42ND INCA - PROCEEDINGS OF INTERNATIONAL CONGRESS

09-II Nov 2022

ON

DIGITAL CARTOGRAPHY TO HARNESS BLUE ECONOMY

Organised By

National Hydrographic Office, 107-A Rajpur Road, Dehradun - 248001

Uttarakhand, India

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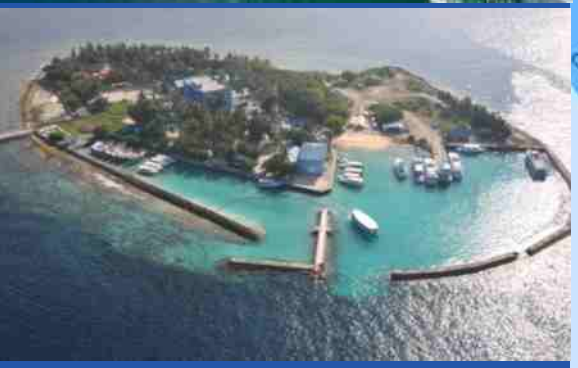

Chief Editor

Dr BK Ramprasad

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GLIMPSES OF 42nd INCA

42ND INCA - Proceedings of International Congress

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DIGITAL CARTOGRAPHY TO HARNESS BLUE ECONOMY

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Mr.M P Gupta did M.Sc. (Tech) in Exploration Geophysics from Banaras Hindu University, Varanasi and presently working as an Assistant Chief Civil Hydrographic Officer at National Hydrographic Office, Dehradun, India. He has qualified IHO-IMA Cartographic Course from Trieste, Italy and awarded top meritorious students in the batch of year 2003. He has contributed to the department in the areas of nautical cartography by producing charts and ENCs, quality assurance of nautical products and planning & scheming of charts in compliance with international standards. He worked on the CARIS GIS suit of software for more than 15 years. Mr. Gupta is a Life Member of INCA and also Member of IHO's working group TWCWG (Tides, Water Level and Currents Working Group). He is also a member of INCA Editorial Board for the Journal "Indian Cartographer".

Mr. Vijay Deep Singh, Civil Hydrographic Officer is an Engineering graduate in Hydragraphy and an M.Sc GIS with more than eighteen years of experience in Marine Geo-spatial domain, contributing in imparting education and production of nautical products. Presently perusing Ph.D from IIT Roorkee, his research interest includes Hydrography Cartography, Satellite Derived Bathymetry, and GIS, Participating in research work. Mr Vijay Deep is life member of Institution of Surveyor (IOS) and Indian Cartographic Association (INCA). He has been representing NHO in the International Hydrographic Organaisation's (IHO) Working group called S-100WG.

Contents

Preface

Indian National Cartographic Association (INCA) is a premier organisation consisting of Geographers & Cartographers and was established in 1979, Hyderabad as its Head Quarters. Since its inception the Association is witnessed the transformation of cartography to its modern digital era. The Association is a conglomerate of eminent scholars, professionals and industrialists as Honorary Fellows, Life Fellows, Life Members, Associate Members and Student Members. INCA has been promoting the Cartographic research and maintaining cooperation with International organizations with the similar objectives and holding National Cartographic Conferences once in a year. Continuing its legacy, the 42nd INCA International Congress was organised by the National Hydrographic Office (NHO) in Dehradun from 09-11 Nov 2022 on focal theme - "*Digital Cartography to Harness Blue Economy*". A total of 67 papers were received from the authors on various sub-themes. After thorough review by the editorial board 36 papers had been selected for presentation during the conference under the following technical sessions:

(a) Trending Cartography – Past, Present and Future
(b) Modern Precision Surveying & Mapping Tool
(c) Geospatial Solution for Sustainable Water Resource Management
(d) Hydrographic Surveys and Mapping for Coastal Zone Management
(e) GIS Application for Climate Change and Environmental Studies
(f) Mapping Solutions for Risk Assessment, Mitigation Measures and Disaster Management
(g) Application of Artificial Intelligence tools for Urban Planning and Resource Management

Keeping the issues of predominance and relevance to the modern technological trends, 36 papers which were presented in various technical sessions out of which 29 papers have been selected for publication in the 42nd INCA International Congress Proceedings. Seven selected papers contributed to the "INDIAN CARTOGRAPHER" (peer reviewed Journal of INCA) for publication.

The authors had enlightened on Data Acquisition in Ka-band frequency range data analysis to meet Cartographic Applications, Discussed the transformation of nautical charts from hand drawn techniques to the modern digital Electronic Navigational Charts (ENCs). The authors also elaborated the different image fusion techniques using CARTOSAT-3 images, novel approach for image Destripping in case of cloud and water. A new theme of making tribal development maps using GIS tools is informative about the Government initiatives towards these backward communities.

The intriguing technical papers on the modern precision methods in surveying and the advanced technological development in the geospatial technologies i.e Artificial Intelligence (AI) and its applications in the urban development are very interesting. The authors have also deliberated the smart solutions to develop smart city planning using RS& GIS technologies, use of AI for natural resource management. The techniques of multi polarization and multi resoulution SAR sensors based on the wavelet transform were also discussed.

Technical papers on "Geospatial Solutions for sustainable water resource management", GIS based solutions for Catchment Assessment and Sustainable Lake Water Management, water quality, E-Governance for types and distribution of water sources, use of Sentinel -1A SAR and Sentinel -2A Optical data for wetland mapping are inspiring.

"GIS Applications for climate change and Environmental Studies", spatio-temporal analysis of the heat waves, assessment of forest fragmentation, analysis of spatio-temporal drought characteristics and trends are informative. The authors have also deliberated their views on estimation of cropping intensity.

Research findings on "Mapping solutions for risk assessment, mitigation measures and Disaster management", flood vulnerability assessment, impact of climatic variability on crop productivity in coastal areas and drought prone areas is an eye opening. Air Quality Index, relationship between land use/ land cover and surface temperatures were also addressed in these technical papers. The findings of Disaster Management, development institute, Patna have given the insight on the government initiative to mitigate the loss caused by lightning using INDRAVAJRA mobile App. The authors also threw some light on landslide risk assessment and changing pattern of sex ratio in Jharkhand. Matters related to Hydrographic Surveying and Mapping for Coastal Zone Managemnt was also discussed by the authors.

I am grateful to the authors those who had contributed their research findings for publication in the 42nd INCA International Congress Proceedings. I believe that the contents and the quality of technical papers are best suits

for the conference theme "*Digital Cartography to Harness the Blue Economy*". I am thankful to my associate editors for their effort towards scrutinizing the papers. My sincere thanks to the officers and staff of NHO for their cooperation during the conduct of conference. The grand success of 42nd INCA International Congress would not be possible without the financial support of beloved sponsors and exhibiters namely Indian Navy, Survey of India, PAN INDIA Consultation Pvt. Ltd, HEXAGON, KONGSBERG, DEEKAY Group, Census of India, NSDI, NRSC(ISRO), Inland Waterways Authority of India, IIC Technologies, ESRI, GRSE Kolkata and ASB Systems Pvt. Ltd.

I take this opportunity to thank Vice Adhir Arora, Chief Hydrographer, Rear Admiral LS Pathania, Joint Chief Hydrographer and Commodore Peush Pawsay for their continued support in making the event grand success and bringing up the Congress Proceedings on time.

Dr BK Ramprasad
Chief Editor

Inaugural Address

By
Lt. Gen. Gurmit Singh,
PVSM, UYSM, AVSM, VSM (Retd.)
Hon. Governor of Uttarakhand

Vice Admiral Adhir Arora, Nao Sena Medal, Chief Hydrographer to the Govt of India and President Indian National Cartographic Association,

Rear Admiral Lochan Singh Pathania, Joint Chief Hydrographer,

Shri Sunil Kumar, Surveyor General of India,

Shri Pankaj Kumar, Secretary General INCA,

Invitees, distinguished guests, dignitaries, friends from media, industry, academic and scientific institutions, representatives of reputed organisations, children from schools, delegates, ladies and gentlemen.

I am delighted to be here, for the prestigious 42nd International Congress of Indian National Cartographic Association and feel honoured to address the eminent gathering.

I am aware that this gather consists of professional cartographers, experts in Geographic Information System (GIS) research scholars, scientists, academicians, administrators and stakeholders of varied disciplines striving to make new beginnings for better society and new India utilizing the best practices of cartography.

The focal theme of this Congress 'DIGITAL CARTOGRAPHY TO HARNESS BLUE ECONOMY'. This subject is contemporary and has vital significance worldwide and more so for us Indians. I must compliment Indian National Cartographic Association for selecting this theme. I am hopeful that the deliberations during this congress would bring innovative ideas for implementation.

Gone are the days when maps were referred to by specialists in various field. As rightly said earlier each one of us is utilizing Maps and Apps each day for making plans and decisions in our personal lives and our respective field of excellence. Referencing each entity and identity to a geographic location has become the new world order. Therefore, Cartography is not mere art and science for representing details on a map. It has become the art, science, technology dealing with the spatial data acquisition, processing, analysis, visualization and production of customized products as well as services on the go for informed decisions.
The spatial data is being gainfully utilized for betterment of society. Cartography has made inroads in to our lives and the respective field expert's stakeholders are utilizing the applications and services regularly. In fact no project planning monitoring for before, during and after is complete without reference to spatial data.

To understand the significance of spatial data, I would name few applications but the list is endless. It is being used for town planning, public health services, environmental modeling and analysis, observing and monitoring climatic changes, agriculture and e-governance, The specific applications have immense value addition totransport networking, aviation, biodiversity and the list goes on. Ladies and Gentlemen we all would agree unanimously, this vital spatial data and applications have translated in to ease of doing business.

Ease of doing business relates to our strengths and opportunities to design collaborative mechanisms for a holistic approach in all round sustainable development. Thus the theme 'DIGITAL CARTOGRAPHY TO HARNESS BLUE ECONOMY' is relevant. India has taken lead and adopted best practices in utlising the essential spatial data. In recent past when the pandemic of COVID-19 had impacted us, the spatial data was utilized by experts of respective fields to deliver public services effectively.

Today we Indians are committed to our national objectives of Blue Economy. Which is a natural outcome of UN Sustainable Development Goals, with specific reference to Goal 14 –to conserve and sustainably use the oceans, seas and marine resources for sustainable development". The guiding principle for global governance and use of ocean resources.

In order to continue our journey to achieve the goals and objective, we need to harness the goods of digital spatial data. Further, we need to give impetus for fruition of green initiatives implemented for sustainable development be on land or at sea.

The Sagarmaala project is a package of many initiatives which will result in clean seas and oceans, as well as holistic development of hinterland.

Towards this government and non-government agencies, public-private partnershipsare utilizing spatial data for making scientifically analysed and informed decisions with an inclusive and innovative approach. The inclusive and innovative approaches are examining multi-disciplinary relationships and the systemic audits are

aiding in evolution and sustainable development.

The digital spatial data and cartography has paved new ways for data gathering. Various teams of data aggregators, data analysts are porting vital cartographic data in to systems. In conjunction with latest information technology the cartographic data is being subjected to statistical analysis, modelling and visualizations. Thus data visualization with statistical analysis has become a major ingredient in our decision making processes. Thus digital cartography has evolved as ONE STOP SHOP for all stakeholders in three dimensions of nature LAND, AIR and WATER. On the similar lines digital cartography has a significant role to play in the SIXTH DIMENSION of our BLUE ECONOMY POLICY.

Today, we Indians have adequate expertise and potential in digital cartography to deliver products and services for specific needs and projects. I am confident that the potential to address today issues and tomorrow's challenges is only going to evolve for betterment. For that we need to ask right questions at right time and our services must ensure reinforcement of virtuous cycle for sustainable development conserving our natural resources and eco-systems.

Today addressing this energetic gathering in the beautiful premises of National Hydrographic Office, I would also like to mention few mile stones and achievements of hydrographers. The National Hydrographic Office under the aegis of Chief Hydrographer to the government of India, has evolved over times and has gained prominence in the Indian Ocean Region. The products and services of this office are being made available to all mariners for safe navigation at sea. The spin offs of hydrographic data, products and services have been fundamental for India's commerce and trade through maritime sector. I am happy to note that this office has taken lead and collaborating with various friendly foreign countries for capacity building in the field of hydrography.

I am sure that the Congress being organized by our Indian National Hydrographic Office on the subject 'DIGITAL CARTOGRAPHY TO HARNESS BLUE ECONOMY' will enhance our understanding about maritime dynamics.

And I am confident that this opportunity will be gainfully utilized by the participants to have invigorated intellectual proceedings and crystalise their thoughts and approaches for both implementable and tangible solutions towards sustainable socio-economic development and blue economy using the modern-day cartography. And some of you would be ETCHING THE HISTORY OF OUR BRIGHT FUTURE.

I extend my best wishes to the organisers and all participants of the Congress.

My best wishes on the auspicious formation day of Uttarakhand anniversary.

Jai Hind

Presidential Address

By
Vice Admiral Adhir Arora, AVSM, NM
Chief Hydrographer to Govt. of India

His Excellency Lt Gen Gurmit Singh, ParamVisisht Seva Medal, UttamYudh Seva Medal, Ati Visisht Seva Medal, Visisht Seva Medal, Honorable Governor of Uttarakhand, Dr. Prakash Chauhan, Director NRSC, Shri Sunil Kumar, Surveyor General of India, Rear Admiral Lochan Singh Pathania, Joint Chief Hydrographer, Shri Pankaj Kumar, Secretary General INCA, Admiral SK Jha, PVSM, AVSM, NM, former Chief Hydrographer, distinguished guests, dignitaries, friends from media, industry, academic and scientific institutions, researches, representatives of reputed organizations, children from schools, delegates, ladies and gentlemen. On behalf of Indian Naval Hydrographic Department and Indian National Cartographic Association, I extend a very warm welcome to each one of you to this beautiful and serene city of Dehradun on Uttarakhand formation day.

