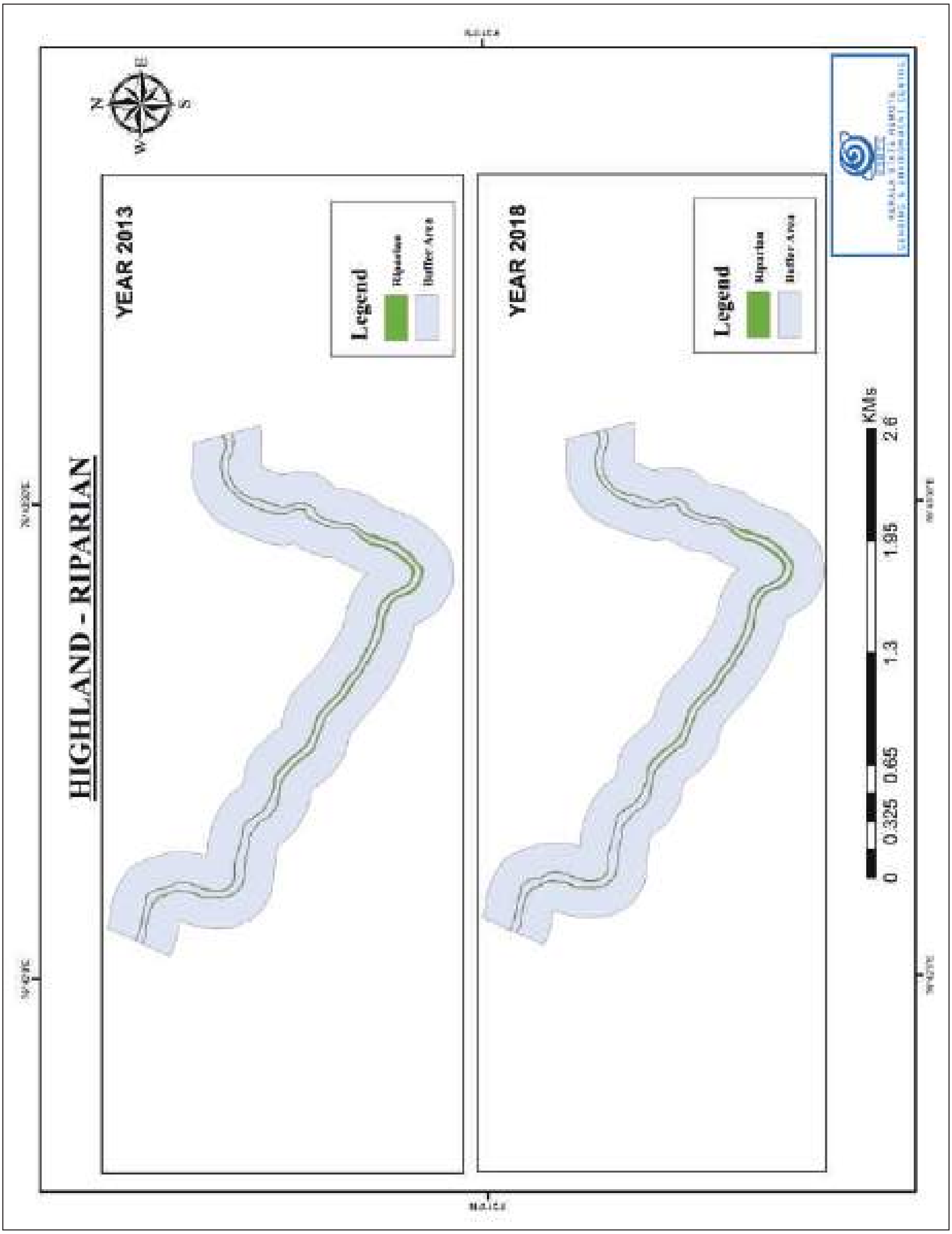


Fig. 7.16. Riparian vegetation –High land

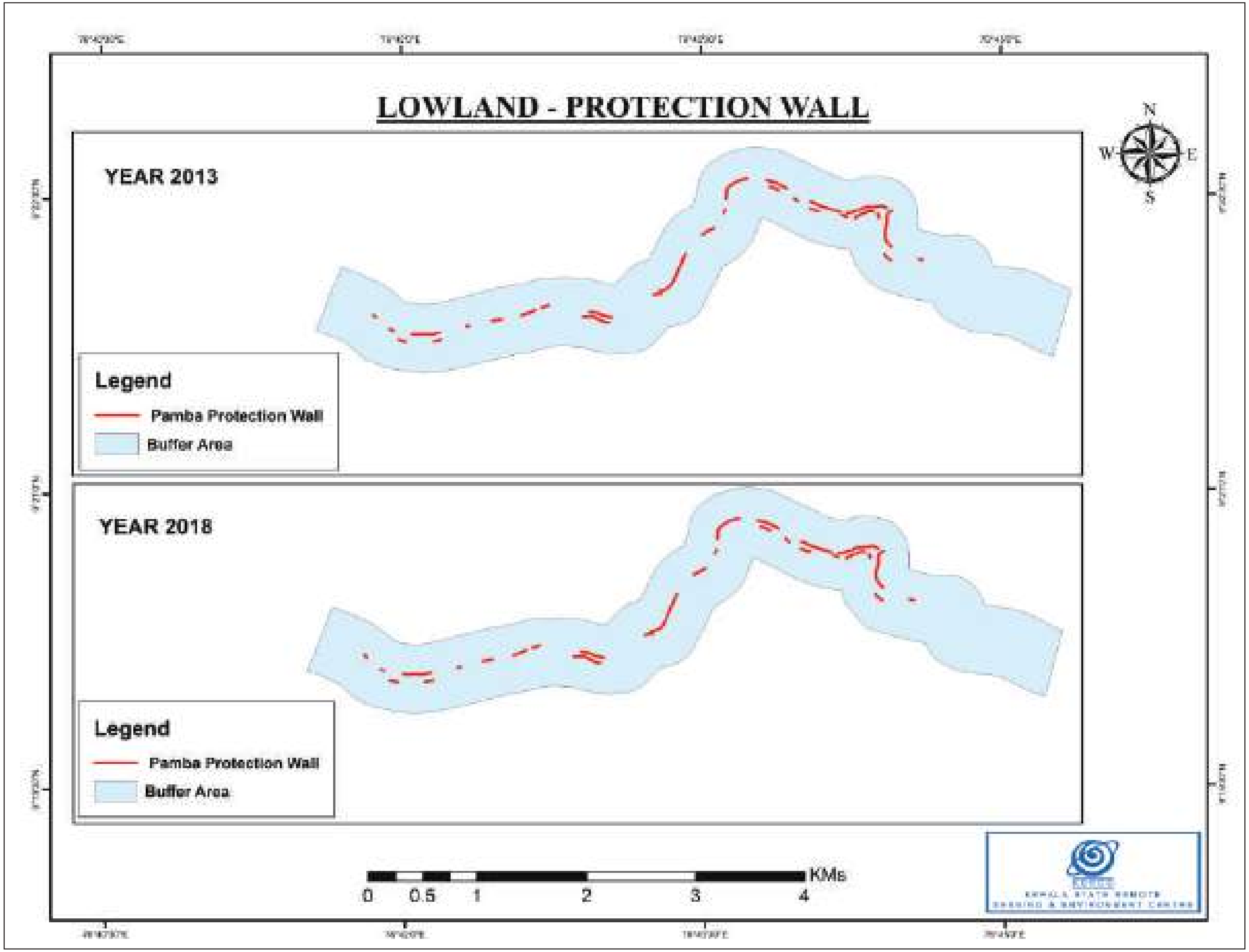


Fig. 7.17. Protection wall –High land

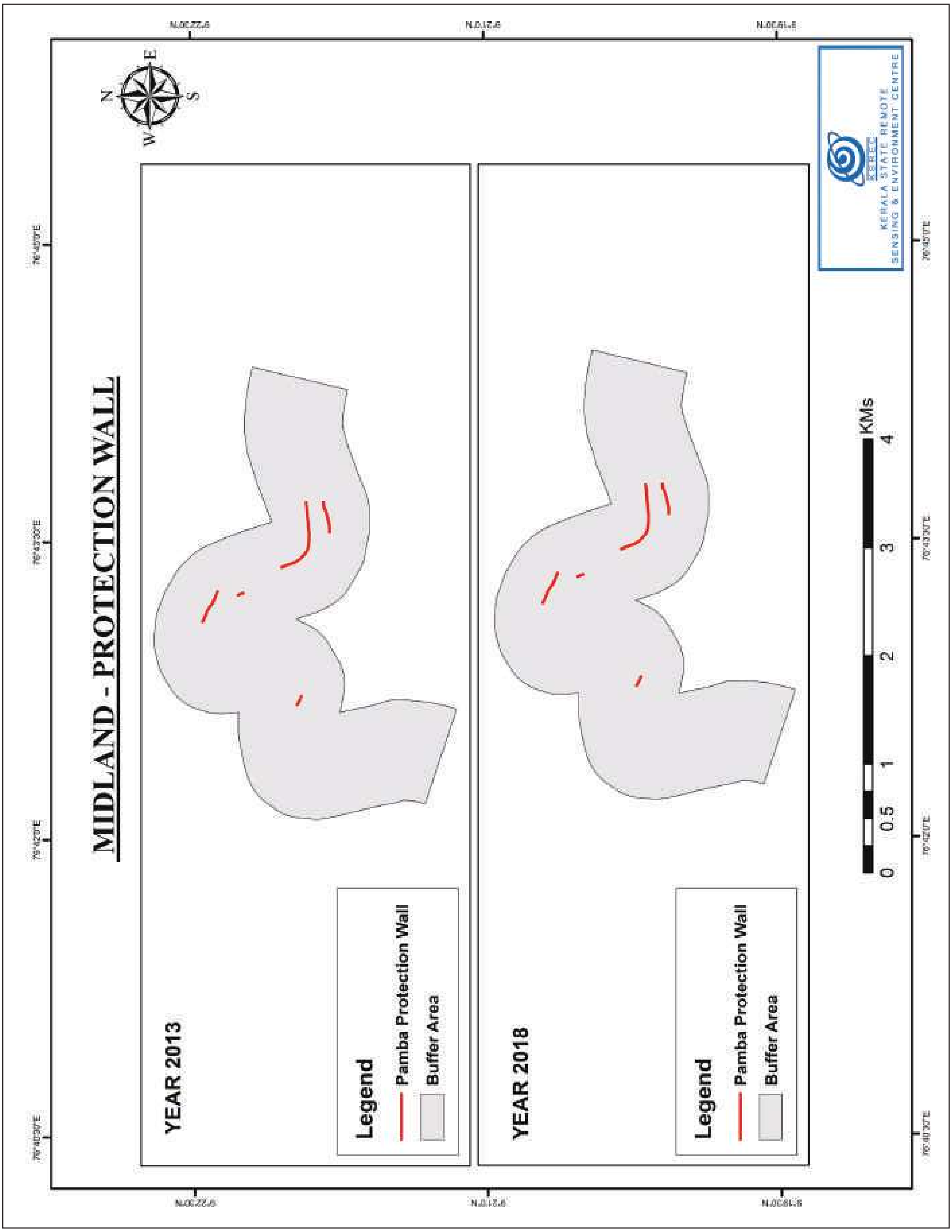


Fig. 7.18. Protection wall – Mid land

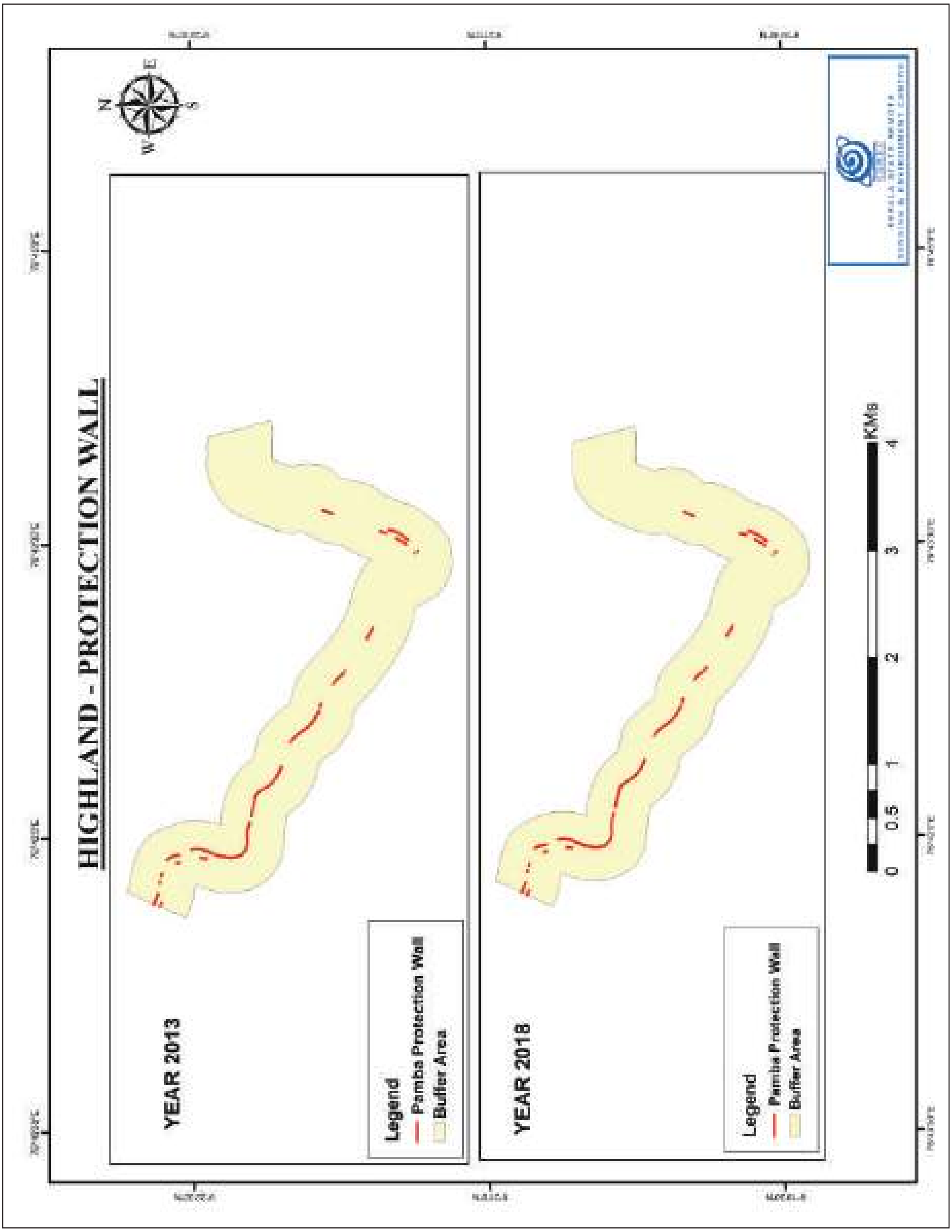