It is singular honour and gives me immense pleasure to be amongst you and address this august gathering on this momentous occasion of 42nd INCA Congress being organised at National Hydrographic Office, Dehradun.

This decade has been declared as the 'decade of the ocean' and what better than to chose a theme which is not only contemporary but also very relevant. This year's theme is "DIGITAL CARTOGRAPHY TO HARNESS BLUE ECONOMY".

Ladies and Gentlemen, India has a very rich maritime history, dating back few millennium when inhabitants of the Indus valley initiated maritime trading contact with Mesopotamia. On the other hand, the Kalinga's opened the sea routes for trade in South East Asia and the Chola's expedition through Malacca and Sunda are testimony to the maritime character of our nation extending to the present day 'Indo - Pacific'. But have we ever thought how these expeditions were even possible without the knowledge of hydrography or marine cartography?

Cartography in yesteryears meant to make a map, and is true even today, such maps are combination of science, art and mathematics. The cartographer would understand the scientific aspects and delimit a geographic area with boundaries and borders. Ladies and gentlemen, in new world order, the new age cartographer is crossing the boundaries of inter-disciplines of science, geography, commerce, economy, technology and governance. Contrary to age old adage 'a picture is worth a thousand words' the Cartographer in this new avatar are translating the scientific data from 'Map to App'. Each one of us is already shaping the digital world mapping, whether it is Apps with Maps or Maps in Apps we are providing near real-time information and that is what is this community's singular contribution world over.

Having shared a little insight on India's rich maritime heritage and cartography, please allow me to spare a few minutes on blue economy which is the key focus of this Congress.

According to the United Nations, the commercial value of various activities in the world's oceans is estimated to be between US$ 3 trillion to US$ 6 trillion or INR 20 lakhs crore to 40 lakhs crore. This is accrued from services and resources such as marine transport which carries 90% of global trade, global communications by submarine cables which carry 95% of all digital data, fisheries and aquaculture feed 4.3 billion people with more than 15% of annual consumption of animal protein, 30% of oil and gas accounts is produced from offshore, marine tourism accounts for 5% of the GDP, 13 of the world's top 20 megacities and over 40%, or 3.1 billion, of the world population lives within 100 km of the sea in about 150 coastal cities located along the coast and island nations. Thus, it is evident that Ocean is a common heritage of all humanity and provides livelihood to millions of people across the world. Having portrayed the potential of ocean resources, let me define Blue Economy.

"Blue economy" is an economic term linked to exploitation and conservation of the maritime environment and is sometimes used as asynonym for "sustainable ocean-based economy". UN first introduced "blue economy" at a conference in 2012 and underlined sustainable management, based on the argument that marine ecosystems are more productive when they are healthy. This is backed by scientific findings, showing that the earth's resources are limited and that greenhouse gases are indeed having an adverse effect on the Planet. In 2015, UN adopted 17 Sustainable Development Goals (SDGs) in which the 14th Goal laid emphasis to conserve and sustainably use the oceans, seas and marine resources. In order support efforts to reverse the cycle of decline in the ocean health, the UN has proclaimed the 2021-2030 as the "Decade of the Ocean for Sustainable Development". In 2015, Hon'ble Prime Minister of India, Shri Narendra Modi whilst speaking in Mauritius, mentioned Blue or Ocean Economy by comparing it with the blue chakra or wheel in India's national flag. The Government of India's Vision of New India by 2020 highlighted the Blue Economy as one of the ten core dimensions of growth.

Why is it important to think about it now? A healthy ocean is key for a sustainable future both for people and the

planet. As per United Nations Blue Economy Framework, "Mapping, assessment and valuation of marine and coastal ecosystem" is one of the primary requirement for sustainable Blue Economy. In this context the cartographers must innovatively exploit Geospatial data along with Information and Communications Technology (ICT) to invent tools that could be utilised across the spectrum to sustainably utilise the ocean resources. Thus, thetheme chosen for the 42nd INCA Congress "Digital Cartography for Harnessing Blue Economy" would bring into focus the role of cartographers in enhancing the economic prospectus of the nation in this ever expanding digital Geospatial world.

As you all aware, the Government has liberalized the mapping and data acquisition and is now in the process of publishing a comprehensive National Geospatial Policy. These major policy decisions are expected to boost the mapping sector that includes marine sector and encourage AtmaNirbhar Bharat in producing geospatial products, services and solutions. As per industry estimates, the contribution of geospatial sector to the Indian economy is around INR 20,000 crore including INR 7,000 crore in terms of export of geospatial services. The Nations Hydrographic department will continue to support these policies and engage with all stakeholders in use of the oceans and contribute to build the nations Blue Economy.

Ladies and gentlemen, this is the fifth time the National Hydrographic Office is hosting and organising INCA. This is the forum which brings the cartographers, academicians, industry, various stakeholders and users together for benefit of the society. I am confident with the arrangements in place, the deliberations and discussions during this congress by experts will give us more incisive insights and stimulate collaborative mechanisms in inter-disciplinary studies to crystalize innovative ideas forimplementation. The wide range of sub-themes and technical sessions have been grouped accordingly. I am hopeful that this Congress will provide unique methods in data visualization for time bound deliverables and wish the congress a great success as they discuss and deliberate on the theme "DIGITAL CARTOGRAPHY TO HARNESS BLUE ECONOMY".

On behalf of cartographic and hydrographic community of Indian Naval Hydrographic Department of the Indian Navy and Ministry of Defence, I Once again Welcome all the guests and dignitaries to this congress, and hope they will have a comfortable stay as well as very fruitful deliberations. I wish to convey my heartiest gratitude to our chief guest Lt Gen Gurmit Singh, PVSM, UYSM, AVSM, VSM, Honourable Governor of Uttarakhand for having spared valuable time to be here today with us.

Jai Hind !

Todarmal Endowment Lecture

By
Vice Admiral SK Jha PVSM, AVSM, NM (Retd.)

Digital Cartography to Harness Blue Economy

Introduction

Oceans have around 95% of earth's biosphere and covers around 70% of the planet earth. We know that water is the source of life. It is likely that the First cell arose in mud fed by volcanically heated steam. Another theory advocates that the life began in sea vents, where warm alkaline water seeps up from geological formations underwater. Interaction between warm water, and rock would have provided chemical energy that could have first driven the simple metabolic cycles, which could have started the process of making and using chemicals such as RNA, somewhere around 4 billion years ago. However, one aspect is very clear that without water the process of evolution of human race could not have been possible. Without water in some form or the other, support for life cannot be thought of. In fact, in modern times without the fresh water and the Seas and Oceans this planet earth will not be able to sustain. In other words, life originated at sea, and it is sustained from the sea through food security, commerce and with a balanced ecosystem which is essential for survival of human species. Oceans are today the main drivers of the global economy however; Oceans are also under tremendous pressure. Similar situation exists for mother Earth and the Global Environment. On one end of scale we have developed nations who consume the rich natural resources of under developed nations, but the citizens of such natural resources rich nations now face the hunger, imbalance of the environment and the very survival.

To address this imbalance and to improve the quality of life as a whole United Nations Organization (UNO) Commissioned a study, to reflect on the future Business Model which was to be presented in Conference of Parties (COP 3) in Kyoto, Japan. Prof Gunter Pauli, a Socio –Economic entrepreneur from Belgium proposed a zero emission, zero waste concept in 1994. At that point of time, the magnitude of environmental degradation and consequent climate change and its effect on the mankind was perhaps not that alarming and hence the proposal was not accepted. However, 15 years later in 2010 in Rome the concept was not only accepted but it was considered that the sky is blue, oceans are blue and the exterior of the universe is blue, therefore the sustainable economy model was unanimously named as BLUE ECONOMY. The definition of blue economy as articulated by the World Bank is "Sustainable use of ocean resources for economic growth, improved livelihood and job creation, while preserving the health of the ocean." The European Commission defines it as:-"All Economic activities related to Ocean, Sea and Coast". The Conservation International definition is, "Blue Economy refers to the range of economic uses of the ocean and coastal resources such as energy, shipping, fisheries, aquaculture, mining, and tourism. It also includes economic benefits that may not be marketed, such as carbon storage, coastal protection, cultural values and biodiversity." The following statistics indicate our dependence on the oceans:-

70%	Area of the Earth is Covered with Water
80%	People Live within 200 miles of the Coast
90%	Trade is through Sea Route
50%	Oxygen is generated at Sea
30%	Green House Gas & CO2 is absorbed by Sea
80%	Pollutant generated on Land flows to sea
30 m Tons	Plastic generated Yearly on land flows to sea

Dependence on sea resources have their down size also. It is estimated that about 200 million tons of plastic is littering our Oceans. There are five identified Gyres, the floating pile of Garbage, one each in East Pacific, West Pacific, North Atlantic, South Atlantic and the Indian Ocean. The largest amongst them known as the Great Pacific Garbage Patch contains about 2 million plastic pieces per square mile. These are neither biodegradable nor Photodegradable but breaks into smaller pieces in Sunlight, known as micro plastics, which is consumed by the sea animals. These fishes and sea animals starve to death with belly choked with plastic. Those which survive long enough form a part of human food chain which adversely impacted the health of the society.

The value of ocean assets has been estimated to be at least US dollar 24 trillion, with the annual value of goods and services of US dollar 2.5 trillion. The estimated commercial value of various activities in the Ocean world over is between US dollar 3 trillion to US dollar 6 trillion. We depend on the ocean for living and non-living resources, for earning a livelihood from minerals, fossil fuels like oil and gas, various rare earth metals and renewable energy. It may be concluded that the human race cannot sustain without the sea resources and therefore, it needs to be managed and conserved. The idea of the Blue Economy has evolved out of these necessities. The concept of Blue Economy is still under development and requires a long-term strategy. The concept is based on the

thought process of social-economic development, with due regards to environmental degradation, Fisheries, deep-sea mining, oil & gas, ports & shipping, marine tourism, marine biotechnology, trade, logistics and marine transportation etc. These are also considered as various sectors of the blue economy. The blue economy is similar to the kind of economic processes and activities principally understood as the 'marine economy', 'ocean economy' and the 'coastal economy' with the emphasis on optimum use of marine resources. The sustainability aspect means sustainability of resources from oceans, thereby providing food for both animal and in turn human being. By definition the blue economy in itself is not a development model, rather it serves as an important component, of any other existing development model and encompasses productive employment of almost every aspect of human sustainability.

Initiative by the United Nations Organization and SDG

World leaders have been discussing various aspects of Blue Economy for many years. Based on these discussions, united Nations Organization took the initiative and commissioned numerous studies which led to the formulation of Sustainable Development Goals(SDG) 2030 and aims at:-

(i) Sustainable exploitation of natural resources.
(ii) Reduce the adverse effects on the environment.
(iii) A relook in the conduct of business.
(iv) Wealth Creation in Blue Economy, through a strategy with nature-inspired derivatives based on sustainable use of the nature.

SDG 2030 has 17 goals for the world community and goal 14 relates to the sustainable development of ocean resources. As many as 193 countries of the world unanimously adopted this agenda. The goal has 7 targets and 3 sub-targets. Aspects of limiting marine pollution, protecting biodiversity, marine habitat and ecosystem, minimizing and addressing the ocean acidification, regulating fishing and ocean health etc., are covered under these targets.

These goals are also linked to other 16 sustainable goals of poverty reduction, providing food security, providing water and sanitation, clean energy, sustainable economic growth, sustainable infrastructure, reduction of inequality, efficient cities and human settlements, sustainable consumption and production, handling climate change, upkeep of biodiversity and means of implementation through partnerships. These are tracked using 10 indicators which were developed by an expert group on SDGs.

It is well known that most of the new jobs are generated only in 10 countries around the world, and 40% of the population earns less than $3 per day. The time has come to shift towards a competitive business model that responds to the basic needs of all while meeting the local requirement. The world is looking at a model, that allows producers to offer the best at the lowest prices, by introducing innovations that generate multiple benefits, not just increased profits. This economic philosophy first introduced in 1994 by Prof. Gunter Pauli has now been substantiated, by over 180 concrete cases. it is now clear that it is possible to generate more revenue while generating more jobs and still compete on the global market. His ideas for sustainability could be summed up briefly as four recommended steps: -

(i) Multiple Business Approach: The key to this approach is to evolve from a business based on competition to businesses that generate multiple benefits for society and lets nature take its evolutionary and symbiotic path. The business model needs to evolve towards the full use of all its available resources, clusters activities and efficiency. For example, a coffee company can generate income from the coffee, its core business, and it can also generate revenue from the mushrooms farmed on the waste, and thereafter whatever is left after harvesting the protein-rich fungi can be an excellent animal feed. Thus, one revenue model could be transformed into a three revenue model.

(ii) Focus on Local Economy: Present business models focus on cutting costs and therefore pursue a global strategy for the cheapest and most flexible place of manufacturing or service delivery. However, this leads to an increased deprivation of cash in local economies, which have less employment but also less purchasing power, thus leading to less money circulating in the communities and resulting in an economic contraction. The power of the Blue Economy is that it injects money back into the local economy, and contrary to traditional belief, it offers high-quality products at a lower cost price. Coming back to the earlier example, the healthy mushrooms beyond the reach of the majority of the consumers could be made available fresh and abundantly, requiring much less transportation. Cost of transportation in India today is around 17%, So without this requirement the costs are reduced, margins are improved and prices to the consumer are lowered. In a recent case, a group of entrepreneurs got together and undertook a feasibility study to produce ethanol from corn which could be blended with Petrol in accordance with the government policy. They surveyed the area and finally set up a plant on the Bihar Bengal boarder which is a corn producing belt. Locally grown corn is used as the main feed for the plant. The product, Ethanol is supplied to the local unit of the Indian Oil Corporation and residue makes an excellent animal feed which is in demand by the local farmers. The entire cycle of using the local resources, consuming the produce locally and the residue being consumed mainly by the supplier of the raw material is a perfect successful example of harnessing the concept of circular economy.

(iii)Innovative Replacements: The Blue Economy applies to all sectors by the reinjection of cash into the local economy and the use of locally available resources. It also eliminates whatever is not needed. For example, A battery is not replaced by a green battery, it is simply substituted by an energy system for mobile electronic devices and power storage that does not rely on metal-based (and mining-driven) batteries. This gives savings in material and cost while reducing the ecological footprint on the environment and the health risks to the employees and users.

(iv) Future of Blue Economy: The Blue Economy is not tailored for large corporations with an established business model which will be difficult to change. The Blue Economy rather inspires, the young and the entrepreneurs, a broad platform of innovative ideas, that have been implemented, provided we go beyond the known and the obvious.

Government of India Approach

10th February 2019, the Government of India's Vision of India—2030 was announced, highlighting the Blue Economy as one of the ten core dimensions of growth. The Blue Economy was mentioned as the sixth dimension of this vision, which relates to the policies for integrating various sectors to improve the lives of the Coastal community and accelerate development and employment. In the words of the Prime Minister Modi "Blue Economy must act as a catalyst in improving India's Progress". Accordingly, a frame work for the blue economy is prepared by the Economic Advisory Council to the PM which has identified 7 subgroups: -

(i) National accounting framework for the Blue Economy and Ocean Governance.
(ii) Coastal Spatial Planning and Tourism.
(iii) Marine Fisheries, Aquaculture, and Fish Processing
(iv) Manufacturing, Emerging Industries, trade, technology, services and skill development.
(v) Logistics, Infrastructure and Shipping including trans-shipment
(vi) Coastal and Deep sea Mining and Off shore Energy
(vii) Security, Strategic Dimensions and internal engagements.

The draft aims to enhance the contribution of the Blue Economy to India's GDP, and also improve lives of Coastal Communities, while Preserving marine biodiversity and maintain the national security.

Some of the Important Aspects of Blue Economy

Fisheries and Food Security: It is estimated that world population will be around 9 billion by 2050 which will put tremendous load on Earth for feeding such a large population. Resources on the Earth may not be sufficient and therefore only available alternate solution would be to harness sea resources much more than what is being done today. The value of resources in Coastal and Deep sea is about US $ 25 Trillion. It has been estimated that approximately 61.3% of world fisheries are fully exploited and 28.8% are overexploited. Fishing contributes to nearly 20% of animal protein consumed in the world. Therefore, there is a need to review the policies towards keeping the Fisheries and aquaculture sector sustainable. Sea being the Common Heritage of the mankind and fish being the migratory specie, the problem can be addressed only through global efforts and sustainable Economic model.

Seabed resources in the Indian Ocean: There is abundance of natural resources in the sea. Rare Earth minerals which has been over exploited on land are available at sea and technology is being developed to extract these rare minerals from deeper depths. There is practically a race towards identifying and claiming the resources .Ministry of Natural Resources has been tasked to formulate 5 years development plan in this regard.

Multi-Lateral Constructs: The concept is to provide platform, for sharing experience and expertise and join in cooperative mechanism for capacity building.PM Modi's concept of SAGAR (Security and Growth for All in the Region) is aimed at a model of Blue Economy as a sustainable and equitable inclusive development. The Indian Ocean Regional Association presently has a comprehensive arrangement of the entire region in one forum with 21 member states. There are many other bilateral and multilateral agreements amongst the Indian Ocean Littoral Countries. However, these mechanisms appear to have limited focus, especially from stakeholder's point view. These are being monitored and addressed at a very high level.

Capability and Capacity Development Imperatives for India: Indian journey in the marine sphere started with the establishment of the Department of Ocean Development in 1981. The Ministry of Earth Sciences (MoES) is presently the lead agency for the development of Ocean-based economy in India. MoES has joined the United Nations "Clean Seas Programme" to develop strategies for pollution control, which is also a part of SDG14. In addition, India has various scientific missions such as "Deep Ocean Mission," "Oceanography From Space" and "Launching of the Data Buoys" along the Indian Coastline. NITI Ayog, in consultation with the Ministry of Environment and Forest and Climate Change has identified 11 areas to give an impetus to India's Aatma Nirbhar Bharat Abhiyaan. In March 2021, 11 Committees were constituted on Circular Economy headed by Secretaries/ Additional Secretaries of the respective Ministries/ Departments to develop the action plan.

Data Collection and Dissemination: It is well appreciated that without the collection of data and presentation in a user friendly manner, the aspect of inclusive growth while managing and conserving the resources, cannot be achieved. That is where role of Surveyors, Geologists and Cartographers come into Picture. In this regard United Nations Educational, Scientific and Cultural Organization (UNESCO) has taken a lead and defined marine spatial planning as "a public process of analyzing, and allocating, the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic, and social activities which has usually been specified through a political process". Characteristics of Marine Spatial Planning (MSP) is integrated, adaptive, strategic and participatory which is ecosystem and area-based. It is a process of Surveying coastal and maritime zones for different users of maritime spaces, having information relating to various aspects of the zones. MSP being intangible would need to be supported by a robust Marine Spatial Data Infrastructure (MSDI) which is a collection of technologies, policies and institutional arrangements to facilitate the availability and access to spatial data. MSDI not only includes a plan for sustainable exploitation of fishing, but also the Indian adventure to tap into ocean energy. This is tied with marine infrastructure and transport development and tourism potential while keeping in mind the environmental concerns. The Sagarmala project for a port led development initiative in India is yet another policy approved by the government in 2015.

As far as Hydrography is concerned, new induction of platform, improved coverage of data gathering and availability of data in a user friendly manner, which is a continuous process is already being done. Progress from S-57 data format to S-100, the Universal Hydrographic Data Model, is a challenge on which the department is progressing well. The contribution of the department in maritime affairs and foreign cooperation initiatives has

been acknowledged at every level.

Conclusion

A close watch of the nature reveals that it is self-sustaining. The imbalance experienced is mainly because of induced factors with total disregard to the sustainability aspects. The blue economy approach not only focusses on the locally produced and consumed products but a concept of circular economy where the profits are ploughed back to the local economy aimed at enhancing the standard of living and quality life of the local people. In India, blue economy is a subset of the marine economy comprising of entire ocean resources, marine infrastructure, promulgation of maritime zones and its legal jurisdiction. India's blue economy concept is based on objectives of promotion of smart, sustainable and inclusive growth in the Indian Ocean Region which requires regional cooperation in the field of harnessing ocean resources, research and development, sharing various data and respond to each other's requirements in the unforeseen eventuality. The concept is being promoted as part of government's Sagarmala project for the benefit of the coastal community. However, the policy frame work needs to be more inclusive with the participation of national stakeholders and the countries in the Indian Ocean Region.

SP Chatterjee Memorial Lecture

By
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Geospatial Technology for Blue Economy Development in India

Hon'ble dignitaries on the dais, dear delegates to 42nd Indian National Cartographic Association (INCA) conference, ladies and gentlemen, It is indeed an honour and privilege for me to be invited to deliver SP Chatterjee Memorial endowment lecture here at this wonderful city of Dehradun. On this occasion it is pertinent to remember Padmabhushan Prof. SP Chatterjee, a geographer par excellence, who made significant contributions to cartographic world of India. My special reverence to him derives from the fact that he cultivated a special branch of Cartography that can best be conceptualized as Geographical Cartography. This endowment lecture has been running for well over a decade; and the highlights on the life and work of Prof SP Chatterjee are well known to the senior members and delegates here. However, for the benefit of new guests and younger delegates, I believe, will find it inspiring to know about him and his contributions.

Prof. SP Chatterjee was an epitome of Geography and Cartography blended in one, he had a larger vision of Geographers'role in nation building. His important contributions –Bengal in Maps'(1949) – is very simple cartographically and superb in terms of Geographic Analysis and interpretation. National Atlas of India', and Damodar Valley Planning Atlas' are also few such examples of his wonderful contributions. After earning doctoral degrees in Geoggraphy from Paris University english spelling and in Education from London University, he joined Calcutta University, instituted Calcutta Geog. Soc. and founded the Department of Geography around the turn of 1940's and fostered it all through his life. His career is mainly spread over 1940's through 70's, which, incidentally, coincides well with growth span of Academic/Geographic Cartography. 1950's-60's comprise the zenith of his glorious career, when besides raising the National Atlas he made India's presence eminently felt at the International Geographical Union congress. Elected the IGU Vice President in 1960 and President 1964, he urged the Govt. of India to host next IGC; and for the first time the IGC was held in Asia - at New Delhi in 1968 under his stewardship. These highlights of SPC Phenomenon signify that by the very comprehensive and correlative nature of his subject, a sound, genius geographer can make landmark contribution to Cartography and apply the two disciplines towards problem solving and national planning. He is also credited to give name to Meghalaya state of modern India. Rather late – in 1985 – SPC was felicitated with Padmabhushan.

Geospatial Technology for Blue Economy Development in India

Ladies and Gentlemen, I am aware that most of you here will perhaps share the opinion that India has made significant strides in the broad field Geospatial Science and Technology, which is amalgamation of Remote Sensing, GNSS and GIS technologies. In last five decades India has developed a very comprehensive Earth Observation Satellite System providing remote sensing data in optical and microwave range of electromagnetic spectrum. Today we are operating a series EO satellites for very high spatial resolution (~50 cm) to moderate spatial resolution satellite systems like CARTOSAT-2 & 3 and Resouresat-2/2A and recently launched RISAT-1A C Band Synthetic Aperture Radar (SAR) system. Geographical Information Systems which enable a very refined and precise form of mapping, today is being used for digitally mapping of routes, highways, locations i.e. railway stations, post offices, hospitals, schools, agricultural areas, religious locations and other administrative layers. ISRO's BHUVAN portal and other Geospatial web portals of various government institutions are today providing spatial information in digital form to many stake holders and citizens. GIS offers a lot more in terms of details and is updated easily within least time thereby being cost effective. Global Navigational Satellite Systems such as GPS and India's our own NaVIC constellation of satellites are being most effectively being used for location-based services and making precise maps.

The Earth is simply an Ocean planet as oceans covers ~70% its total area. Oceans provide energy, food and mineral resources, facilitate trade and commerce, control weather, climate as well as present an ecosystem to survive. Our economic dependence on ocean has been increasing and will continue to increase in future. India has a very long coastline, and it measures about **7,516.6 km** bordering the mainland and the islands with the Bay of Bengal in the East, the Indian Ocean on the South and the Arabian Sea on the West. As our population is expected to rise steadily and with finite resources on land it expected that we shift our focus to oceans and harvesting coastal resources.

Prof. Guntar Pauli was first to introduce the term 'Blue Economy' to reflect the needs of people for growth and prosperity in view of impacts of climate change. The term 'Blue Economy' has been defined as an ocean-dependent economic development for improving quality of life of people while ensuring inclusive social development as well as environmental and ecological security. It means that there should be certain limitations on the technology-based economic development and emphasis should be on social obligations to protect and conserve coastal and marine environment. The focus is shifting on expanding the “Green Economy” to “Blue Economy” and

subsequently UN has also advocated conservation and sustainable use of ocean resources as one of goals under Sustainable Development Goals (SDGs). UN has also declared 2021-2030 as the "Decade of Ocean Science for Sustainable Development." Hence, it is very apt to discuss about the role of geospatial technology and digital cartography in development of blue economy. The blue economy of India is a subdivision of the national economy that includes the complete ocean resources system as well as human-made economic infrastructure in the country's legal jurisdiction marine, maritime, and onshore coastal zones. India's Blue Economy concept is multi-faceted and plays an important role in the country's economic growth because of its enormous maritime interests. India's blue economy accounts for roughly 4% of the GDP and is estimated to increase once the mechanism is improved. The sector has stood strong despite the challenges caused by the Covid-19 pandemic and have recorded exports worth Rs. 56,200 Cr (US$ 7.2 billion) between April 2021-February 2022.

Six major components of the Blue economy involves i) Sustainable use of living resources, ii) Exploration and utilization of minerals, hydrocarbons and develop renewable energy resources, iii) Development of deep ocean technologies for harnessing resources, iv) Development of shipping and ports to facilitate trade, v) To encourage eco-friendly tourism along the coast and vi) Assessment of hazards and response mechanism (cyclone, tsunami, sea level rise, coastal erosion, etc.). Geospatial technologies such as remote sensing from space and from *in-situ* platform plays key role in surveying of sea bed, exploration of mineral and energy resources, marine eco-system services, fisheries, marine pollution and coastal zone management including marine spatial planning.

Ocean resources, physical infrastructure for maritime economic development, marine amenities, and coastal management services are all part of the plan to ensure economic growth and sustainability, as well as national security. Fisheries and minerals are the two most viable components of the blue economy in India. The coastal economy sustains over 4 million fishermen and coastal towns. India is the second largest fish producing nation in the world and has a fleet of 2,50,000 fishing boats.

Oceanic conditions, Sea Surface Temperature (SST), phytoplankton concentration, salinity, ocean currents, wind speed, and oceanographic features, such as thermal/colour divergent fronts, eddies, rings, meanders and upwelling regions affect fish spawning, and distribution and abundance of fish population. Today Geospatial technology in terms of providing potential fishing zone (PFZ) information to using satellite-based Ocean chlorophyll data and SST along with winds are being provided all along the maritime states of India by Ministry of Earth Sciences. The technique was initially developed at ISRO and now INCOIS, Hyderabad provides daily advisories, not only for India, but many developing countries. PFZ advisories are issued except for fishing-ban period. The information contains details about latitude and longitude, depth of ocean, direction and distance from landing centre/fishing harbour, both in text and map form in relevant vernacular languages. More than 9 lakhs fishermen are dependent on this service. The information is communicated to all stakeholders through various print and electronic medium. ISRO is going to launch the next generation ocean satellite OCEANSAT-3 in this month which will carry an Ocean Colour Monitor, SST mapper and wind measurement Scatterometer sensors. The data from this satellite will help in developing deep sea fisheries grounds and will provide information about marine eco system by giving information on algal blooms, suspended sediments distribution and penetration of light in ocean column for primary productivity assessment.