Fig. 7.19. Protection wall – High land

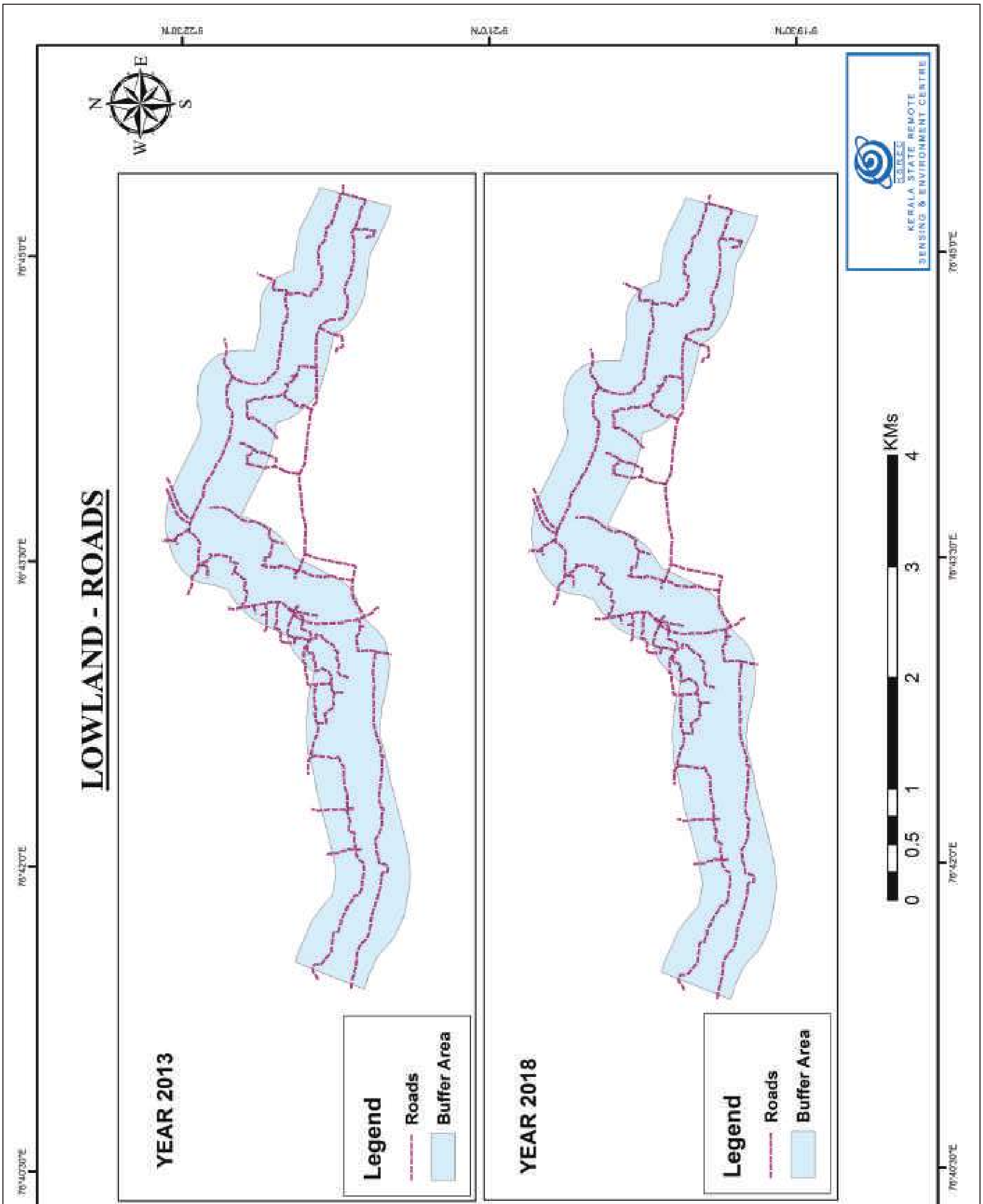


Fig. 7.20. Protection wall – Low land

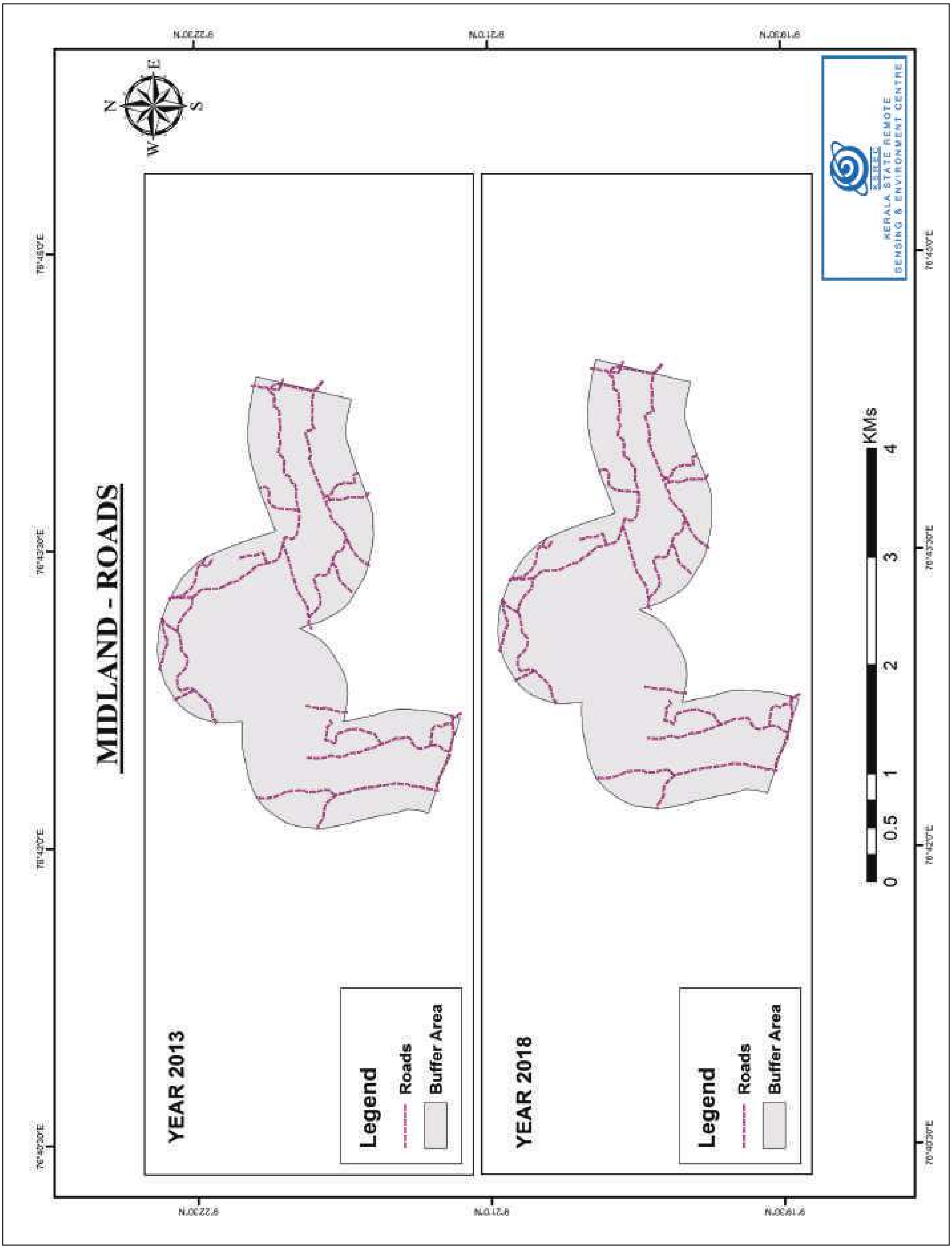


Fig. 7.21. Protection wall – Mid land

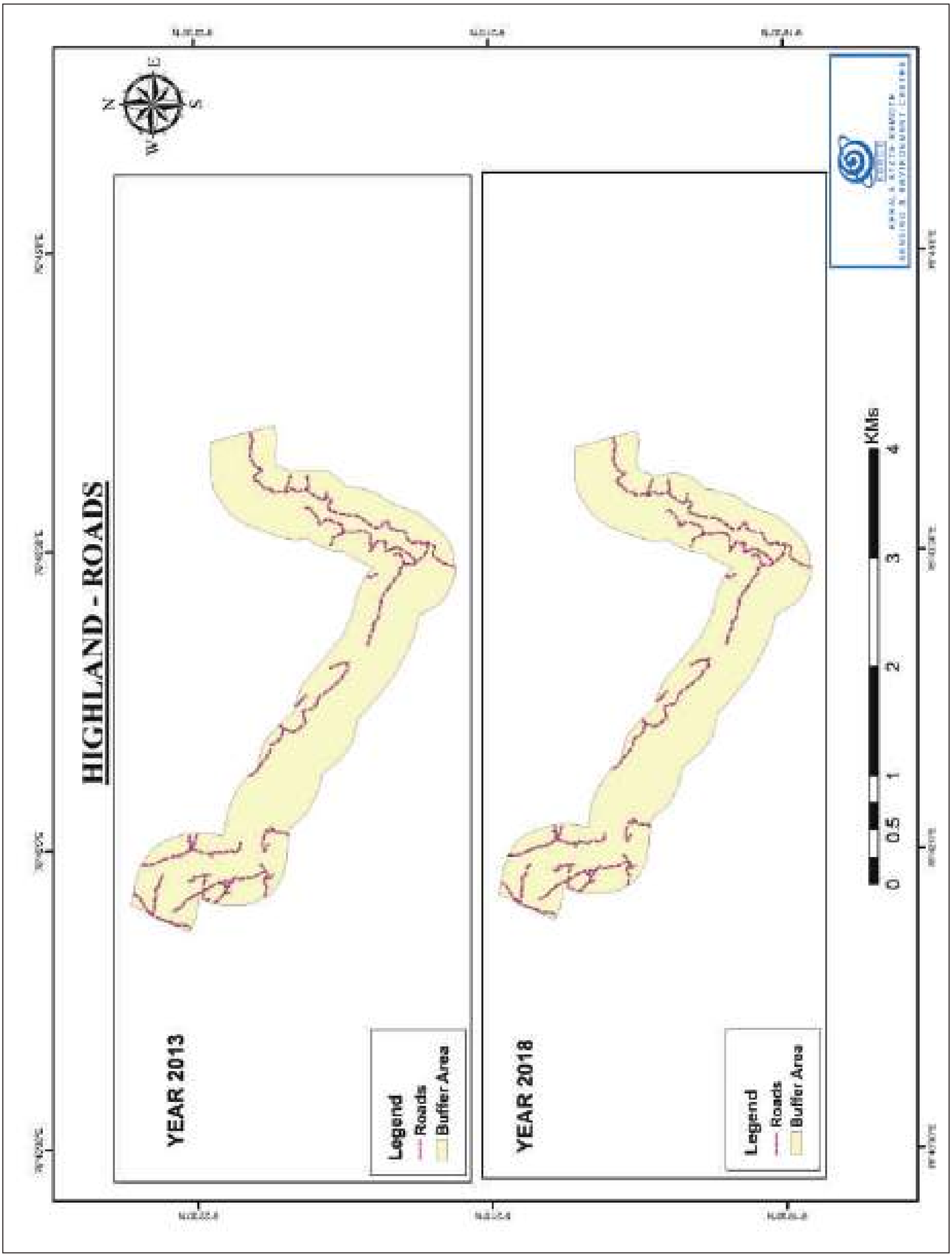


Fig. 7.22. Protection wall – High land

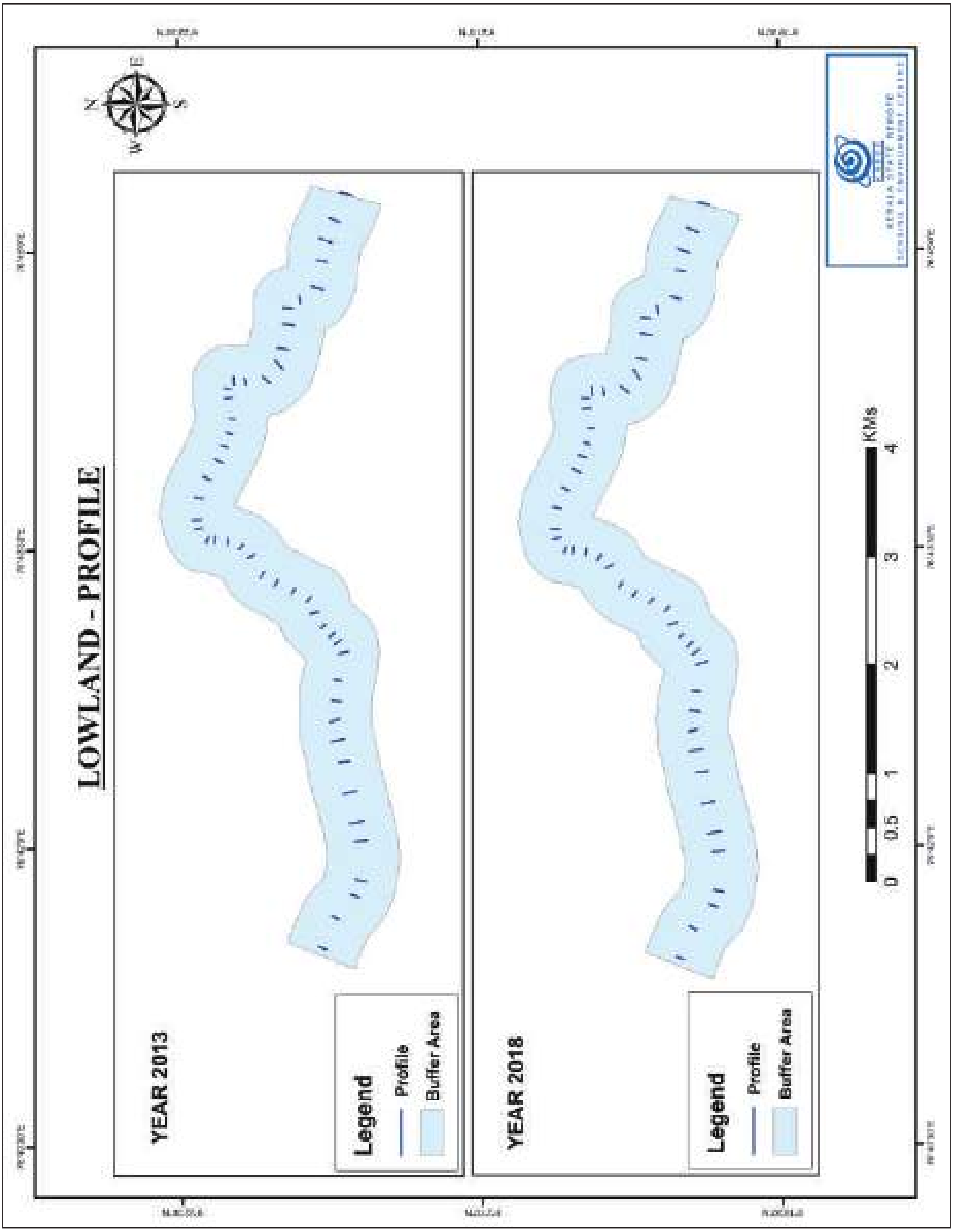