Monitoring of Sea State is vital for navigation and shipping, and use of IR and microwave sensors to derive information on waves, surface wind, surface currents, etc. is very much needed. India has launched altimeters (SARAL-ALTIKA), microwave radiometers and scatterometers to provide information on Sea Surface Height (SSH) and Sea Surface Wind (SSW) for various oceanographic applications. SST observations are critical for short-range prediction and as initial condition for coupled ocean–atmosphere models for sub-seasonal and seasonal range prediction. The upcoming OCEANSAT-3 will provide SST and Wind information which after assimilation to in numerical models has positive impact on prediction of atmosphere and ocean. Today use of Geospatial technology along with advance ocean models not only provides short-term accurate, reliable and timely sea state forecasts, but also identifies dangerous sea conditions for coastal populations and seafarers. It also provides ocean data to users through web interfaces to search, visualise and fetch data generated from different observational programs, both in situ and remote sensing, in the Indian Ocean. Digital Ocean is being developed to integrate all data from a variety of instruments and sensors on a single platform and visualisation facility for quick analysis. The number of registered users is more than 9 lakhs for PFZ, sea state forecast and other services, and has brought immense benefits to the country.

Coastal Zone Management is vital for sustainable use of coastal resources. The coastal zone of India is marked by a variety of landforms and ecosystems. A comprehensive, up-to-date and timely information on various components of coastal zone is required for effective coastal zone management. The use of the satellite images for coastal zone started with identification of various geomorphic features such as mudflats, mangroves, beach, coastal dunes, etc., as well as understanding of movement of suspended sediments, tidal currents and fronts. India with its very long coast line, areal extent, resources and population would have been a huge challenge to the coastal researchers and administrators if not for the Indian Remote Sensing satellite data that provided the much-needed temporal, thematic information for effective mapping, monitoring and management of the coastal areas. The country's large and diverse coastal regions are economically important and ecologically rich but also extremely vulnerable and highly prone to natural and anthropogenic hazards. Through the last three decades, the Indian remote sensing programme has contributed immensely to our understanding of the coast and ocean processes, coastal ecosystems, habitats, marine pollution and the vulnerability of the coast to natural hazards. IRS-1C with its improved spatial resolutions, additional spectral band, improved repetitively ushered in a new era of research specifically in the management of coastal areas and resources. Integrated utilization of remote sensing

data, numerical models, GIS and GPS has paved the way for the development of operation systems for management of coastal areas by providing information on Coastal Erosion and Shoreline Changes across India, Marine Pollution, Critical Habitat Mapping such as coral reefs, sea grass and mangroves for sustainable Management, CRZ mapping, Near Shore bathymetry, Oil spill monitoring, Coastal Resources mapping and assessment of Coastal Vulnerability to Hazards. NRSC has developed Island Information system using 34 attributes for more than 1300 islands in Indian territory. Holistic Development of identified islands taken by Niti Aayog has resulted in Master plans for sustainable development of few islands in Andaman & Nicobar and Lakashdweep Islands. and also have carried out very high-resolution topography mapping for entire Indian coast using ALTM data for coastal inundation modelling.

Ocean For renewable energy are emerging as future thrust areas. With the increasing digitalisation of the modern world and the decarbonisation targets that most countries are adopting to challenge climate change, the attention of populations and politicians is shifting rapidly towards renewable energies. While presenting a huge potential, ocean energy technology overall is still at an early stage of development. This is why it represents only a small share of renewable energies, with an estimated total installed capacity of 535 MW worldwide. This figure is negligible compared to the total renewable capacity installed. Tidal barrage and tidal stream, wave energy, salinity and temperature gradient are the main forms of ocean energy. Most technologies are still in the prototype phase, so there is still a lot of innovation and research undergoing. NITI Aayog in collaboration with Indian Space Research Organisation (ISRO) has developed a comprehensive Geographic Information System (GIS) Energy Map of India with the support of Energy Ministries of Government of India including, wave and wind energy potential along Indian coast. Ministry of Earth Sciences through National Institute of Ocean Technology (NIOT), is pursuing activities towards delineation and resource estimation at prospective targets. While the ocean provides a huge potential for energy generation, there are important barriers that must be overcome to realise this in a sustainable and timely manner. Two key challenges facing the sector are lifecycle cost of the energy produced, referred to as Levelized Cost of Energy (LCOE), and impact on marine ecosystems. There are a number of ways in which space technology can help the sector tackle both of the challenges.

Planning for success

Activities around coastal areas and within world's sea spaces are rising rapidly and these regions are also becoming increasingly congested. Modern, forward-looking marine spatial planning needs to factor in shipping lanes, fisheries, aquaculture, Marine Protected Areas, coastal tourism, the protection of marine cultural heritage and the roll-out of fibre optic cables to feed a data-hungry world. Many factors will affect these sectors' ability to plan ahead, but there's no doubt that what they all need in order to establish planning certainty is an accurate, up-to-date map of the seabed, obtained using modern survey methods. Marine geospatial data is the cornerstone of the Blue Economy. We need to develop ability to quickly update and understand the sea bed changes in coastal regions to sustainably manage natural marine resources with modern high-resolution mapping technology.

To conclude, I would emphasise that the Blue Economy in India is poised for significant growth in the next few years. Blue Economy Mission undertaken by the government will lead to the sector becoming the next economic multiplier, depending on the execution of the policies that have been decided. For e.g., the policies mentioned in the draft policy. The sector is the sixth dimension of the government's 'Vision of New India by 2030'; with the Blue Economy policies aiming for long-term economic advantages in order to achieve the greater goals of growth, job creation, equity, and environmental protection and for sure digital mapping techniques such as remote sensing and concept of 4D Marine GIS will pave this way in upcoming future. I would like to end with quoting "***We cannot have a healthy Planet without having a healthy Ocean***" so we must use oceans in a sustainable manner.

Thank you very much for your kind attention.

42ND INCA INTERNATIONAL CONGRESS

DIGITAL CARTOGRAPHY TO HARNESS BLUE ECONOMY

TECHNICAL PAPERS

Application of Artificial intelligence tools for Urban Planning and Resource Management

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Abstract

Artificial Intelligence (A.I.) has full potential to prove itself as panacea for complex and dynamic problem of Urban Planning and the best Resource Management. Main thrust of this study would be to examine latest growth in the domain of A.I. and its applicability in the Urban Planning. In the last and current decade, potential of A.I. had been recognised, and its various facets like Cellular Automata, IoT, Neural Network, Fuzzy Logic etc had been applied to address the contemporary issues. Urban Planning had been the prominent features of Civilizational Growth ranging from Neolithic civilisations/Ancient civilisation to till date. Every era had used its best techniques to better their urban planning. Twenty first century being the age of A.I. and Data centric age, the usage of A.I. in urban planning will be the next quantum jump in our civilisation. In this context, A.I., improvement in Urban Systems, township management, municipal upgradation must be closely linked with each other. Data collection in uniform pattern, in respect of urban planning around the world would key here. Community involvement is also necessary so that residents can trust the system and volunteer to adopt the A.I. enabled systems. A.I. feed on data and give the best solution available in domain. Efficacy of A.I. will depend on data size and accuracy. To make A.I. effective in urban planning the time has come that experts from every domain like Cartography, Geography, Geology Survey, GIS etc shall come on common platform.

Keywords: Artificial Intelligence, Civilization, Urban Planning, Township Management, GIS, Resource.

Introduction

Artificial Intelligence (AI) is a way of making a computer, a computer-controlled robot, or software performing human like tasks. The term was coined in 1956 by John McCarthy. It refers to the ability of machines to perform cognitive tasks like thinking, perceiving, learning, problem solving and decision making.

There are two subsets under the umbrella terms AI, i.e.,

(a) Machine learning

(b) Deep Learning

Machine Learning involves the use of algorithms to parse data and learn from it. This enables making a predication. Deep learning is a technique for implementing Machine Learning. It can be used for optimising infrastructure in cities, service delivery, crowd management, cyber security, public safety, resource management and waste management (Fig.1).

Materials and Methods

This research article explores the role of artificial intelligence in urban areas, and its impact on socio-economic and territorial cohesion. Available data regarding latest application of Artificial Intelligence in the field of Urban Planning in cities like Trelleborg (Sweden), Amsterdam (The Netherlands), Pilsen (Czech Republic), Santander(Spain), Rennes (France) has been analysed. It argues especially in context of smart city initiatives, but that actual benefits are yet to be fully assessed. To avoid potential risks, local andurban authorities need to fulfil a series of conditions that are inherently challenging. Abovementioned cities have used the AI in the various sectors and mixed response had been received. Their data can be used for improving the features and component of AI application in Urban Planning and Resource management in Indian Smart Cities. The details of the finding are tabulated in table 1.

According to a report published by the *Brookings Institution, Washington, DC*, India is among the top ten countries in the term of technological breakthrough and funding in A.I.

Artificial Intelligence in Urban Planning and Resource Management

The OECD defines smart cities as *"initiatives or approaches that effectively leverages digitalisation to boost citizen well-being and deliver more efficient, sustainable and inclusive urban services and environment as part of a collaborative multi-stakeholder process"* (OECD, 2019a). Smart cities are therefore at the interface between social and technological dimensions. Smart Cities

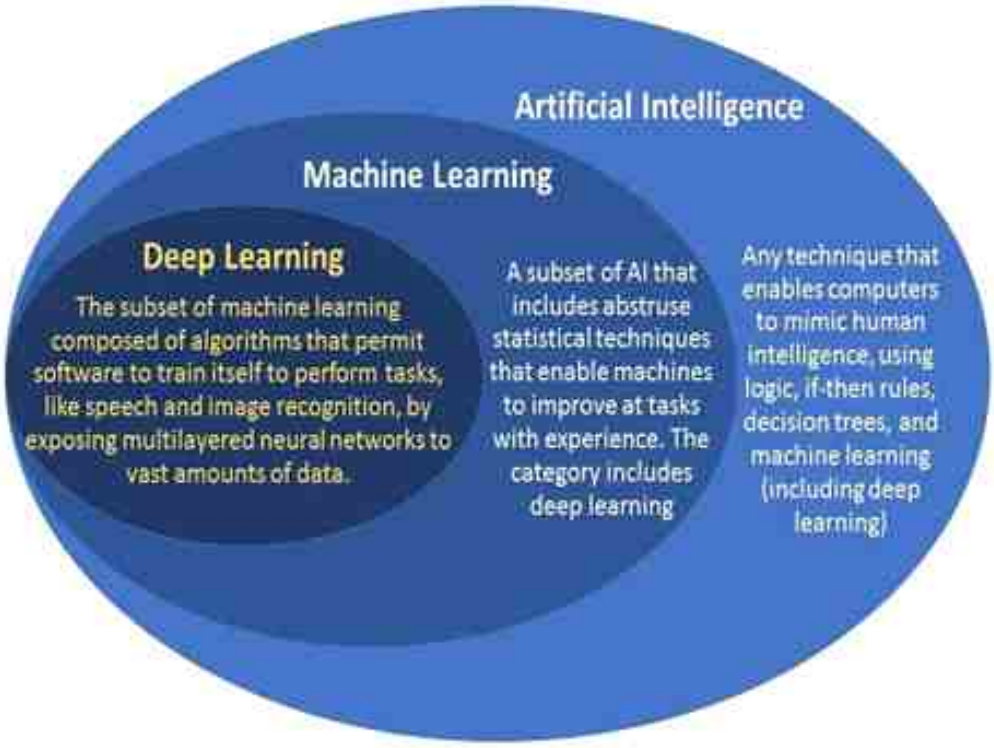


Fig.1:Subsets of Artificial Intelligence

Source: - IBM

is the perfect subject for the digitalisation by the tools of Artificial Intelligence, Local Data Platform, Machine Learnings, IoTs, Cloud Computing, 5G technologies etc. The combination of sensors, hardware, data storage, microprocessors, and software transform urban objects and infrastructure into smart devices that are always connected and embedded in Big Smart Network of City. AI powered systems have the capacity to help us to design effective processes, which can help to conserve power and increase productivity at low cost.

Table-1: Latest Use of AI in Urban Planning

Ser.	Name of City	Artificial Intelligence used	Key Features
1.	Trelleborg (Sweden)	Automated Public Services in welfare, social protection and transportation	Usage of predictive analytics, chatbots, automated decision making etc
2.	Amsterdam (The Netherland)	Amsterdam Smart City (created in 2010)	Traffic and Public Transport, parking occupancy, Energy transition and Environment etc
3.	Pilsen (Czech Republic)	Digital Twin of Amsterdam	Model-model interaction to improve traffic, pollution, energy consumption.
4.	Santander (Spain)	SynchroniCity Project	Infrastructure of Sensors (IoT) for smart devices
5.	Rennes (France)	3D Digital Modelling of Experience-City	Participation of common man in re-modelling of the city

Source: - Authors, based on European Commission 2020

This helps to create better model of towns by taking comprehensive contributions from the available data which can be used to develop sustainable and economic framework for urbanisation in order to comply with the Agenda 2030 where no one is left behind

AI applications in smart cities can be categorised in the following seven dimensions.

(I) AI for governance e.g.: urban planning, disaster prevention and management.

(ii) AI for living and liveability e.g.: smart policing, personalised healthcare, noise and nuisance management.

(iii) AI for education and citizen participation e.g.: locally accurate and actionable knowledge supporting decision-making.

(iv) AI for economy e.g.: resource efficiency and improved competitiveness through sharing services.

(v) AI for mobility and logistics e.g.: autonomous sustainable mobility, supply chain resiliency and traffic management.

(vi) AI for infrastructure e.g.: optimised infrastructure deployment, use and including waste and water management, and urban lighting.

(vii) AI for the environment e.g.: biodiversity preservation, urban farming and air quality management.

AI for future proof infrastructure:

To cope up with demands of energy requirement, limited space availability, scarce labour capacity and limited financial and material resources. AI for spatial object recognition based on satellite imagery with machine learning for route optimisation. AI application can help in understanding energy requirement and help in construction of Grid System. I enabled smart grid can predict the provision for Renewable energy.

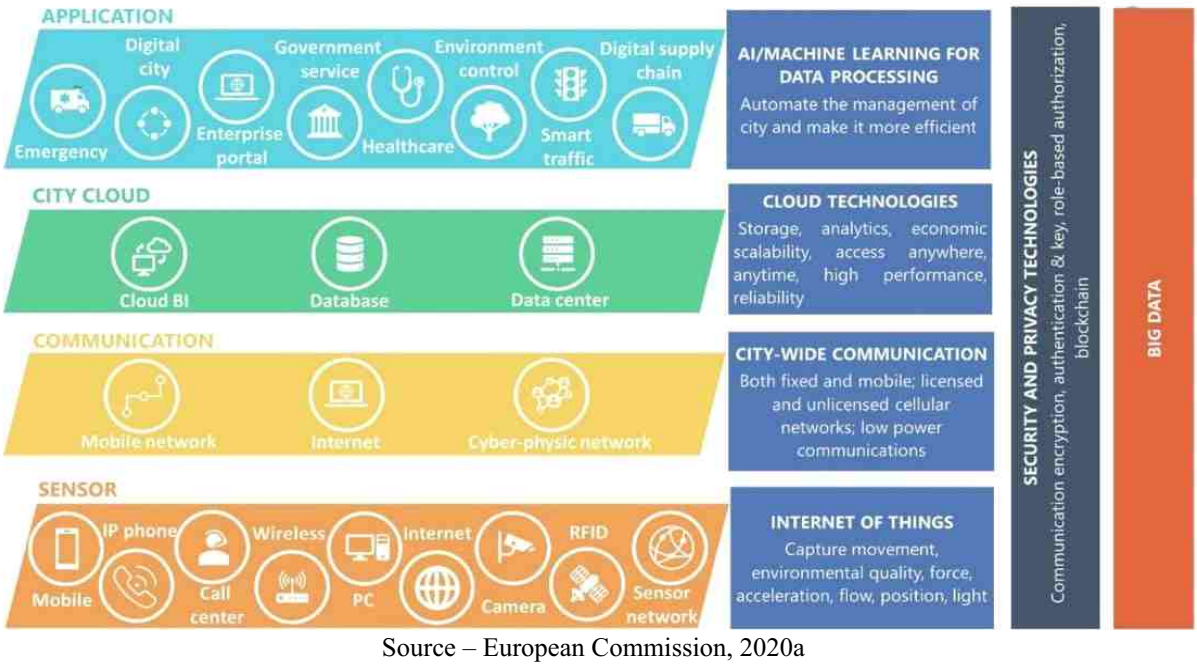
AI for innovation and Smart Services:

Smart services which can be improved by AI, namely smart urban lighting and smart waste management. Smart urban lighting has often deemed the solution to start the smart city evolution of a city.

Improved and efficient public lighting via remote monitoring and control, lampposts are an idea object to equip with IoT devices which can collect, communicate and locally analyse data on traffic and pedestrian flows, environmental factors such as air quality, temperature, winds speed and humidity, and acoustic data for instance for gunshot detection, urban noise etc. AI can also be applied to predict the patterns of how, when, and where waste is discarded, opening up possibilities for urban policy to stimulate efficient Waste Management and Resource Recycle.

Ultimate form of AI taking the shape of the City's Brain as a central point of control. City brain AI makes the progress with specialised AI, e.g., for energy infrastructure maintenance, towards general AI applicable in multiple domains such as urban planning, health, safety& security and governance in an integrated and autonomous city.

Fig.2: Relation between Artificial Intelligence and Contemporary Technologies



Source – European Commission, 2020a

AI for efficient Urban Mobility: AI is a powerful emerging tool that boasts the potential to drive a sustainable transition to a more resource-efficient, liveable and human-centric mobility system, especially in urban contexts. The next-generation mobility is expected to transform Original Equipment Manufacturer (OEM) mobility services companies. Such transition requires stakeholders to collaborate and engage with financial services, insurance companies, telecommunication and utility companies to achieve the common goal of a new sustainable mobility.

AI for resilient and empowered communities:
This section entails AI applications to enable and support resilient and empowered citizens in the city. AI empowers citizens and amplify the local enthusiasm and resources towards local, sustainable and reliable energy systems. In addition to a reliable and sustainable energy supply, a resilient society benefits from local, sustainable and reliable food supply. Generally, urban communities are sometime engaged in activities such as urban farming. AI application relates to automation in crop monitoring and care based on imagery and other environmental sensors.

Fig.3: Relation between Artificial Intelligence and Contemporary Technologies

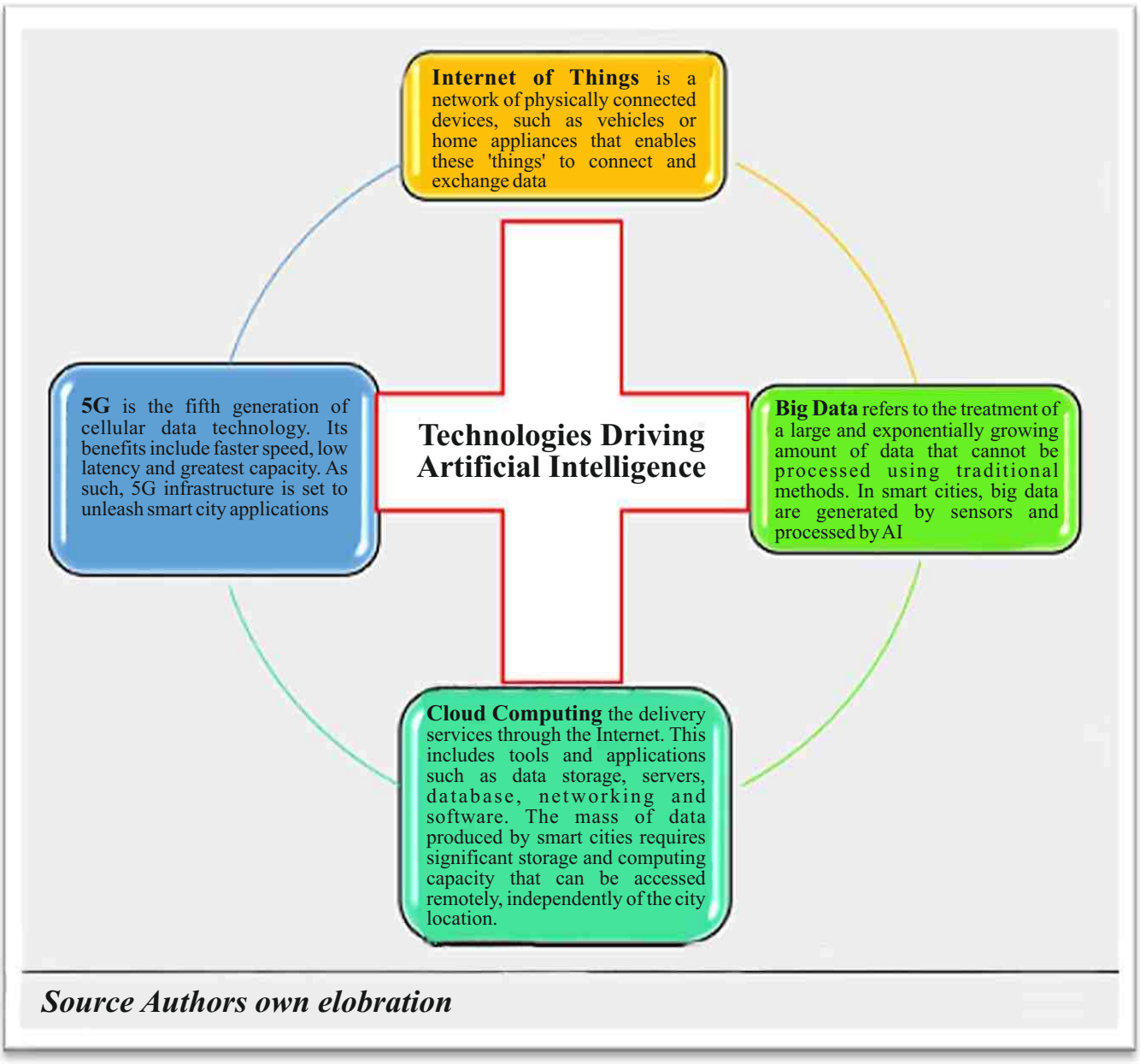


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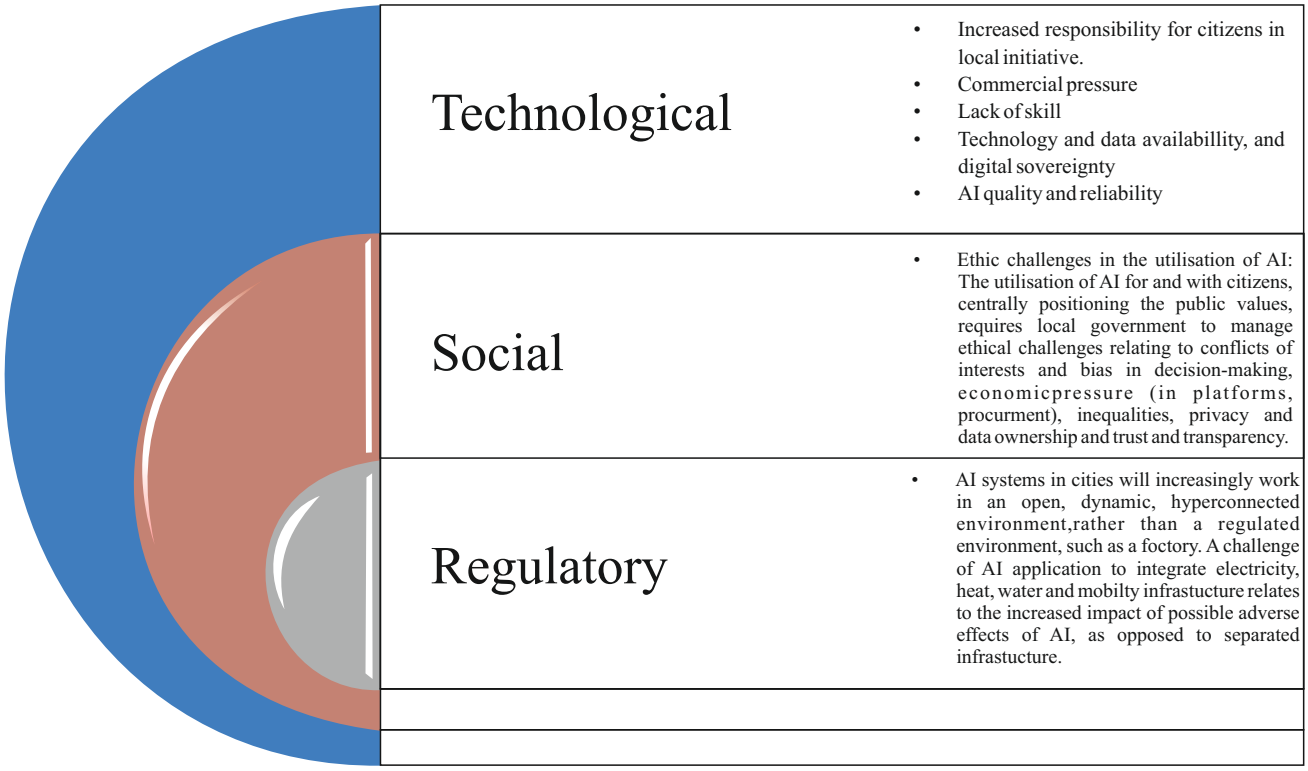
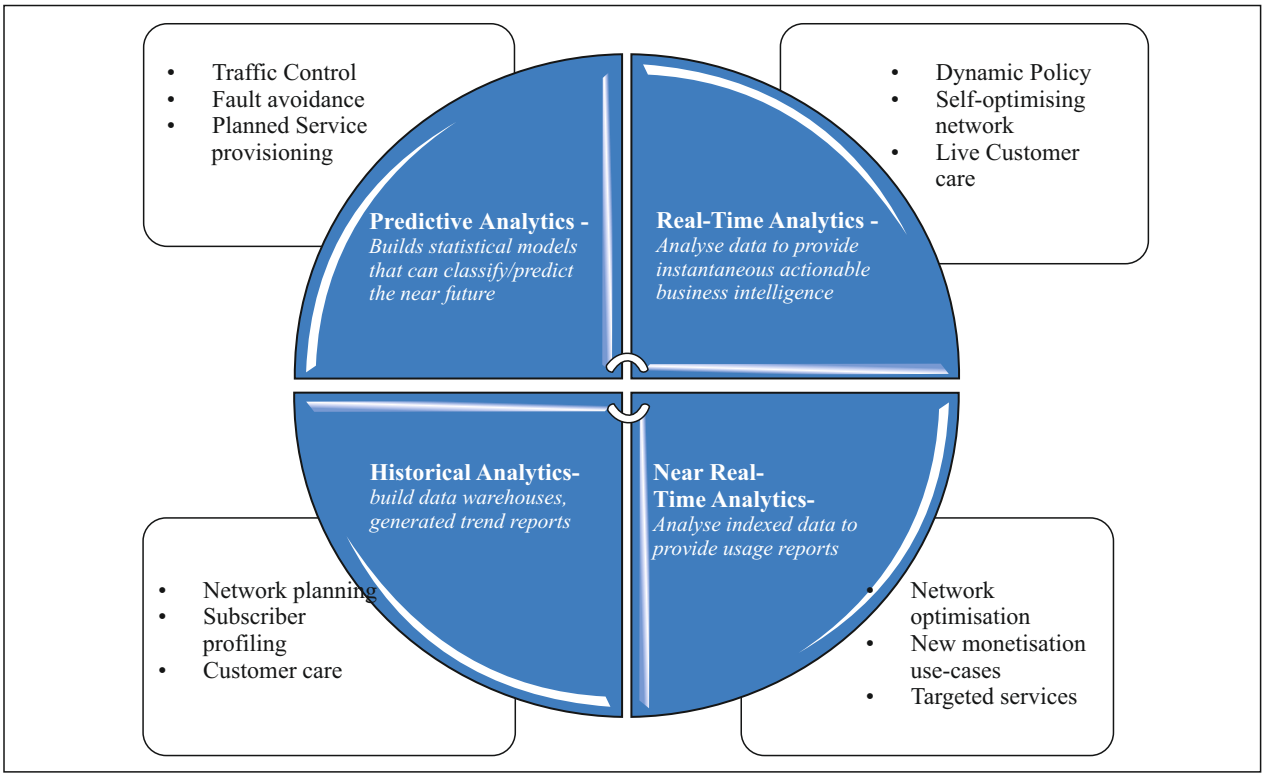
Fig.4: Challenges for deploying AI in Urban Planning and Resource Management



Source: - Authors, based on European Commission 2020a

Fig.5: Types of AI Analysis



Source: - Authors, based on European Commission 2020a

Report on development of Artificial Intelligence in India:

The UN estimated that there are now 33 megacities with a population of over 10 million with five of them being in India. As we pace towards developing an urban utopia and managing the brimming influx into our cities, we face the dilemma of how and where to leverage Artificial Intelligence (AI). The Indian ecosystem requires a smooth course to incorporate AI for spatial planning while simultaneously preparing for contingencies.