Fig:7.23. River Profile of Low land

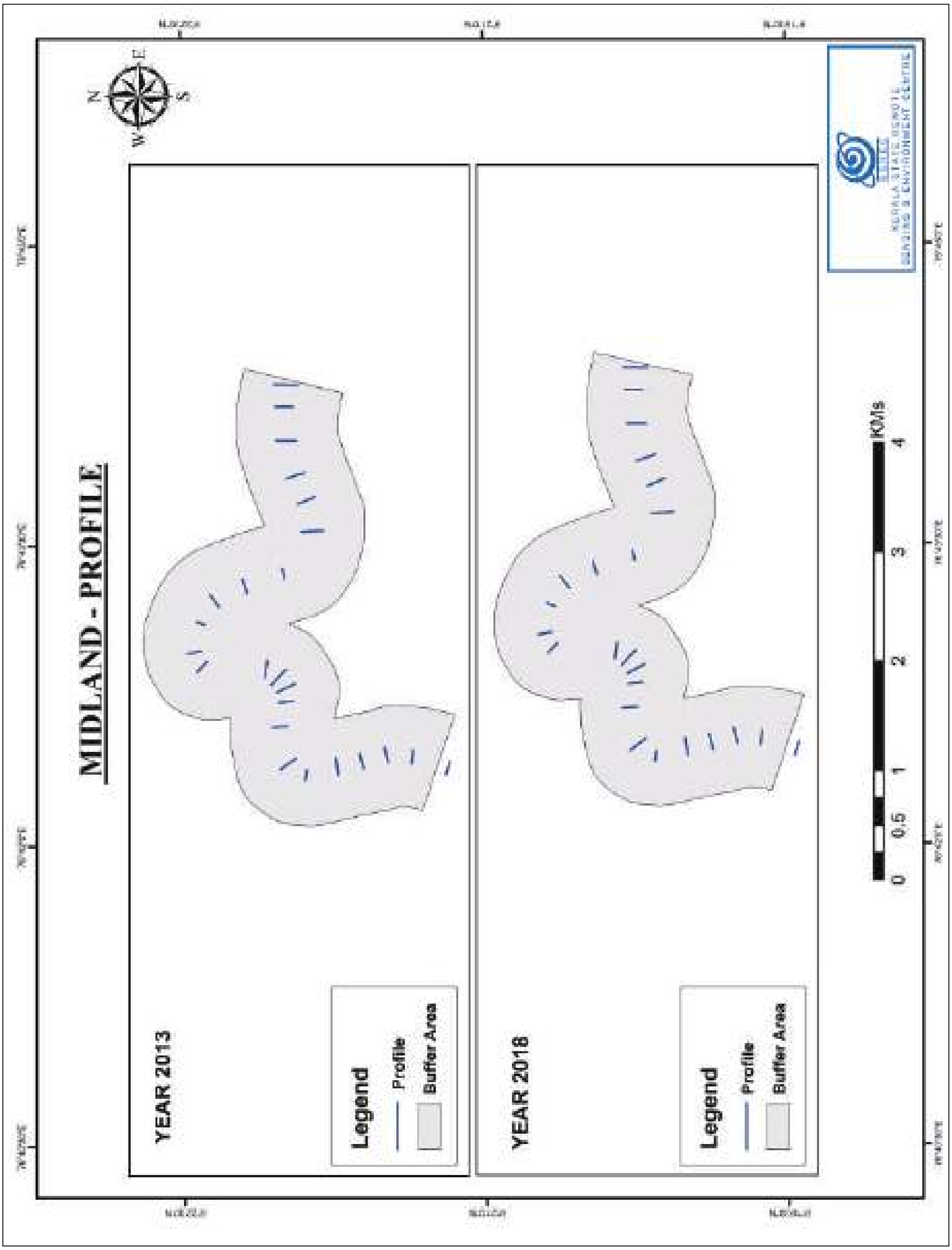


Fig:7.24. River Profile of Mid land

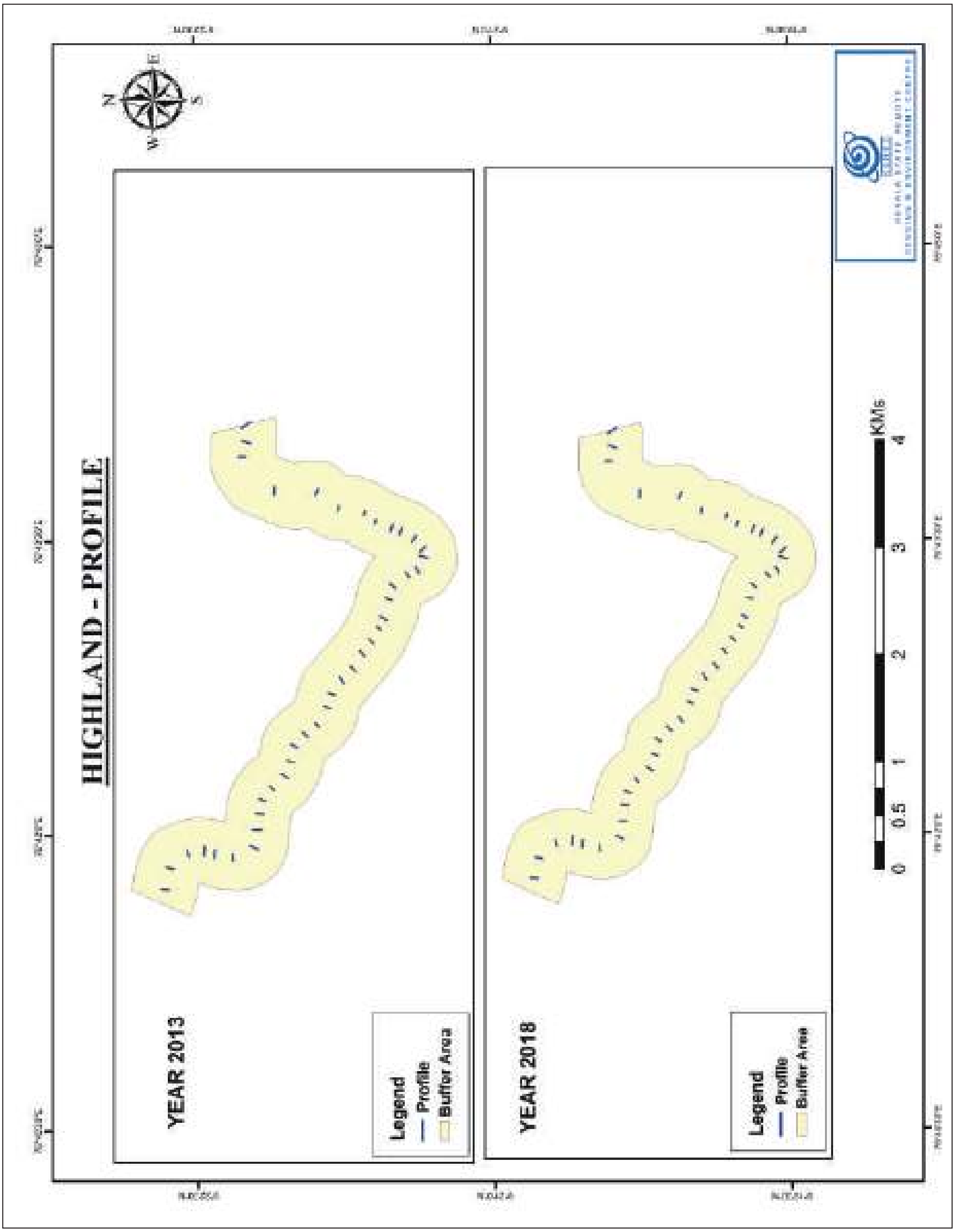


Fig: 7.25 River Profile of High land

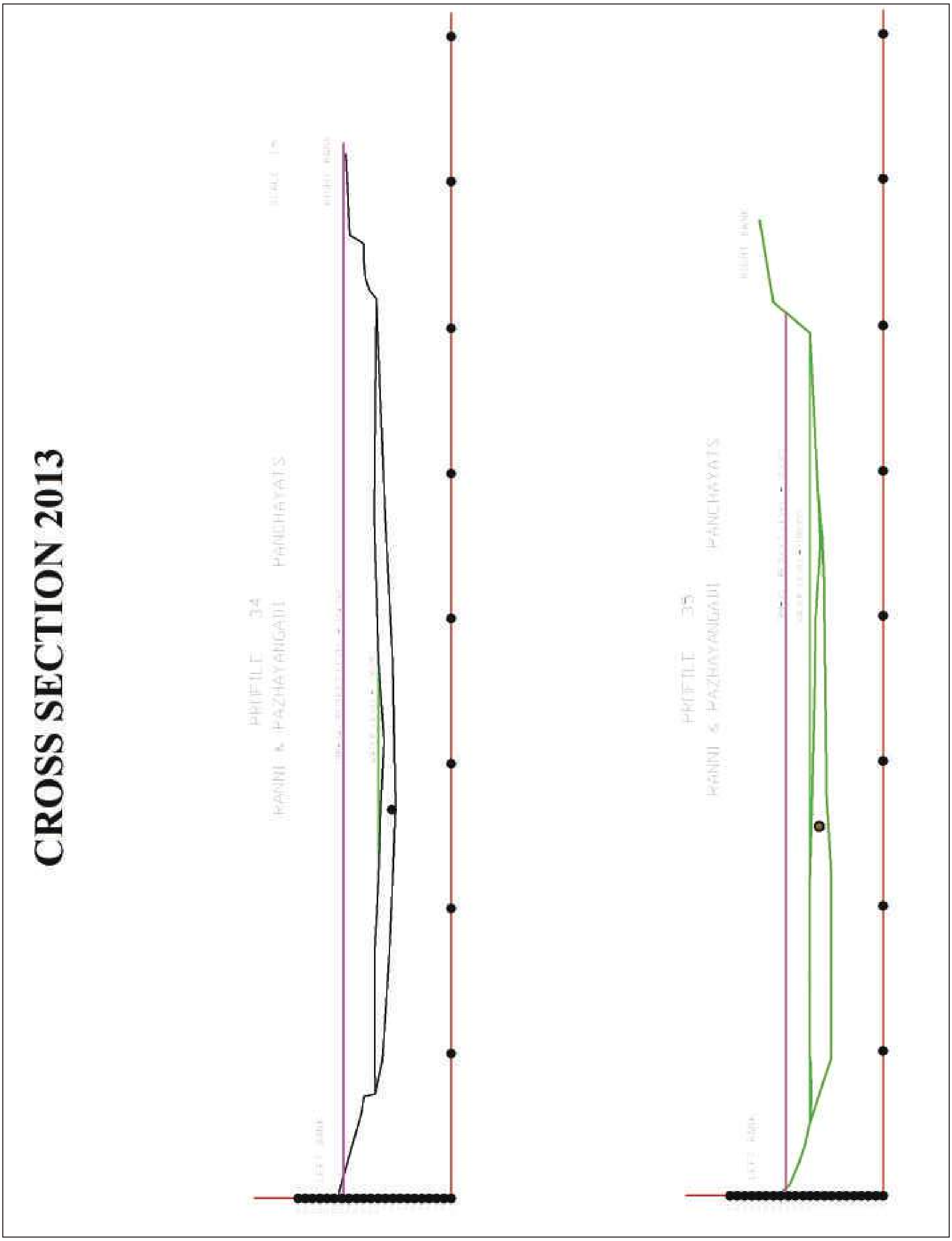


Fig.7.26. Cross section 2013 of Ranni&Pazhayangadi Pan

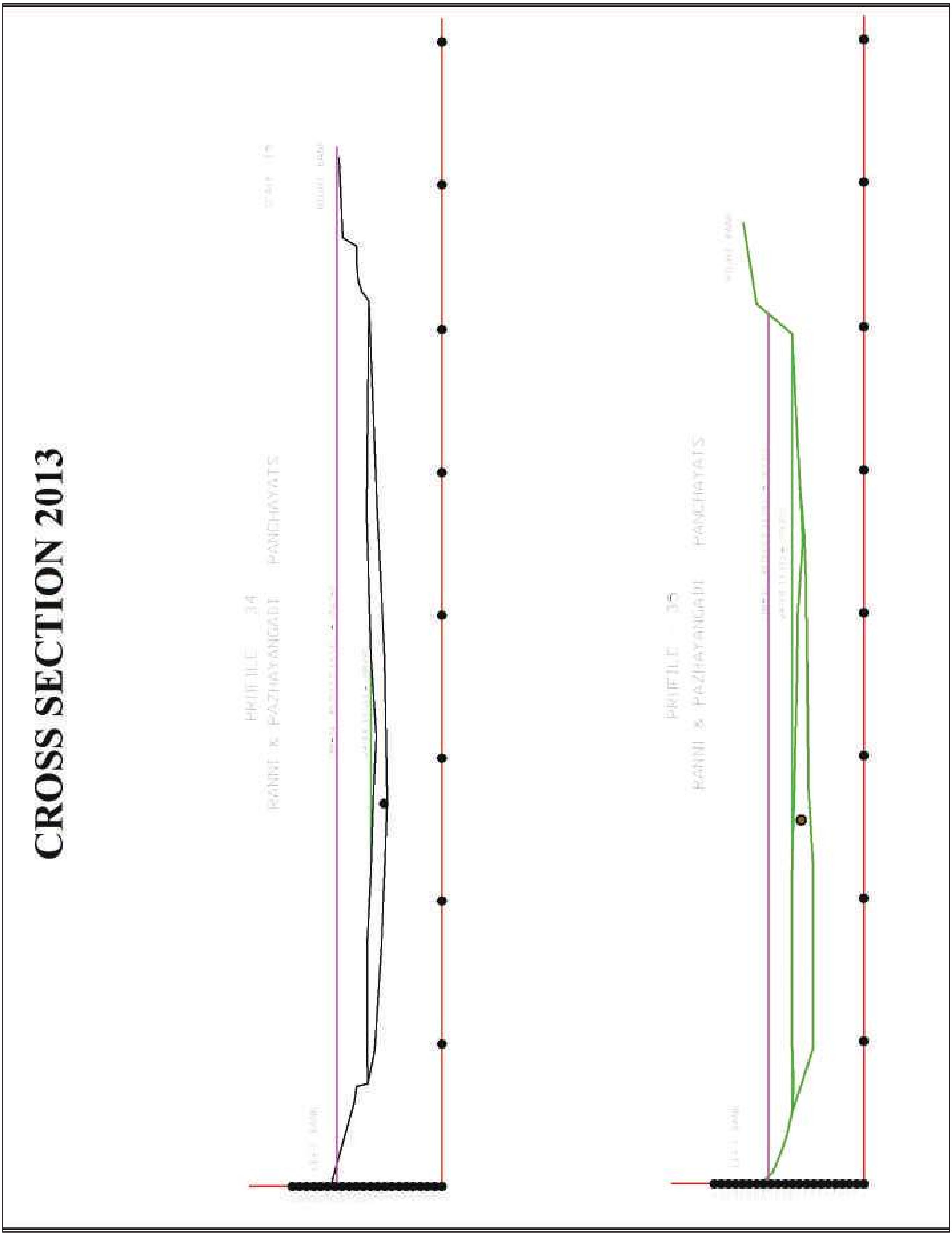


Fig.7.27. Cross section 2018 of Ranni&PazhayangadiPanchayats

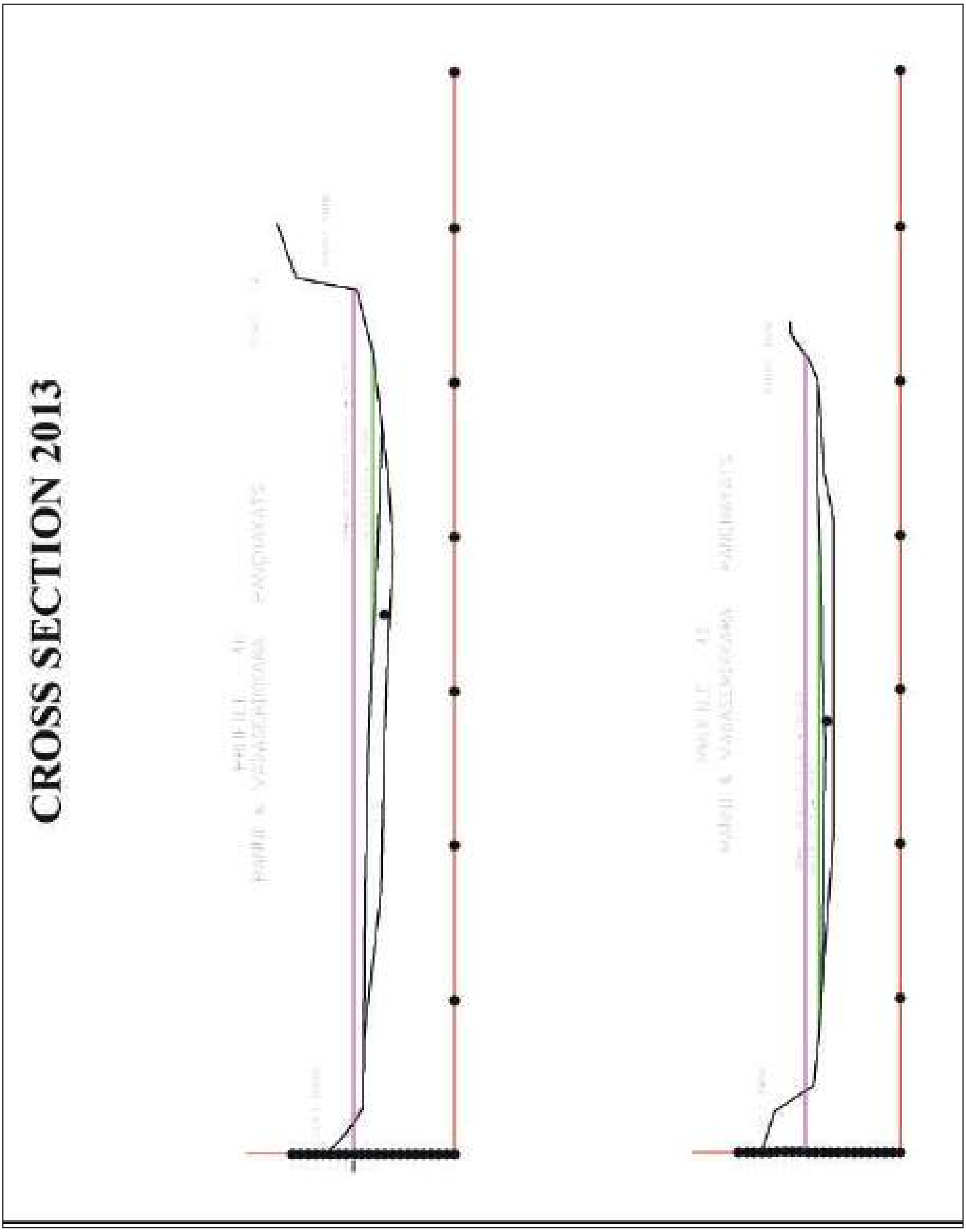


Fig.7.28. Cross section 2013 of Ranni&VadasserikkaraPan

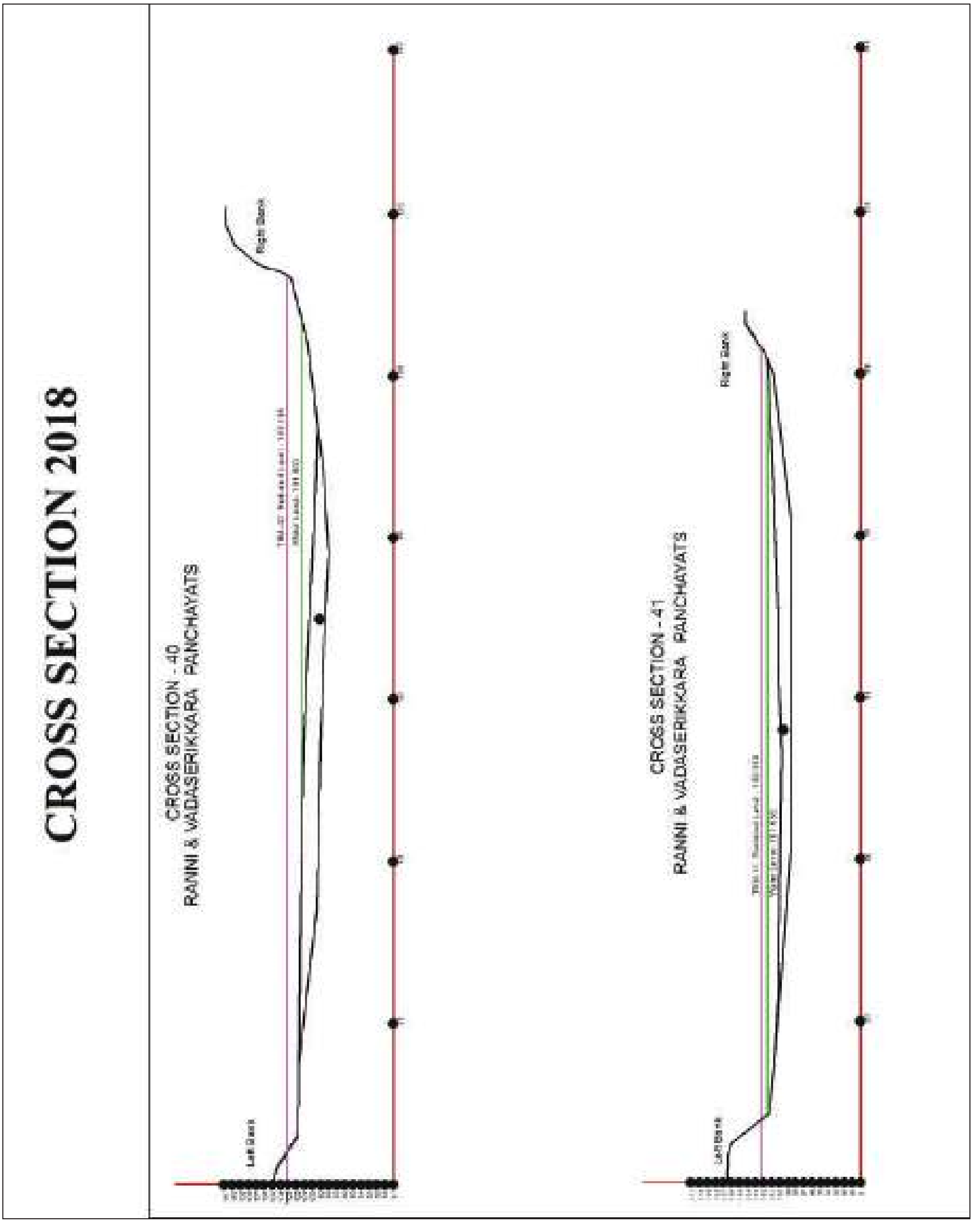


Fig.7.29. Cross section 2018 of Ranni&VadasserikkaraPanchayats