AI solutions are being explored for effective crowd management during emergencies and disasters. In 2015, Accenture worked with the Singapore Government during their SG50 Celebration (50th anniversary of Singapore' independence), and developed solutions aimed at predicting crowd behaviour and potential responses to incidents. The solution resulted in 85% accuracy in high crowd activity, crowd size estimation and object detection. In 2019, the "Kumbh Mela Experiment" in India witnessed the use of Artificial Intelligence via an Integrated Command and Control Centre set up for the police to gauge crowd mobility, predict stampedes and track suspicious activity.

Forging public-private partnerships can be a good start to induce a participatory approach to AI. The AIRAWAT (AI Research, Analytics and Knowledge Assimilation platform) platform in India seeks to provide this connectivity to all stakeholders involved in the AI research and application ecosystem, including start-ups, students, researchers and government organization among others.

Deployment challenges of Artificial Intelligence in Urban Planning.

Every innovation even the most aspiring one like Artificial Intelligence have costs. This cost is not evenly distributed among those who enjoy the results, which result in the conflicting interests. Effective deployment of the AI in the Urban Planning has been due to lack of understanding the solutions it can offer. Major challenges hampering the implementation of the AI is tabulated in Fig 2

Conclusion

Artificial Intelligence should be used as tools to facilitate the effective and efficient deployment of the Internet of Things and IT enabled devices which in return will act as levers to achieve Agenda 2030. Teaching and training of the potential users with the strategy to reach last mile is going to be key for Urban Planning. The way the Artificial Intelligence is implemented will decide the length of incubation period for its full-fledged usage or use on industrial scale. Role of researchers and scientist will increase in its algorithmic risk assessment.

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An Object Based Image Classification Approach for Mapping Different Types of Buildings in Urban Area

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Abstract

Rapid Mapping solutions for risk assessment and recovery mapping in support of disaster management is the need for areas vulnerable to disaster events. The very high resolution (VHRI) satellite imagery is necessary for urban planners to map crucial urban features. The building footprint is a critical element for the planning and design of Smart Cities. The present study utilizes object-based image analysis (OBIA) for accurate building detection and classification. A multi-resolution segmentation method is used to segment the image into different objects. The segmented image has further undergone the classification process. The study identifies the most optimum method for extracting buildings from VHRI. With the fuzzy rule based classification, an accuracy of 97.4% was achieved in the feature extraction. The study demonstrates the potential of Object based image classification for rapid mapping of buildings in large areas for disaster risk preparedness reducing risk to life and property.

Keywords: OBIA, VHRI, Buildings, Segmentation, Classification, eCognition

Introduction

Risk assessment, recovery, mitigation, and managing the disaster issues caused by natural hazards like a flood in urban areas is largely a development problem and needs to be addressed through rapping mapping solutions using geospatial techniques.Disaster management using urban building mapping will contribute to strengthening urbanresilience and sustainable urban development. Feature extraction from the very high resolution satellite imageries (VHRI) is a crucial component of remote sensing for urban planning and infrastructure, detecting changes in property management, and land use analysis (Fan et al., 2017). In particular, detection and classification of building features in an urban landscape play a key role in the estimation of the amount of urbanization, smart city planning, real estate and disaster management. The VHRI have increased in popularity due to their high resolution, accuracy, and efficient acquisition and have been used for a variety of applications (Awrangjeb et al., 2010). Compared to existing medium and high resolution remote sensing datasets like Landsat, Sentinel series, and other HR datasets, the VHR datasets from Worldview satellite provide precise information on specific objects included in an image (Hamedianfar & Shafri, 2015). It is evident that thebuilding footprint detection from VHRI has been challenging due to obstacles like trees, barren land, railway lines, and incomplete buildings (Shukla & Jain, 2020). The techniques for detecting urban feature characteristics fall into two basic categories: pixel-based and object-based classification methods (Martha et al., 2010). Low-level characteristics are frequently extracted using a pixel-based technique. High-level characteristics are extracted using object-based image analysis (OBIA)—(Crommelinck et al., 2016). Spatial information is more crucial than spectral information for distinguishing urban characteristics (Jin & Davis, 2005). The approach known as "object-based image analysis" (OBIA) is carried out based on an object that a person can understand . Image segmentation is used that divides the image into a number of clusters according to the homogeneity of similar pixels and the multi-resolution segmentation technique is offered by e Cognition software for operation , . The classification approach is needed as a remedy to enhance segmentation.

According to numerous published studies, it is clear that the extraction of different types of building footprints through OBIA has been done only for less dense urban environments , , . Due to the diverse urban landscapes inherent in India and the variety of complex building materials, it is challenging to distinguish one building from another through traditional approaches. The scene is also made even more difficult to analyzeurban features like roadways and railway tracks, which are the most similar pixels to be mixed with building materials. The extraction of different sorts of building footprints from VHRI data is also one of the challenges for the current scenario. Hence the study fills the gap by using the OBIA approach in these difficult circumstances, together with sampleand rule-based classification techniques, which is innovative and can be very beneficial for building

detection from dense, unplanned urban areas. The study presents the most effective approach for achieving high accuracy in feature detection after assessing the accuracy of extracted buildings. It also demonstrates the potential of Object based image classification for rapid mapping of buildings in large areas for disaster risk preparedness reducing risk to life and property.

Study Area

The study uses various sorts of buildings situated in the Angamally locality of Ernakulam district, Kerala. The region of interest covers approximately 152 hectares and is located between the longitudes of 76°22'1.21"E and 76°22'42.44"E and the latitudes of 10°10'35.04"N and 10°11'13.93"N.Urban structures with varying roof pitches were chosen for accurate extractionof footprint extraction. **Figure 1** displays a map of the study area.

Materials & Methods

Datasets Used

The high resolution image was acquired from the Worldview-2 satellite and the same was used in this study. The details of obtained satellite dataset are shown in **Table 1** and are used to create a subset in accordance with the boundary of the study area. The map projection and coordinate system of the subset have been changed to EPSG: 32643 - WGS 84 / UTM zone 43N for the purpose of completing further tasks in the study. The eCognition Developer 9.2 is used for segmenting and classifying image objects.

Methodology

The general flow of methodology is shown in Figure 2.

Multi-resolution segmentation

The initial and crucial process during the implementation of the OBIA technique is image segmentation which is a type of bottom-up, region-based segmentation. Figure 3 (a)–(d) illustrates objects created using various segmentation parameters. Scale, form, and compactness factors are the primary factors taken into account for the multiresolution segmentation and different parameters are evaluated for experimentation. The image is segmented by considering four different parameters to find the most optimum one for further classification.

Object Classification

The next critical stage in OBIA is the classification of the segmented data. In this step, the objects are classified by applying the chosen supervised classifiers and rule-based classification in the study. The classification algorithms begin by taking into consideration the segmented image with a scale of 100, the shape, and the compactness factor of 0.5 and 0.7 respectively for achieving higher accuracy.

In sample based classification, Nearest Neighbour (NN) classifier is used to classify the segmented objects and a group of pixels is chosen as a training sample for each class. Support Vector Machine (SVM) uses the linear kernel to show the relationships between samples from different classes. Cost (C) is a crucial tuning parameter for the linear kernel which was set to 2 by default. A random tree classifier was used to set the maximum depth, categories, and maximum no. of trees to 20, 16, and 80, respectively after multiple iterations. The rest of the parameter settings were kept default.

In Rule based Classification, the fuzzy membership function is applied as a rule set to extract buildings. It classifies the image, with each object's value falling between the ranges of 0 and 1 . The Grey Level Co-occurrence Matrix (GLCM) homogeneity was obtained from texture data and employed to distinguish between pixels with the same spectral reflectance. The minimum to maximum membership function of GLCM homogeneity was set as 0 to 0.23 for the non-building class and above 0.23 for the building class for the detection.

Accuracy Assessment

An essential phase in the object-based image classification process is accuracy assessment. In this study, the error matrix was calculated for all the classified results produced by the supervised classification approaches such as NN, SVM, and RT. It is used to calculate the overall accuracy, producer accuracy, user accuracy, and kappa coefficient .The area-based accuracy measurements were determined as percentages for the results generated from the same supervised classifiers. The following set of equations was employed by referring to an existing study in order to determine accuracy . Additionally, for each extracted building, the proportion of difference error has been computed.

a) Percentage Accuracy = Extracted building area / Reference building area $*$ 100 ……Eq. (1)

b) Overall Accuracy = Σ Percentage accuracy of each building / Total Number of considered buildings ……Eq. (2)

In object-based accuracy evaluation, only the detected

buildings from the fuzzy rule based classification were considered for this assessment. The assessment was carried out with reference to the hands on digitized buildings. Three components, including True Positive (TP), False Positive (FP), and False Negative (FN), were discovered by comparing extracted and reference buildings . These elements wereutilized to accurately appraise the extracted buildings. The below mentioned equations were employed to determine the correctness percent, completeness percent, and quality percent for evaluating the accuracy of extracted buildings.

a) Correctness (%) = TP / TP+FP ……Eq. (3)

b) Completeness (%) = TP / TP+FN ……Eq. (4)

c) Quality (%) = TP/ (TP+FP+FN)*100.....Eq. (5)

Results and Discussion

Image Segmentation

In this study, the appropriate scale, shape, and compactness parameters were set as 100, 0.5, and 0.7 accordingly after testing with several iterations.

The different segmentation parameters examined are displayed in Table 2.

Image Classification

The standard NN classifier is applied to the features to be extracted from the image and the classified result is shown in Figure 4 (a). Once the cost parameter was set, the SVM-classified buildings are created and depicted the same in Figure 4(b). The essential RF classification parameters such as Maximum depth, Categories, and a no. of trees were applied to produce the resulting image, as seen in Figure 4 (c). In rule based classification, the buildings were set apart from all other features for which GLCM homogeneity was applied using the fuzzy membership function. As per the considered threshold values, image segments are classified into buildings and non-buildings. Figure 4 (d) shows the classification outcome of the fuzzy rule set.

Accuracy Assessment Analysis

The building and non-building classes of the sample points were examined and served as standards to compare against the derived classes by computing the confusion matrix. The classification result of NN, SVM and RT is displayed in a confusion matrix as shown in Tables 3, 4, and 5 respectively. The samples collected for each classification method are also mentioned in the following tables.With reference to the shown error matrix tables, the overall accuracy of information extraction using the NN classifier is 90.81% and the kappa coefficient is 0.812. The overall accuracy of the SVM classifier is 87.01% and the kappa coefficient is 0.7388. The RT classifier achieved an overall accuracy of 90.78% and a kappa coefficient of 0.813. The effect of overall classification is well except for the misclassification few objects into other classes. It is obvious that the nearest neighbour classifier can extract more information accurately than the other investigated classifiers.

In area based accuracy measure, the seven different sorts of building footprints were digitized from HRS image and deployed as a reference for comparing with the extracted data. The building area in both reference image and the classified image is estimated in m^2 as shown in Table 6.The accuracies were determined as percentages for extracted buildings and the percentage of difference error also was calculated as shown in the Tables 7 and 8 respectively. The results revealed that the Fuzzy rule based classification provided a far higher overall accuracy percentage at 97.74%, followed by RF, NN, and SVM at 96.84%, 96.2%, and 96.12%, respectively.

In object based accuracy measures, the extracted buildings of rule based classification were used as it came out to be more accurate in area based accuracy assessment. The outcome of this assessment is shownin Table 9. The accuracy evaluation for the fuzzy rule-based extracted buildings is shown in Figure 5. The accuracy of extracted buildings achieves a greater accuracy rate with 88.24% completeness, 85.71% correctness, and 76.92% quality.

The classification of the image using the Nearest Neighbour approach was more accurate than other methods that were taken into consideration, according to the results of the error matrix. The results indicated that the fuzzy rule set classification is providing more accurately identified building information by calculating the percentage accuracies and difference error with regard to the area-based accuracy measure. The extracted buildings from the same classification result are only taken into account in the object-based accuracy evaluation since the fuzzy membership function produces accurate results in area-based quantitative assessment. The ability of building feature detection has been computed using the percentages of completeness, accuracy, and quality.