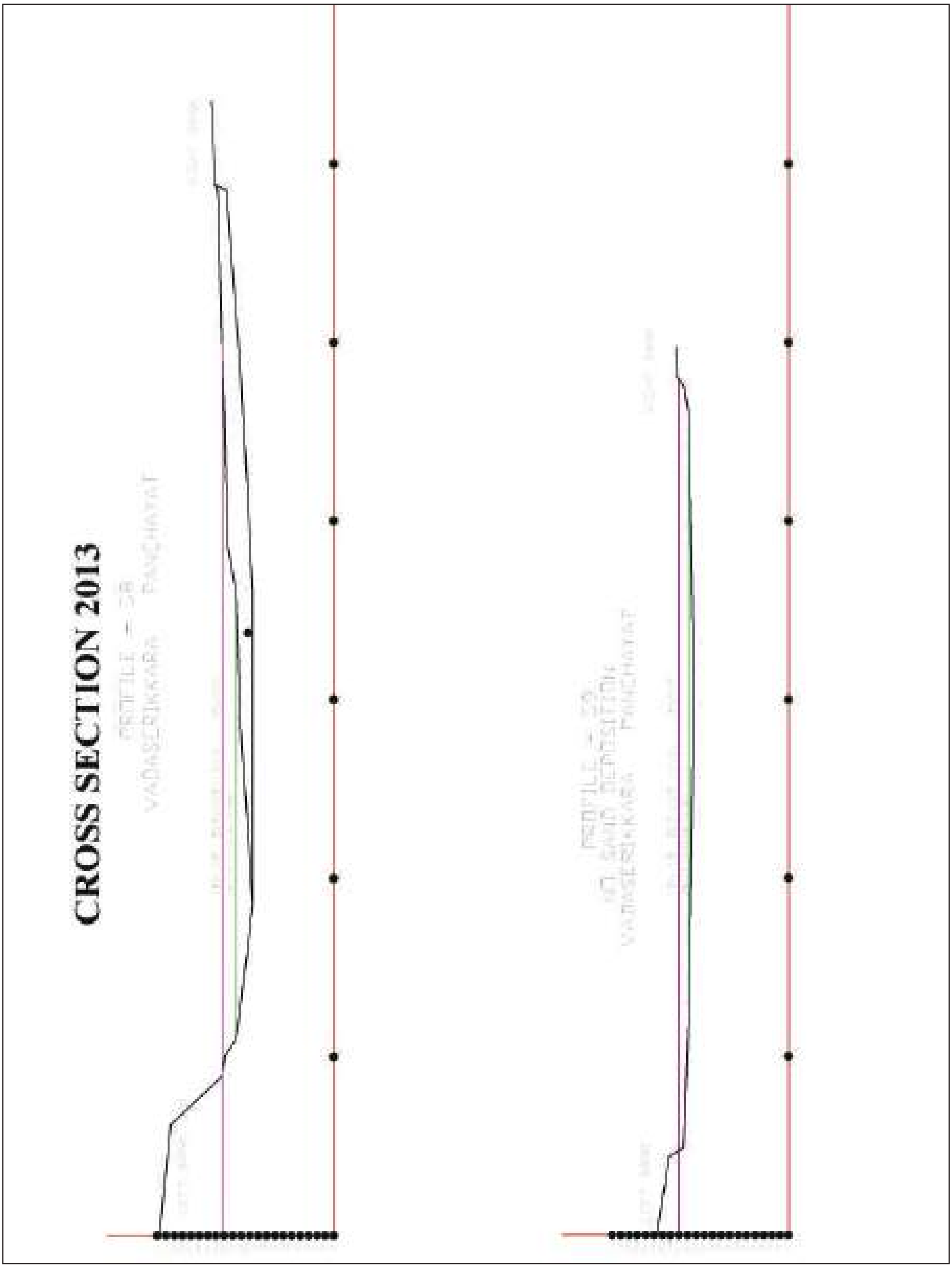


Fig.7.30. Cross section 2013 of VadasserikkaraPanchayat

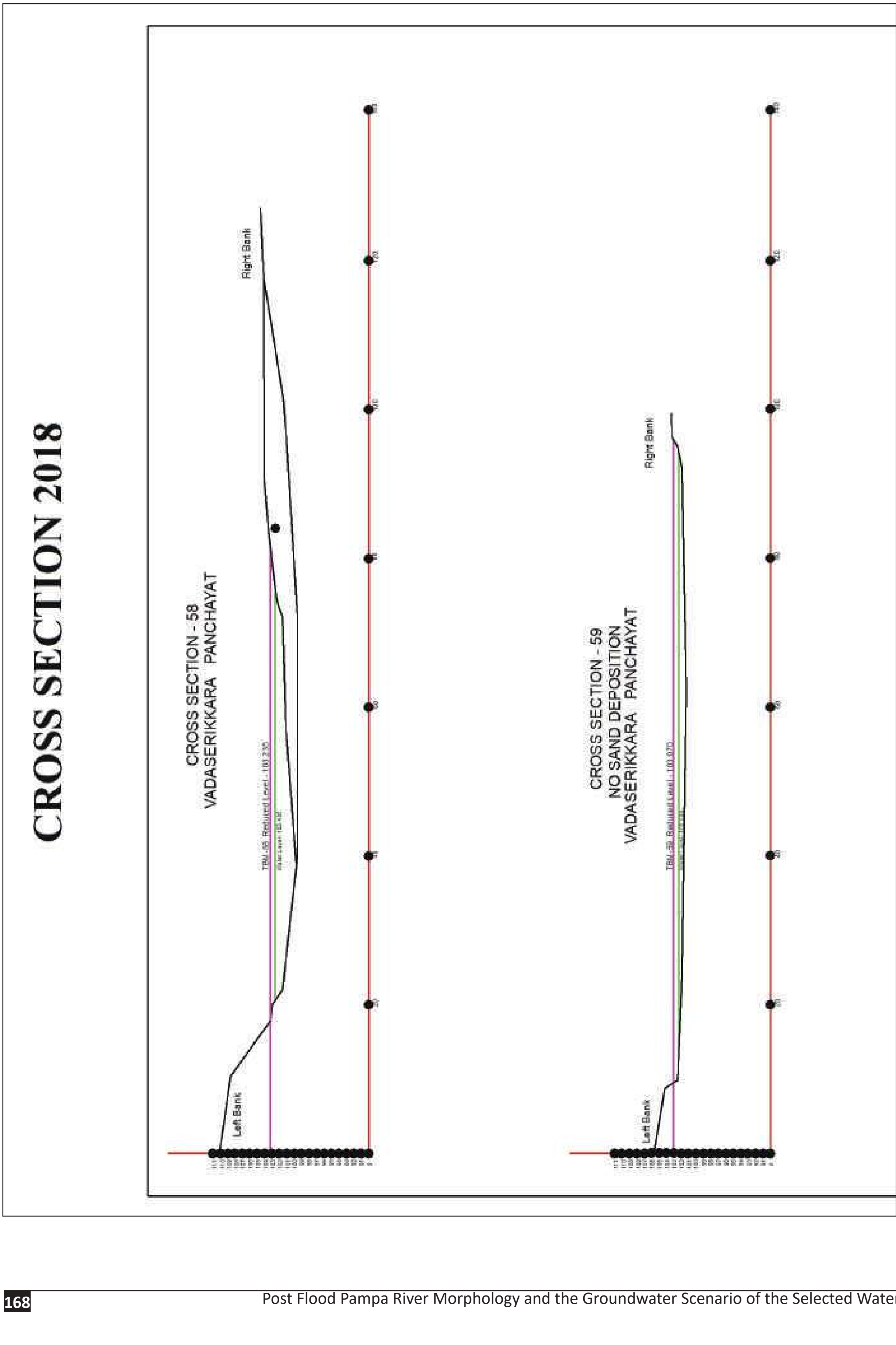


Fig.7.31. Cross section 2018 of VadasserikkaraPanchayat

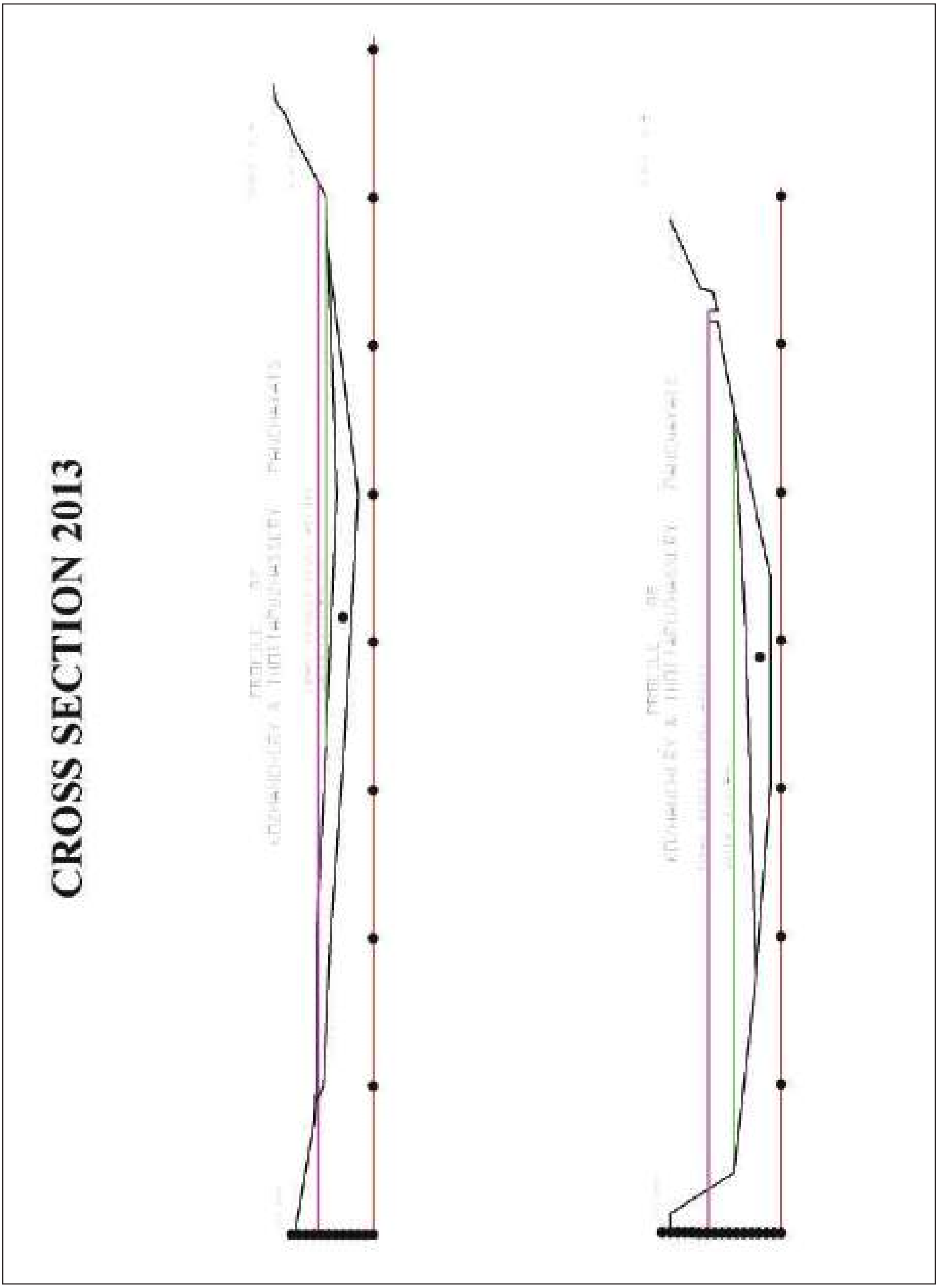


Fig.7.32. Cross section 2013 of Kozhenchery and ThottapuzhasseriPan.

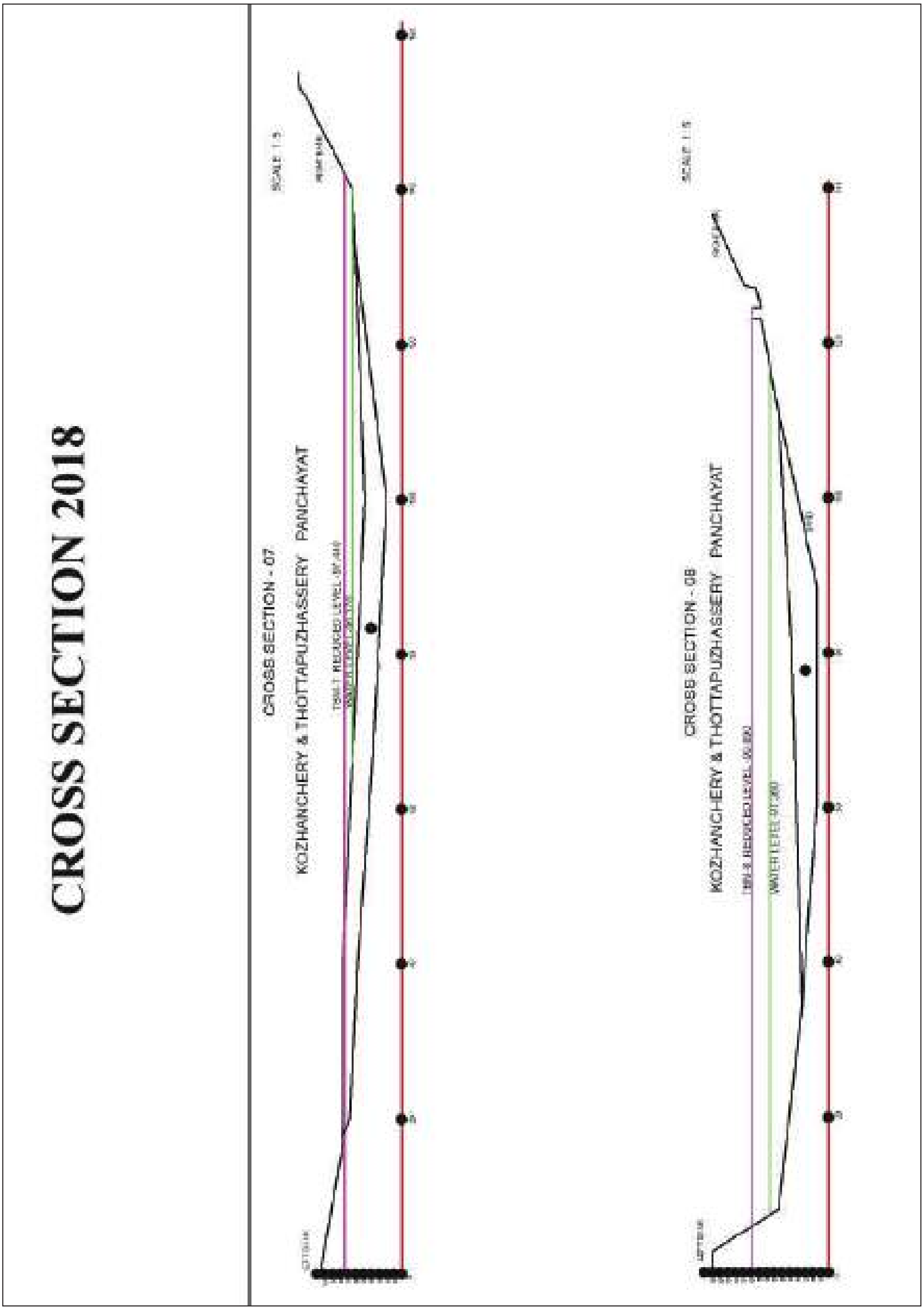


Fig.7.33. Cross section 2018 of Kozhenchery and ThottapuzhasseriPanchayat

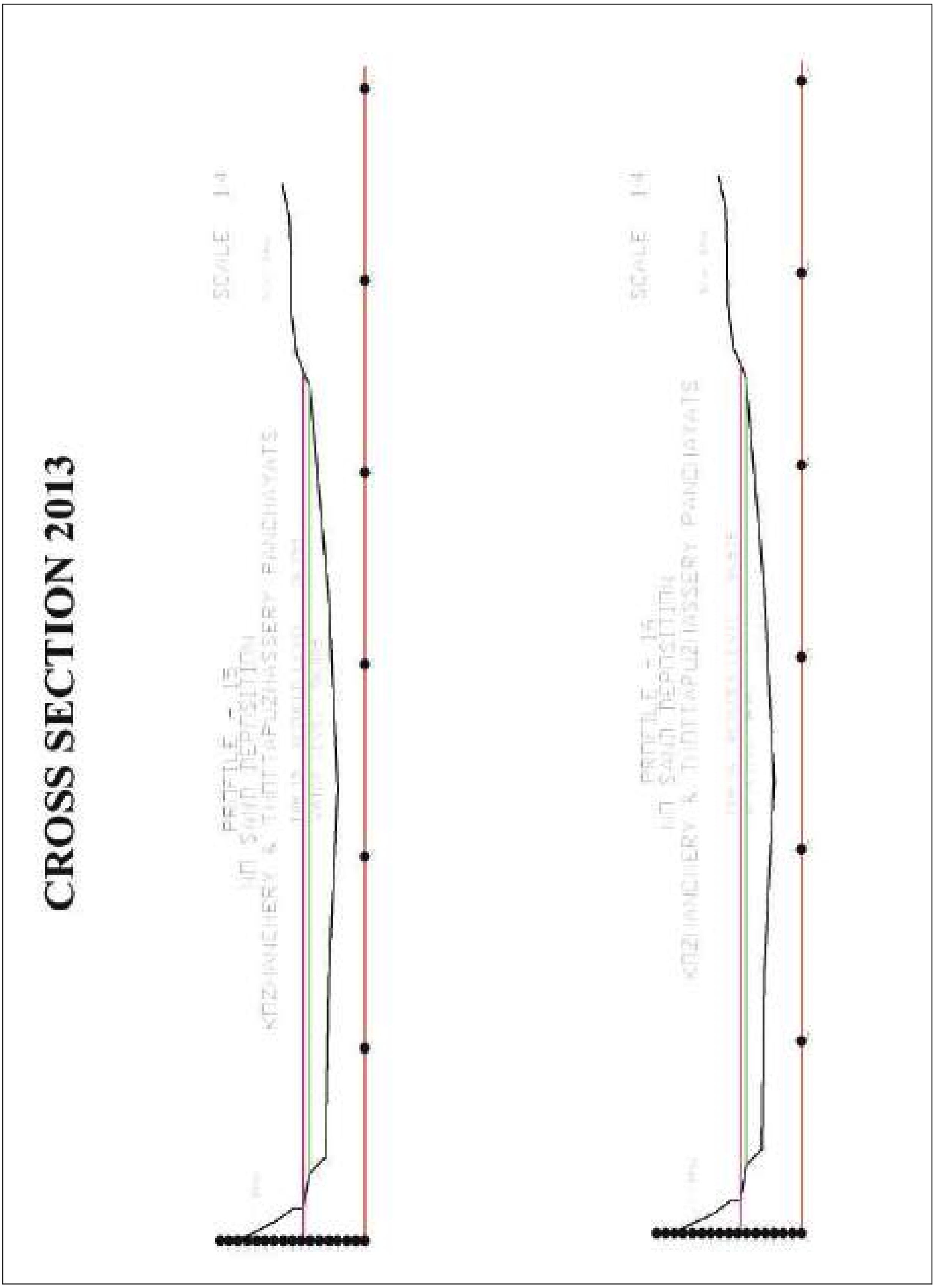


Fig.7.34. Cross section 2013 of Kozhenchery and ThottapuzhasseriPanchayat

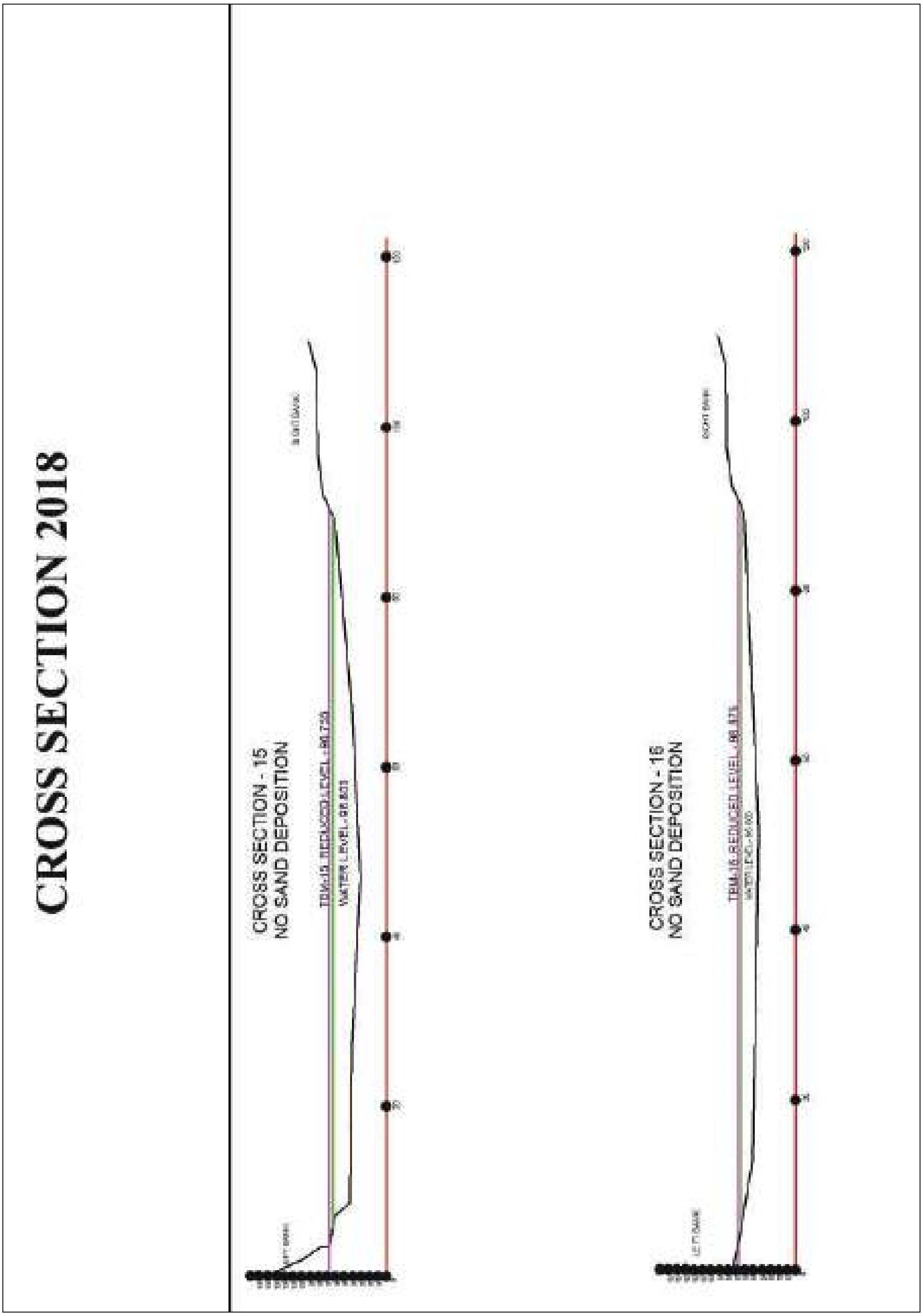


Fig.7.35. Cross section 2018 of Kozhenchery and ThottapuzhasseriPanchayat

7.6.6.3. Pre and post flood Cross profiles comparison for Low land

In the cross section 1, Pandanad panchayath(Fig.7.36and 7.37) and cross section 2, Pandanad panchayath(Fig. 7.38 and 7.39) of Low land there is no sand deposits on the 2013 survey or the 2018 survey. There is increase in the water level in the post flood scenario for both the sections. In the case of Kadapra and Mannar panchayath sections (Fig.7.40 and 7.41) of low land, there are no sand deposits and there is decrease in water level.

7.6.7. Conclusion

The field survey for the cross sectional profiles, the river morphology and land use mapping are useful provided there is no very high resolution or high resolution information available. The detailed mapping of the river on a repetitive manner can be easily conducted with the remote sensing techniques. But the specific information on the protection wall, riparian vegetation and plot level land use requires field based knowledge. A combination of the field based and the Remote Sensing techniques can provide optimal results and information, especially in the volume estimation, for the river management.