After comparing the outcomes of accuracy assessment, fuzzy rule based classification is shown to be the most ideal classification technique for extracting various building footprints.

Conclusion

In the present study, an HRS image is used to aid in the feature recognition and feature extraction of buildings from the complex industry area. To detect and extract the buildings, multi-resolution segmentation has been offered, with the parameters of scale, shape, and compactness, user defined samples, and rule sets. The accurate building feature detection from different classification algorithms has also been verified using the estimated error matrix and the obtained area-based and object-based accuracy measures. According to the accuracy check findings, it is more accurate to detect buildings in an industrial region using object-based image classification. This methodology may be applied to high resolution satellite images. The buildings were extracted more precisely using the NN classifier, with an overall accuracy of 90.81 % and a kappa coefficient of 0.812, according to the confusion matrix results. By adopting area-based accuracy measures, the competence of four supervised classifiers in classifying high-resolution images has been assessed and compared. The fuzzy rule based technique is the most effective way of extracting building footprints, and it has a 97.74 % overall accuracy. The fuzzy rule set's extracted buildings were put through an object-based accuracy test while taking ground reference data into account, yielding results of 88.24 % completeness, 85.71 % correctness, and 76.92 % quality. The detected and extracted building footprints can be the most basic information necessary for evaluating the vulnerabilities of a building for a specific hazard like flood and the same building property information can be maintained for disaster risk management.

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Table 1. Details of Worldview-2 high resolution dataset used with the present study

Sat.	Date of Acqn.	GSD	Bands.	Tile No.
World view-2	03-02-2017	0.3 m	Blue Green Red	10400 10028 ACAA00
Source:*Maxar's open data program* (*Open Data Program	Disaster Response Geospatial Analytics*, n.d.)			

Table 2. Different segmentation parameters are used for experimentation purposes.

Parameter	Trial 1	Trial 2	Trial 3	Trial 4
Scale	50	70	100	120
Shape	0.3	0.3	0.5	0.5
Compactness	0.5	0.7	0.7	0.8

Table 3. Error Matrix for the NN classified image

User Class	Buildings	Non-Buildings	Sum
Buildings	115	12	131
Non-Buildings	16	162	174
Sum	131	174	
Producer's accuracy	0.8778	0.9310	
User's accuracy	0.8778	0.9310	
Overall accuracy = 0.9081		KC = 0.8126	

Table 4. Error Matrix for the SVM classified image

User Class	Buildings	Non-Buildings	Sum
Buildings	109	14	123
Non-Buildings	16	92	108
Sum	125	106	
Producer's accuracy	0.872	0.868	
User's accuracy	0.8861	0.8518	
Overall accuracy = 0.8701		KC = 0.7388	

Table 5. Error Matrix for the RT classified image

User Class	Buildings	Non-Buildings	Sum
Buildings	119	18	137
Non-Buildings	10	157	167
Sum	129	175	
Producer's accuracy	0.922	0.897	
User's accuracy	0.868	0.940	
Overall accuracy = 0.9078		KC = 0.813	

Table 6. Area of reference buildings and extracted buildings

S. No	Building	Area (Sq. Km)				
		NN	SVM	RF	Fuzzy	Ref
1	Metal Sheet	2162	2162	2162	2162	2243
2	White Sheet	3887	3887	3887	3887	4001
3	Metal Roof	3921	3921	3921	3921	4022
4	Tin Roof	3826	3826	3826	3826	3827
5	White Sheet 2	1772	1772	1772	1772	1799
6	Concrete	4051	4086	3960	4232	4315
7	Fully concrete	3445	3373	3675	3675	3805

Table 7. Percentage accuracies of the extracted buildings

S. No	Building	Percentage Accuracy (%)			
		NN	SVM	RF	Fuzzy
1	Metal Sheet	96.40	96.40	96.40	96.40
2	White Sheet	97.15	97.15	97.15	97.15
3	Metal Roof	97.51	97.51	97.51	97.51
4	Tin Roof	99.97	99.97	99.97	99.97
5	White Sheet 2	98.50	98.50	98.50	98.50
6	Concrete	93.89	93.89	93.89	93.89
7	Fully concrete	90.53	90.53	90.53	90.53
Overall Accuracy		96.28	96.12	96.84	97.74

Table 8. Difference error percentage of the extracted buildings

S. No	Building	Percentage Accuracy (%)			
		NN	SVM	RF	Fuzzy
1	Metal Sheet	-3.59	-3.59	-3.59	-3.59
2	White Sheet	-2.84	-2.84	-2.84	-2.84
3	Metal Roof	-2.49	-2.49	-2.49	-2.49
4	Tin Roof	-0.02	-0.02	-0.02	-0.02
5	White Sheet 2	-1.50	-1.50	-1.50	-1.50
6	Concrete	-6.10	-6.10	-6.10	-6.10
7	Full Con	-9.46	-9.46	-9.46	-9.46

Table 9. Object based accuracies for the result of fuzzy rule based classification

Ref	TP	FP	FN	Comp.	Corr.	Qual.
35	30	5	4	85.71	88.23	76.92

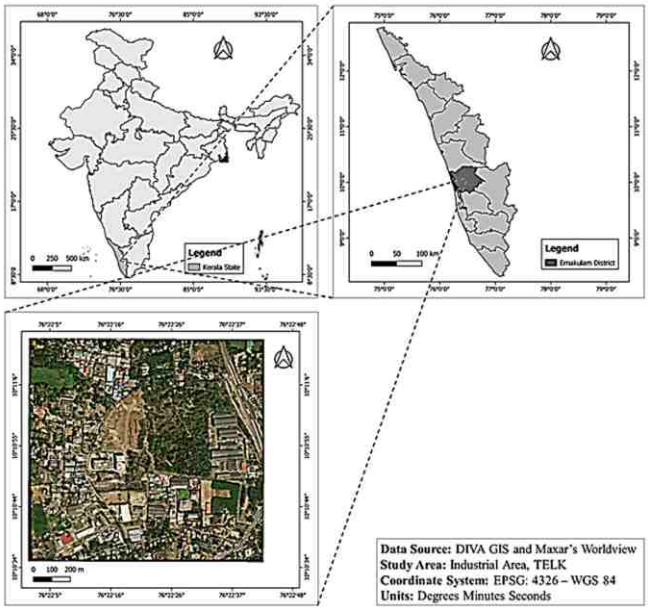

Fig.1 Study Area Map

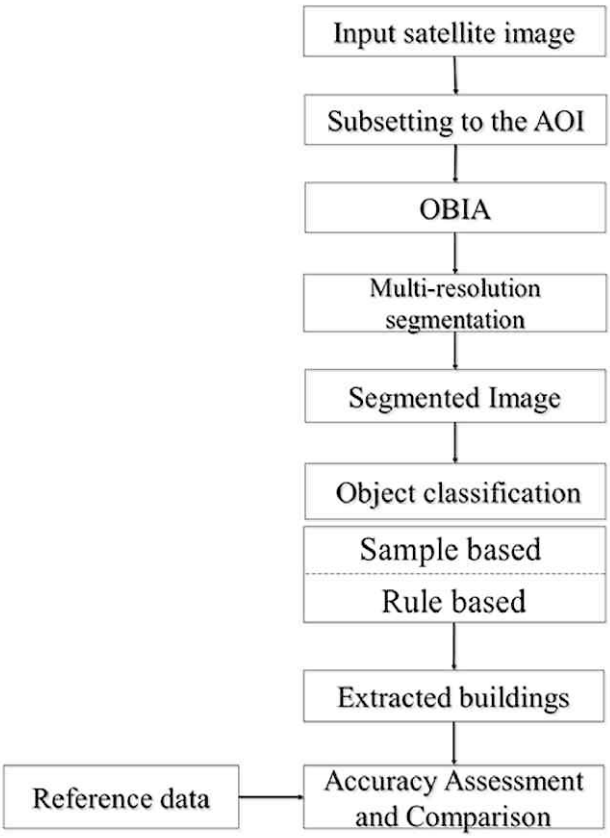

Fig.2 General Methodology

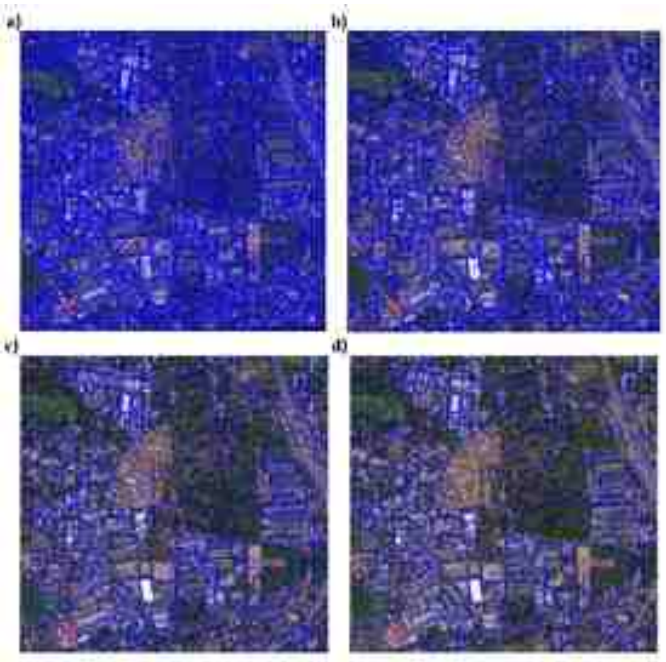

Fig.3 a) Trial 1 segments, b) Trial 2, c) Trial 3, d) Trial 4

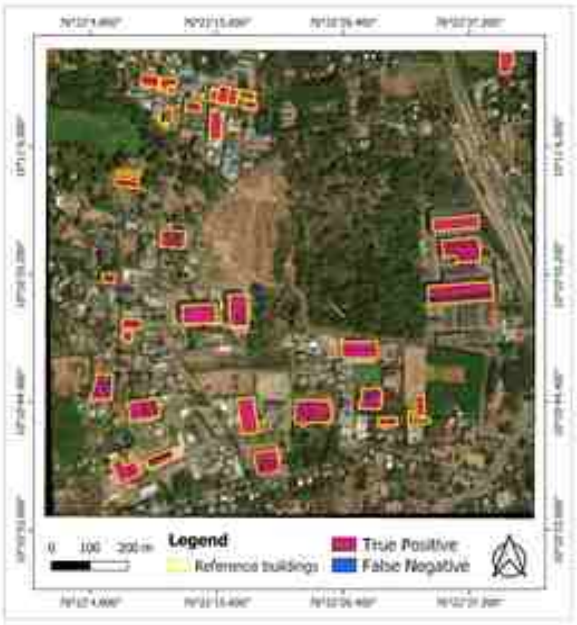

Fig.5 Object based accuracy assessment of fuzzy rule based classified buildings.

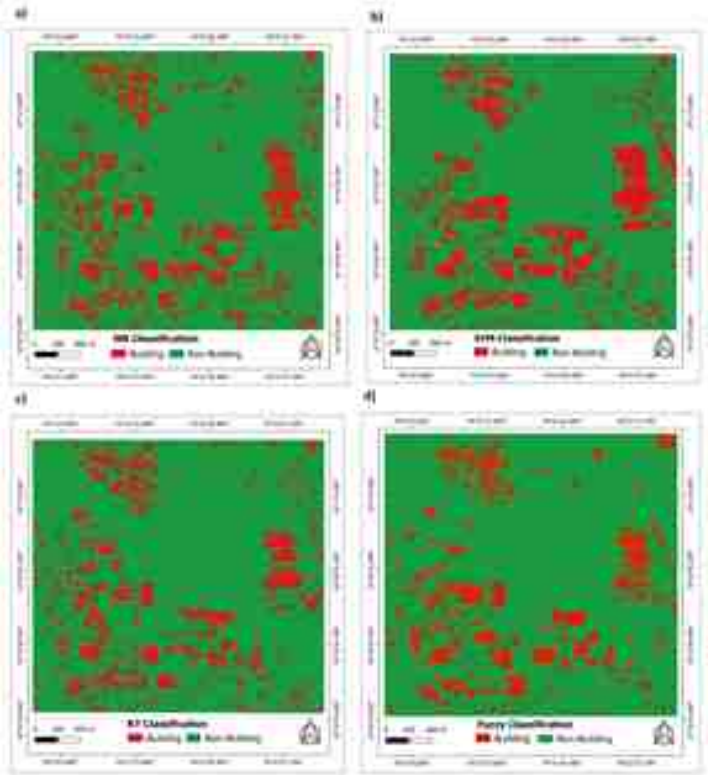

Fig.4 a) NN classified buildings, b) SVM, c) RT, d) Fuzzy rule based

A GIS-Based Assessment of Asan River Basin for Watershed Management

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Abstract

Watershed prioritization, management, and development are crucial for conserving not only the water resources but also associated soil and vegetation. This furthermore depends on the hydrological assessment of a specific river basin. The present study aims to evaluate and understand various topographical as well as morphometric characteristics of the Asan River basin for sustainable watershed management. Spatial Analysis Tools of ArcGIS software has been used to delineate watershed and execute other geospatial operations. SRTM DEM data at 30m resolution has been utilized to perform the morphometric analysis of the watershed. Also, Sentinel-2B data at 10m resolution has been used to evaluate the Vegetation Index. Various maps related to Basin, Slope, Aspect, Elevation, Land use & Land cover, and NDVI (Normalized Differential Vegetation Index) have also been prepared. We found a positive correlation of NDVI with elevation & slope and a negative correlation with drainage density of the basin. The elevation ranging from 400m to 900m, and slope ranging from 0° to 20°, favoured the vegetation growth. The highest vegetation at drainage density ranging from 1.7 km/km^2 to 9.8 km/km^2. This study concludes that the Asan River basin is less elongated in shape with moderate relief, the DEM-based hydrological assessment at the watershed scale is more practical and precise compared to other available techniques and has a promising impact on basin vegetation. This study would be helpful to various decision-makers and managers for sustainable natural resource management and watershed management.