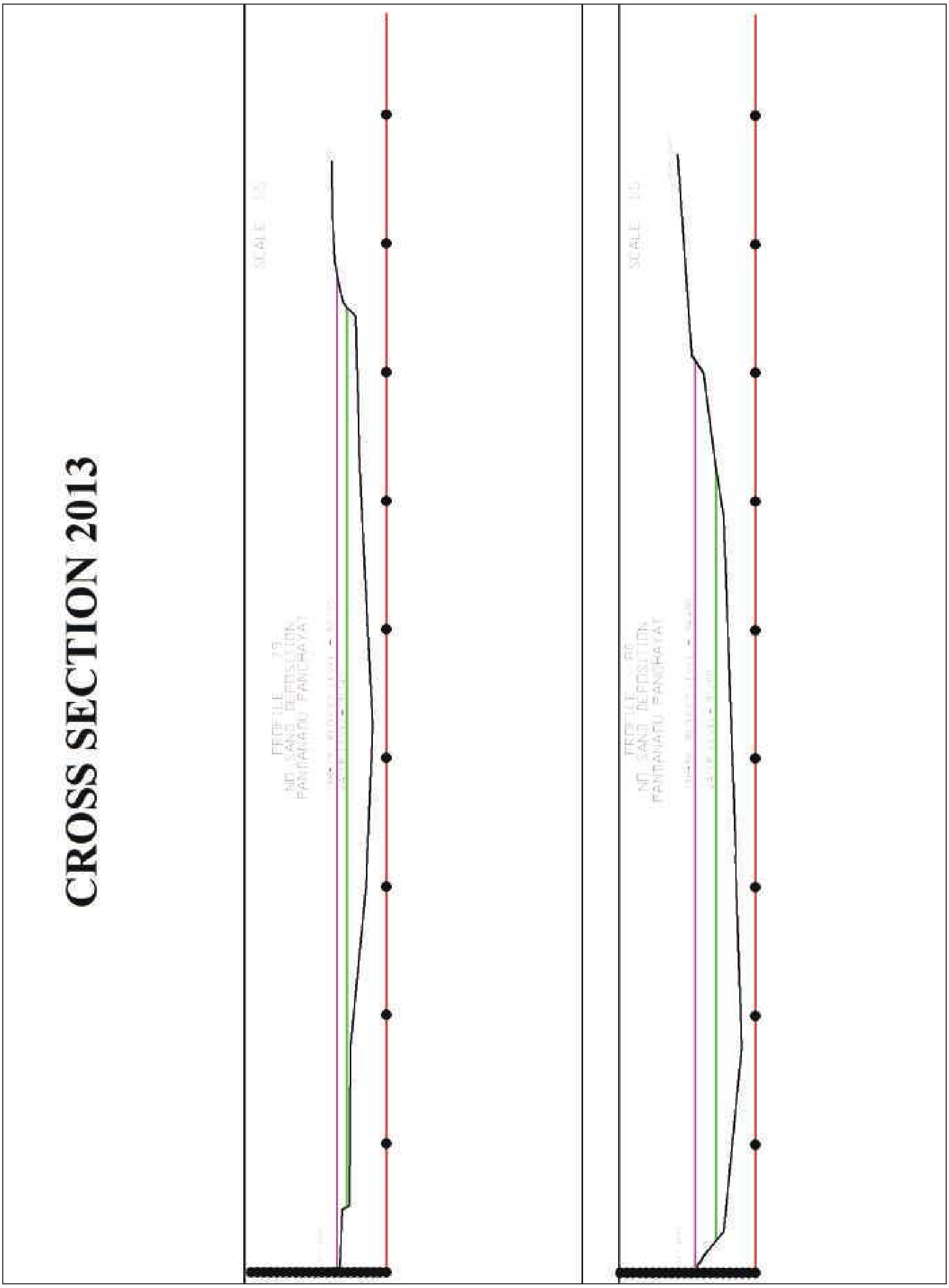


Fig.7.36. Cross section 1 -2013 of PandanadPanchayat

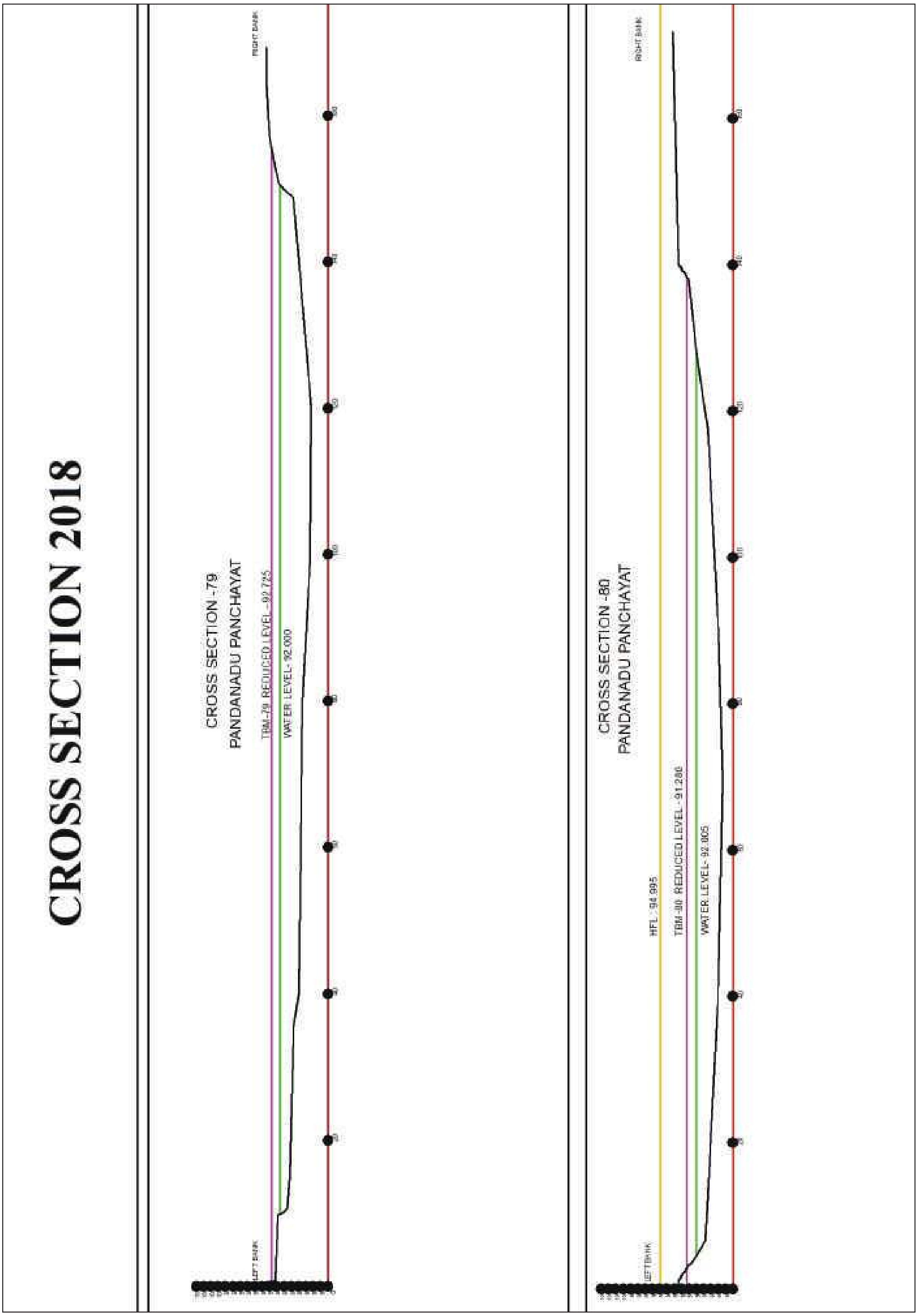


Fig.7.37. Cross section 1- 2018 of PandanadPanchayat

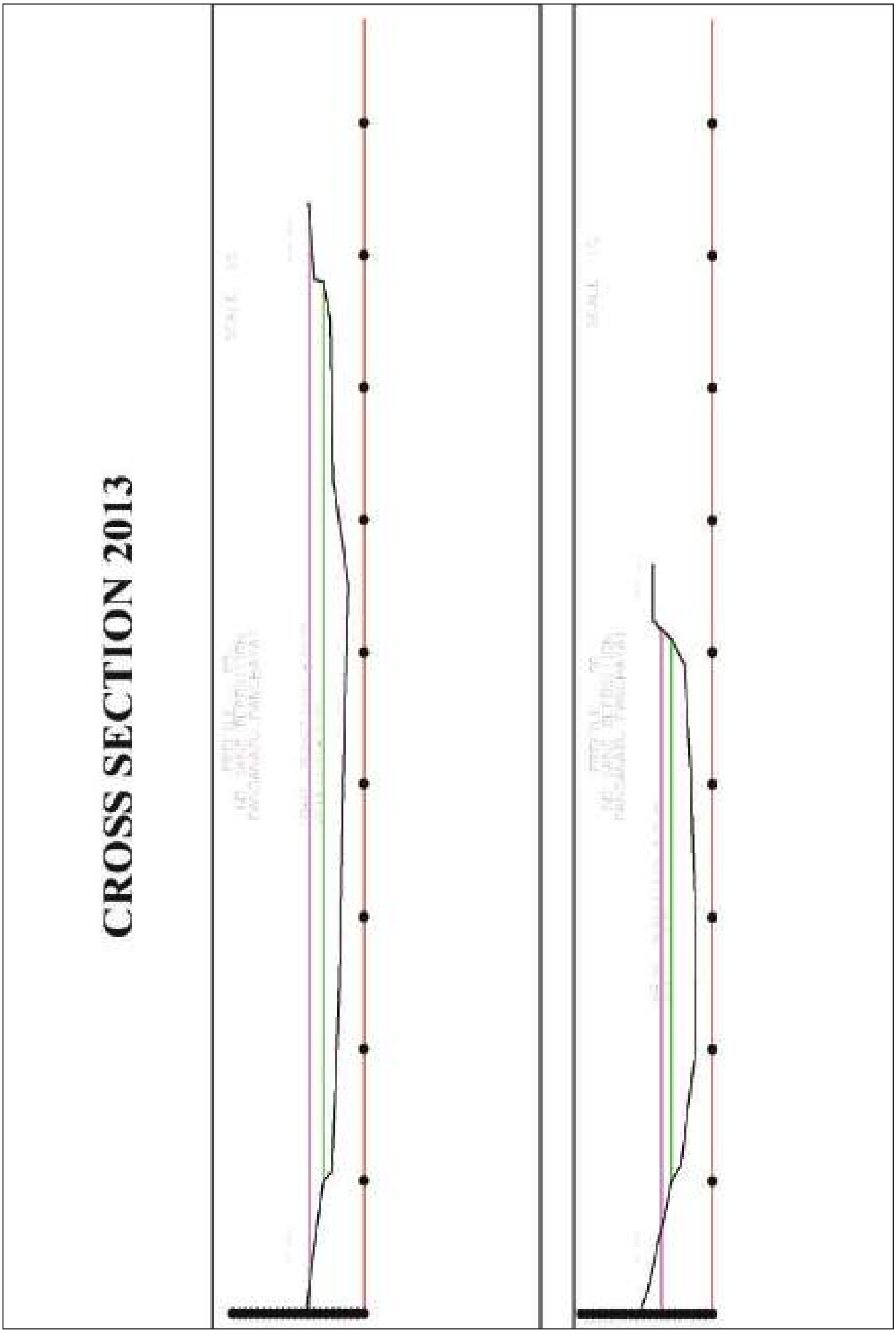


Fig.7.38. Cross section 2013 of PandanadPanchayat 2

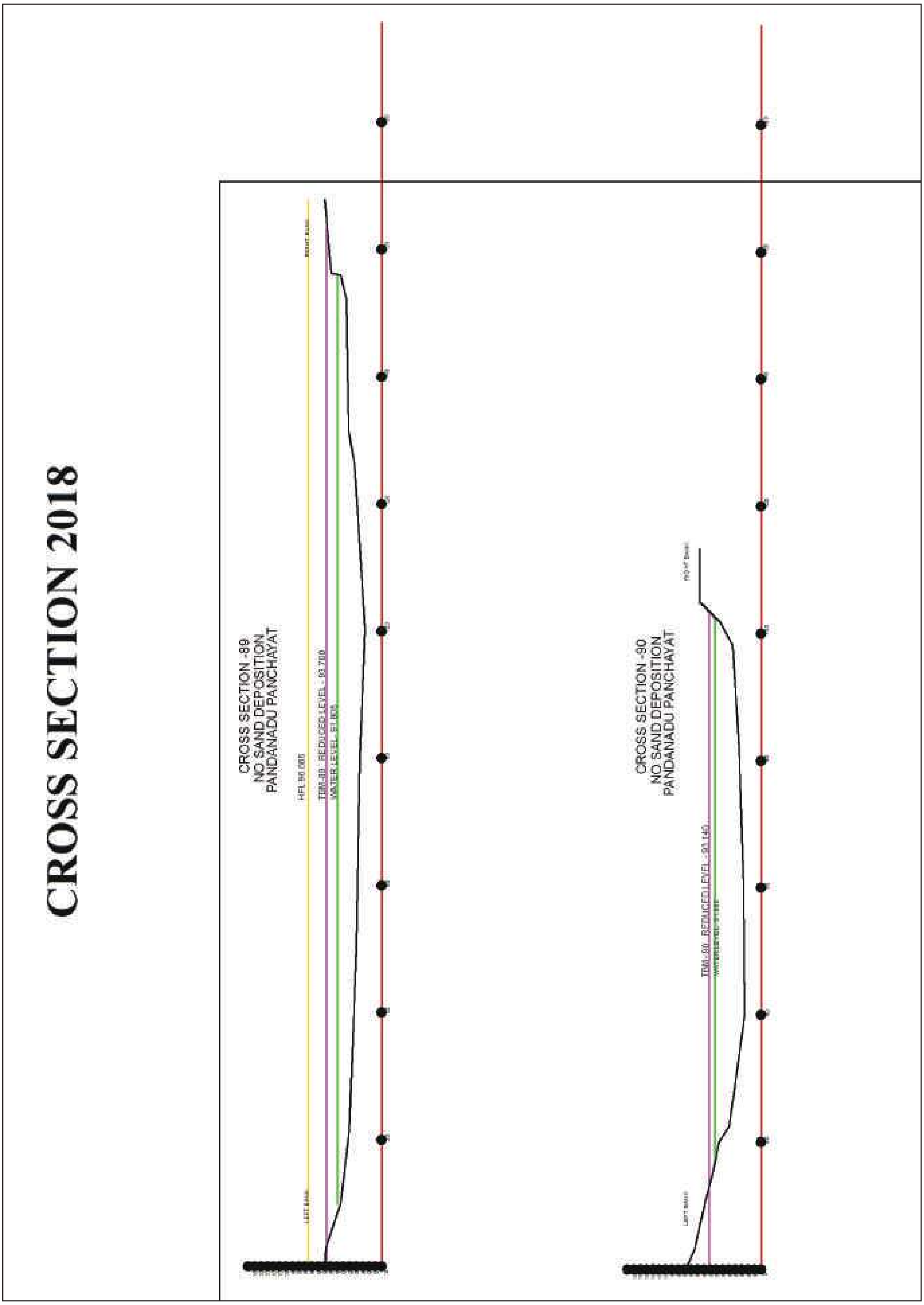


Fig.7.39. Cross section 2018 of PandanadPanchayat 2

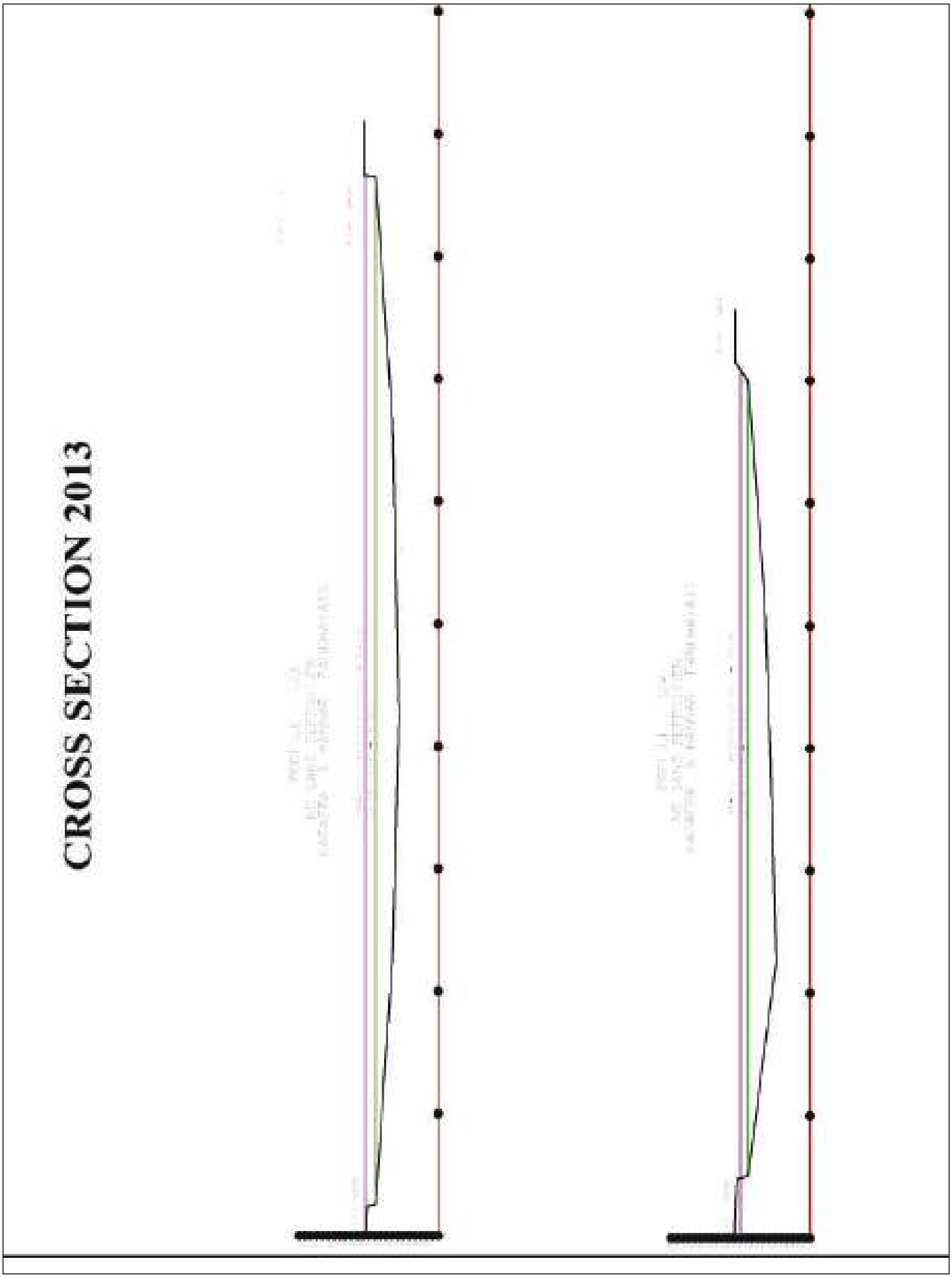


Fig.7.40. Cross section 2013 of Kadapra and MannarPanchayat

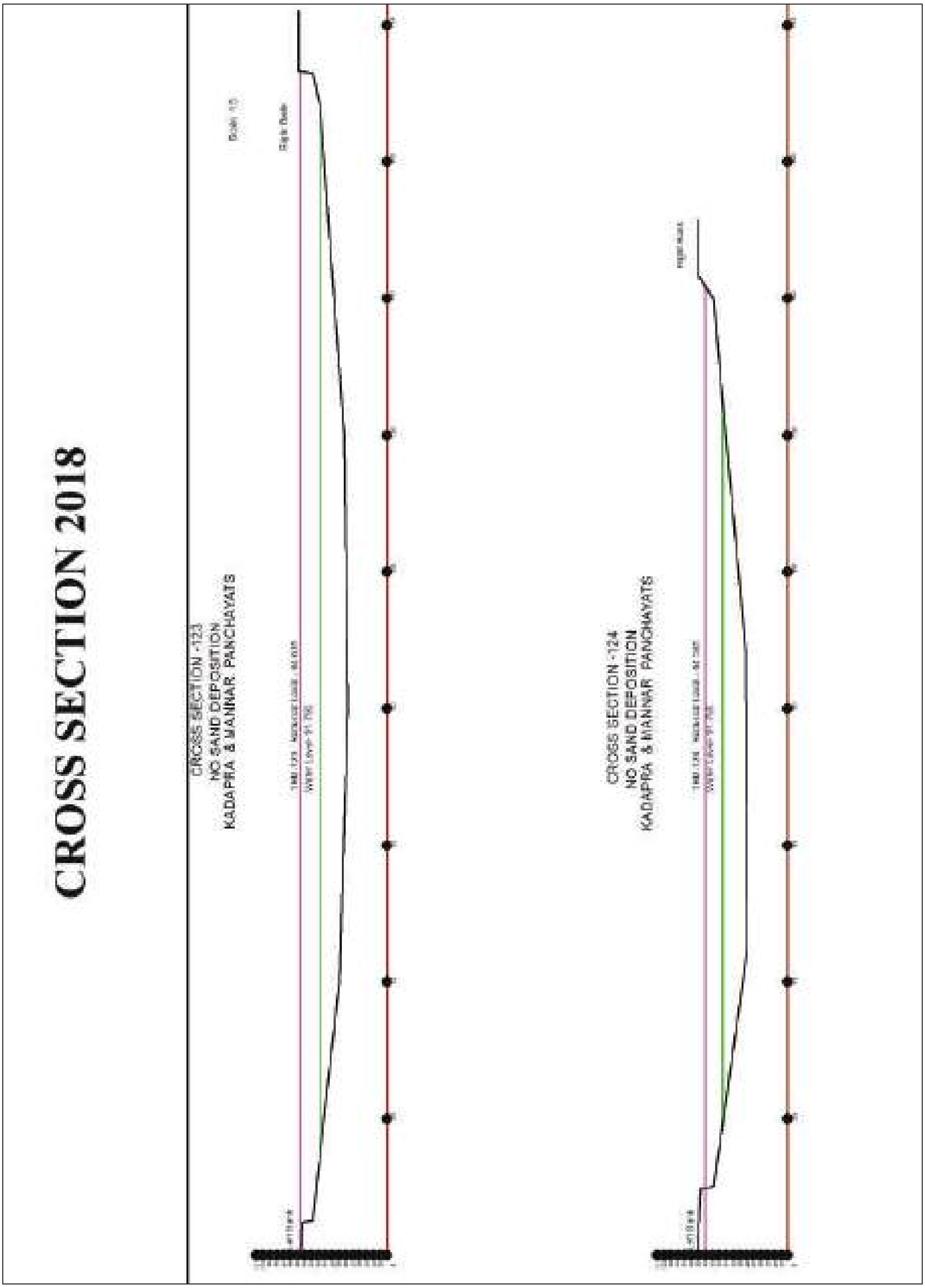


Fig.7.41. Cross section 2018 of Kadapra and MannarPanchayat

CHAPTER VIII

RESULTS AND DISCUSSIONS

8.1. Soil Quality Model

A plant's sufficiency range is the range of nutrient amount necessary to meet the plant's nutritional needs and maximize growth. Mobile nutrients include N, P, K, Cl and Mg.Because these nutrients are mobile, visual deficiencies will first occur in the older or lower leaves and effects can be either localized or generalized. In contrast, immobile nutrients B, Ca, Cu, Fe, Mn, S and Zn cannot move from one plant part to another and deficiency symptoms will initially occur in the younger or upper leaves and be localized.

Soil quality model was generated using the analytical results from Surface samples and Micronutrient samples. The micro nutrient model shows that the micronutrients are adequate in most of the area except for a small portion in the midland zone where there is deficiency for most of the micronutrients. The region which is deficient in micro nutrients may be due to heavy erosion and this is the area where there is change in the river course.

Surface soil quality model shows that there is a deficiency of Major Nutrients and other parameters in the High land segment of watershed region. This model is an integration of the characteristics including pH, EC, WHC, Organic matter etc. along with major nutrients.

8.2. Soil Porosity

Soil porosity is the gap between solid particles, which contains water and air. Soil moisture is one of the most important material components in agro-ecosystems, which is vital to plants and animals. Soil moisture is usually expressed by the available water capacity. Soils generally come in three different varieties: clay, sand and silt. Clay particles are especially small and cause the soil to become extremely dense when water is added. Silt has slightly larger particles, but again, when water is added to it the particles bind in a way that is not conducive to plant growth. Sand contains the largest soil particles with single particles available to the naked eye. May soils are composed of the three different varieties.

The porosity of the soil is found to be in the highly and extremely porous category in the flood samples and also in non flood samples. Moderately porous samples are very rare. This shows that there is no post flood porosity reduction to reduce the recharge of groundwater.

8.3. Land Use Change Model

Land use change modeling, especially if done in a spatially-explicit, integrated and multi-scale manner, is an important technique for the projection of alternative pathways for conducting experiments that test the processes in land use changes. Land-use change models should represent part of the complexity of land use systems. They offer the possibility to test the sensitivity of land use patterns to changes in selected variables. They also allow testing of the stability of linked social and ecological systems, through scenario building.

The Land Use change is the best indicator that can bring out the morphology change of the area. The depositional and erosion location along the course due to the flood is specifically brought with the help of very high resolution drone based remote sensing. 3cm resolution images were analyzed which could bring out the slightest changes that happened after the flood.

8.4. Groundwater Model

A groundwater model is a simplified representation of a groundwater system.Groundwater systems are affected by natural processes and human activity, and require targeted and ongoing management to maintain the condition of groundwater resources within acceptable limits, while providing desired economic and social benefits. Groundwater management and policy decisions must be based on knowledge of the past and present behaviour of the groundwater system. Groundwater models provide additional insight into the complex system behavior and can assistin developing conceptual understanding.

The groundwater analysis comparing the monthly groundwater level in general shows there is drastic difference in groundwater level only for the August and September 2017 and August and September 2018. The other months doesnot show major variations in groundwater pattern. The available 2019 data was also compared which also is not showing major variations in groundwater pattern. The groundwater level in 2018 August has considerably risen and has aligned to the terrain height.

8.5. River Bed Profile

River morphology develops from the action of water flow and sediment movement, which are, in turn, influenced by the bed morphology. Rivers can be described as having two distinct profiles: long profile and the cross valley profile. Long profile is the change in altitude and gradient from the source to the mouth of a river. The cross - valley profile is the cross section through the river valley at any given point along the long profile.A river will respond to changes in energy available,perhaps through an increase in discharge caused by higher seasonal precipitation and the amount of erosion and deposition which occurs as a result will be adjusted to the new input conditions.

The river bed profile also shows the changes in the profiles taken every 100 mts. The water level in the river is also showing variations in the pre flood and post flood profiles taken in 2013 and 2018. The profiling study also brings up the deposition and erosion zones of the study stretches. The variations in the river bed, water level, depositional and erosional characteristics shows correlation with the land use changes derived from the Very High Resolution images.

8.6. Conclusions

8.6.1. Soil Quality

Micronutrients are essential for plant growth and play an important role in balanced crop nutrition. They include boron (B), copper (Cu), iron (Fe), manganese (Mn), zinc (Zn), nickel (Ni) and chloride (Cl). They are as important to plant nutrition as primary and secondary macronutrients, though plants don't require as much of them. A lack of any one of the micronutrients in the soil can limit growth, even when all other nutrients are present in adequate amounts.

- Micro nutrient quality is poor in Midland segment covering Thottapuzhasseri and Kozhenchery Panchayaths.
- Macro nutrients are deficient in a major area of High land covering RanniPazhavangadi, Ranni and Mylapra Panchayaths and some pockets in the mid land area falling in Ayiroor Panchayath.
- Textural differences were noticed in flooded wetlands.
- Soil acidity decreased after flood and electrical conductivity values are satisfactory for crop production. Acidity ranges from strongly to very strongly acidic in post flood samples.
- Organic carbon and available phosphorus showed increase while available potassium showed decrease in post flood samples.
- The content of Calcium, Magnesium and Sulphur are high in post flood period.
- Micronutrients are available in sufficient quantity in post flood period.
- Magnesium deficiency is observed in some pockets of flood affected areas.

8.6.2. Land Use

Land use planning is the process of regulating the use of land in an effort to promote more desirable social and environmental outcomes as well as a more efficient use of resources. Land use is the backbone of agricultural economies and it provides substantial economic and social benefits. Land use change is arguably the most pervasive socioeconomic force driving changes and degradation of ecosystems.

- Morphologically in the post flood scenario, High land river course has found to have depositional trend and has channel bars along the banks of river and also braid bars within the river.
- The Mid land river course is also found to have depositional trend and has development of channel bars along the banks of river and braid bars within the river.
- The Low land segment of the river is showing eroding trend along the banks and also the channel bars are eroded.
- The general Land Use Change is the increasing built up, increased impervious area like roads, laying of tiles surrounding built ups had all contributed along with the natural causes to the flooding and the resulted morphological changes in the river course.

8.6.3. Groundwater Level

Groundwater is a prime natural resource in the Earth. It supports all types of life forms to exist in the Earth and also helps for many other purposes includes domestic, industrial, irrigation purposes etc. It is the water located beneath the earth's surface in soil pore spaces and in the fractures of rock formations. A unit of rock or an unconsolidated deposit is called an aquifer when it can yield a usable quantity of water. The depth at which soil pore spaces or fractures and voids in rock become completely saturated with water is called the water table.

- Groundwater levels in all the segments of the study area showing a general improvement in the level after the flood in all the low land, mid land and high land segments.
- The pattern of the groundwater does not show any major variation except for the flood month of August 2018 and September 2018.
- As the porosity of the soil even in the post flood is showing extremely and highly porous category, it can be assumed that the recharge characteristics are not affected by the flood deposition.

8.6.4. River Profile Variation

- The Water level in the river compared to the pre flood scenario of 2013 had shown variation from Low land to High land.
- The Mid land region of the river is showing a rise in the water level compared to 2013.
- The Low land the river profile shows an increase in water level in the post flood sections and areas like Kadapra and Mannar show a decreasing trend.
- In the High land region also showed an increasing trend in the water level during the post flood cross sections.
- The long profiles of the river shows the variations which depicts the depositional characteristics of the High land and Mid land region and the erosional characteristic of the low land region in the post flood scenario.
- The morphological changes of the river has got bearing to this rise and falling of river water level.

CHAPTER IX

RECOMMENDATIONS

- Land Use planning and policy is essential to improve the recharge mechanism by restricting the impervious area.
- Agricultural activities in the Paddy field, rather than keeping it fallow and also the culture of trenching around coconut trees for manure, before the onset of monsoon will also help in the recharge of groundwater.
- River bank protection and the room for river concept is essential for reducing the future flood situations.
- Benchmarking of all the rivers and water bodies with the help of drone based very high resolution surveys integrating with cadastral information will protect the wet lands from future depletion.
- The river network system to be re established, as the same is blocked and chocked by human interventions, by removing obstructions. Rejuvenating the mid land streams should be given priority.
- Water conservation measures should be ensured which can include regulatory model check dams, sub surface dykes etc.
- Location specific models should be adopted for check dams.
- Bandhara model water conservation measures can also be promoted.
- Water conservation calendar starting from November should be popularized.
- Groundwater recharging measures should be taken up at plot level.
- The deposition of sand in the high land and mid land can be removed based on a study.
- Low land is adversely affected with Magnesium deficiencies which will affect major crops of the area like Coconut, Nendran banana and Rubber. This should be rectified by application of required quantity of Magnesium Sulphate or Dolomite.
- It can be inferred that the soil is observed with extremely acidic to slightly acidic in most part of the study area of lowland and midland. Application of lime is essential to improve soil condition.
- Phosphorus also found to be high in lowland, midland and high land which can be treated and removed using chemical treatment of using alum, ferric chloride and lime has shown excellent Phosphorous removal efficiencies despite their expensiveness.
- Planting maize is also good, as maize require more phosphorus and absorbing more phosphorus from soil as compared to most of the other crops.
- Calcium deficiencies observed in the lowland, midland and highland portions can be treated with calcium sources like farmyard manure, Calcium Chloride, Gypsum, dolomite, lime pyrites, single superphosphate or triple superphosphate or lime nitrate. Additional calcium can be applied through the nutrient solution by means of liquid lime fertilizers such as a calcium nitrate solution etc.
- Micro nutrient deficiencies can be addressed by basal application to soil and or foliar sprays of Zn, B and Mo, and foliar sprays of Fe and Mn.
- Plant nitrogen-fixing vegetables to increase nitrogen without increasing phosphorous. Examples of such vegetables include beans and peas (legumes).
- Addition of $CaCO_3$ or substitutes which are having low-medium level of alkalinity residue might be able to provide some desired solution under very high Phosphorous soil status.

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