Keywords: GIS, Remote Sensing, Morphometric Analysis, NDVI, DEM, Watershed Management.

Introduction

The world is moving toward water scarcity crises due to higher water demand, climate change, and urbanization, (Boretti and Rosa, 2019). To protect the globe from water crises, water resource management and watershed characterization become necessary. Watershed management is a part of water resource management. It combines soil, vegetation, & water to conserves the precious natural resources and also enhances the land use productivity (Phansalkar and Verma, 2004). Since a watershed is part of the land that is used for farming, groundwater infiltration, industrialization, and other anthropogenic works, watershed management is become necessary for social, economic, and environmental point of view (Asgari, 2021; Schmidt & Morrison, 2012).

In several hydrologic and soil modelling methods many input parameters are required, also their equation can be a complicated depending on the environment and landscape variability. Manual extraction of these input parameters can be error-prone and tedious, particularly with macroscale watersheds. (Nangia et al.,2010). A GIS-based approach is more scientific, cost-effective, and accurate for the watershed basin assessment. DEM data, along with multispectral satellite imagery from various GIS-based platforms have a better impact on water and land resource management (Singh et al., 2012). Remote Sensing and GIS based watershed basin evaluation has been carried out by several scientists and researchers for the multiple terrains and it has been proved one of the eminent scientific techniques for the generation and characterization of drainage basin parameter (Singh et al., 2014; Hlaing et al., 2008; Grohmann, 2004; Korkalainen et al., 2007; Pankaj and Kumar, 2009; Javed et al., 2009). The present work deals with the GIS-based assessment of the Asan River basin for the watershed management. This study would be beneficial for the policy makers/decision makers of various disciplines for a better understanding of natural resources.

Study Area

Asan River basin lies on the west of the Dehradun city of Uttarakhand, India. Basin's topmost stream originates from the lower Mussoorie ranges, but the origin of the Asan River is at Chandrabani in Dehradun near shiwalik hills (Ramsar Site report, 2020) and the basin outlet merges with the Yamuna River. The coordinate of the study area falls between Latitude (from 30°14'N to 30° 28'N) and Longitude (from 77°38'E to 78°05'E). The east part of the basin is the core city area and the west part is the outer city area. The total area of our study is 701.15 km^2 with elevations ranging from 390 m to 2218 m. The total annual rainfall in the area is 1945 mm. The summers are generally hot and the winters very cold. The yearly temperature varies from 41°C in summers to 2°C in winters. The map of the study area has been shown below in (Fig 1.)

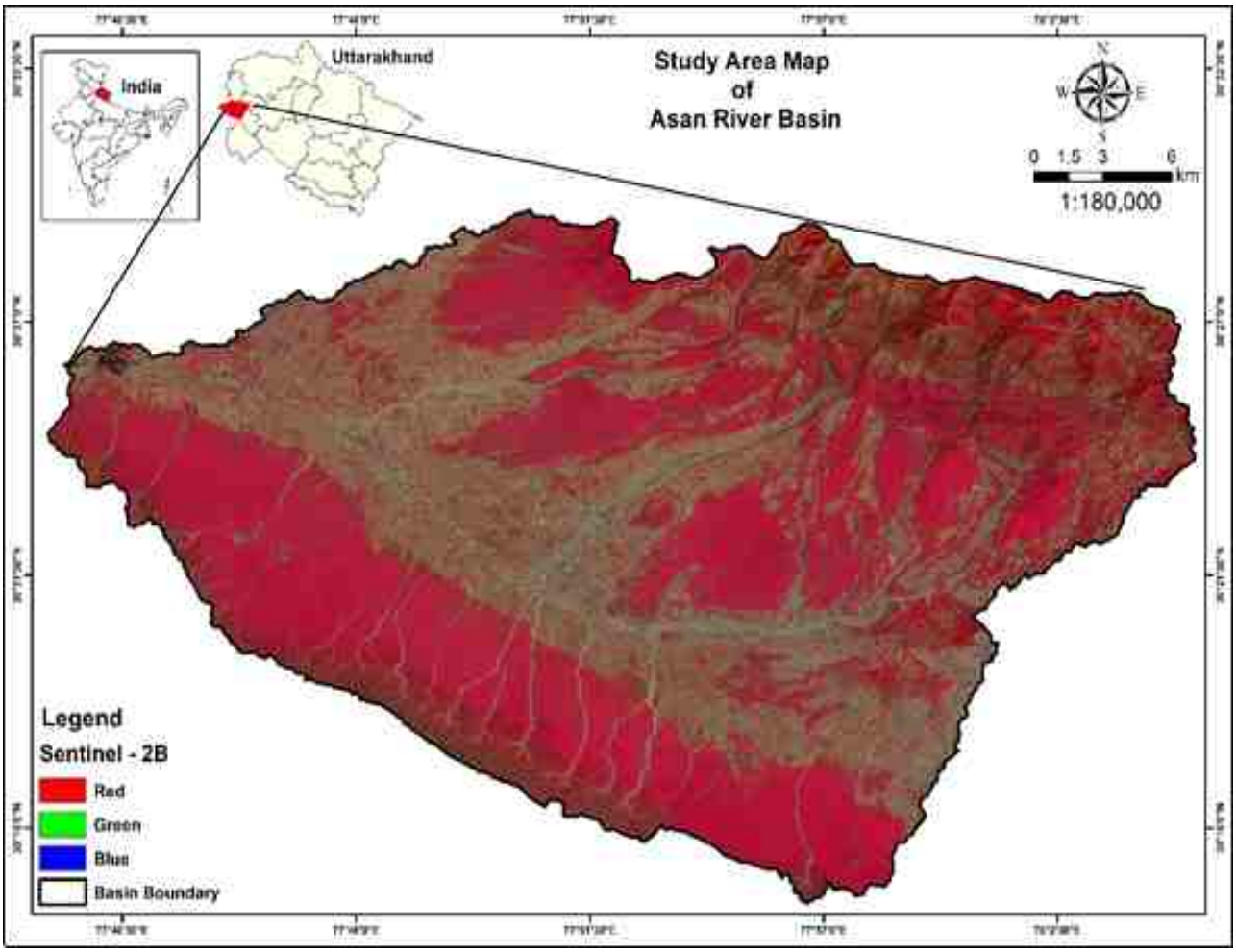

Fig.1 The Study Area Map

Materials & Methods

In this present work, the combined use of multispectral satellite images and DEM data has been utilized for the generation of a spatial dataand evaluation of various hydrological parameters and vegetation analysis. For delineating the watershed basin boundary and stream network the Hydrology tool a sub-tool of the Spatial Analysis Tools in Arc GIS desktop software has been used. Also, the Aspect map, Elevation map, Drainage Density map, NDVI map, LULC map, and Slope map of the Asan River basin has been prepared.

Normalized Differential Vegetation Index (NDVI) Formula:

[NDVI = ((Nir) - (Red)) / ((Nir) + (Red))]

Where, Nir = Sentinel-2B (Band-8) and Red = Sentinel-2B (Band-4).
Range: (-1 to +1)

Table 1. Data type and date source used for present work

Sr. No.	Type of data	Date of data	Source
1.	Sentinel-2B satellite imagery	19/04/2022	http://scihub.copernicus.eu/dhus/#home
2.	SRTM DEM	23/09/2014	http://earthexplorer.usgs.gov/

Table 2. Formulas and Parameters for computation of morphometric analysis.

Sr. No.	Formulas	Parameters	Reference
1	Hierarchical rank	Stream order (w)	(Strahler,1964)
2	Length of the stream	Stream length (L_u)	(Horton, 1945)
3	$L_{sm} = L_u/N_u$	Mean stream length (L_{sm})	(Strahler,1964)
4	$R_L = L_u / (L_u — 1)$	Stream length ratio (R_L)	(Horton, 1945)
5	(R_b) = Nu/Nu + 1	Bifurcation ration (R_b)	(Schumm, 1956)
6	R_{bm} = average of bifurcation ratios of all order	Mean bifurcation ratio (R_{bm})	(Strahler, 1957)
7	$D_d = L_u/A$	Drainage density (D_d)	(Horton, 1945)
8	$T = D_d \cdot F_s$	Drainage texture (T)	(Smith, 1950)
9	$F_s = N_u/A$	Stream frequency (F_s)	(Horton, 1945)
10	$Re=2v\,(A/ð)/L_b$	Elongation ratio (R_e)	(Schumm, 1956)
11	$R_c = 4\,ð\,A/P^2$	Circularity ratio (R_c)	(Strahler,1964)
12	$F_f = A/L^2$	Form factor (F_f)	(Horton, 1945)
13	$R = H — h$	Relief	(Hadley and Schumm, 1961)
14	$R_r = R/L$	Relief Ratio	(Schumm, 1963)

Results and Discussion

Morphometric Analysis:

The morphometric analysis explains the linear aspects, areal aspects, and relief aspects of the drainage basin which is useful to understand its hydrological characteristics.

Linear Aspects

In linear aspects, the basin's linear characteristics such as Stream Number (Nu), Stream Order (W), Bifurcation ratio (Rb), and Stream Length (km) are defined. The total number of streams in the basin is 2616. The basin follows Horton's first law wiz., the stream number (Nu) in each category falls in a geometric sequence, as represented by the graph in (Fig.2). The stream orders are ranging from (1st order to 6th order) as shown in (Fig.3). The bifurcation ratio is ranging from 2 to 12 and the mean bifurcation ratio is 5.45. The bifurcation ratio defines the drainage pattern in the basin, where the pattern is dendritic in shape.

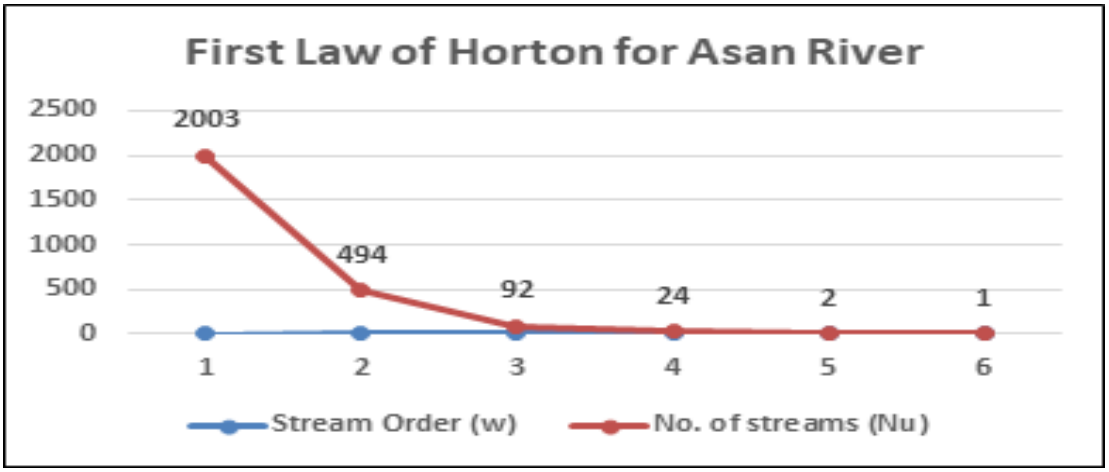

Fig.2 First Law of Horton for Asan River

Table 3. Linear Aspects Table

Stream Order (w)	Number of streams (Nu)	Bifurcation ratio (RbF)	Mean bifurcation ratio (Rbm)	Total length of streams (km)	Mean length of streams (km)	Length ratio (RL)
1	2003			973.75		
2	494	4.05		511.67		0.53
3	92	5.37	5.45	303.09	0.77	0.59
4	24	3.83		155.62		0.51
5	2	12.00		29.31		0.19
6	1	2.00		32.41		1.11
Total	**2616**		**Total**	**2005.85**		

Areal Aspects:

Areal aspects include the areal elements such as Area (km^2), Elongation Ratio (Re),Form factor (Ff), Stream Frequency (Fs), Parameter (km), Drainage Density (Dd), Drainage Texture (T), and Circularity Ratio (Rc). The total area of the Asan River basin is 701.15 km^2 and the parameter is 137.35 km. As per Schumm, the elongation ratio has been classified into three classes; (i) (>0.9) = circular, (ii) (0.9–0.8) = oval, (iii) (0.8–0.7) = less elongated and (iv) (<0.7) = elongated. Here, 0.7 is the value of the elongation ratio which implies that thebasin is less elongated in shape with moderate relief. The circulatory ratio value is 0.47 which explains that the basin is less circular or less elongated in shape. The form factor is the flow intensity of the basin. The 0.38 value of the form factor indicates that flow intensity inside the basin is very low. As per Horton, the stream frequency is directly related to drainage density. Hence, the value of stream frequency is 3.73, and the Mean drainage density is 2.86 km/km^2 which implies that both are directly related to each other. The drainage texture value is 10.67 implies that the drainage texture is coarse with highly resistant permeable material.

Table 4. Areal Aspects Table

Basin area (km^2)	Perimeter (km)	Length(km)	Form factor (Ff)	Elongation ratio (Re)	Circularity ratio (Rc)	Drainage density (km/km^2)	Stream Frequency (Fs)	Drainage Texture (T)
701.15	137.35	43	0.38	0.70	0.47	2.86	3.73	10.67

Relief Aspects

Relief Aspects defines the 3D elements of the basin. The total basin relief is 1828m which indicates the basin is having moderate relief. The value of the relief ratio is 42.51. The low value of the relief ratio implies that the maximum area of the basin is having a very gentle slope.

Table 5. Relief Aspects Table

Height of basin mouth (z) m	Maximum height of the basin (Z) m	Total basin relief (R) m	Relief ratio
390	2218	1828	42.51

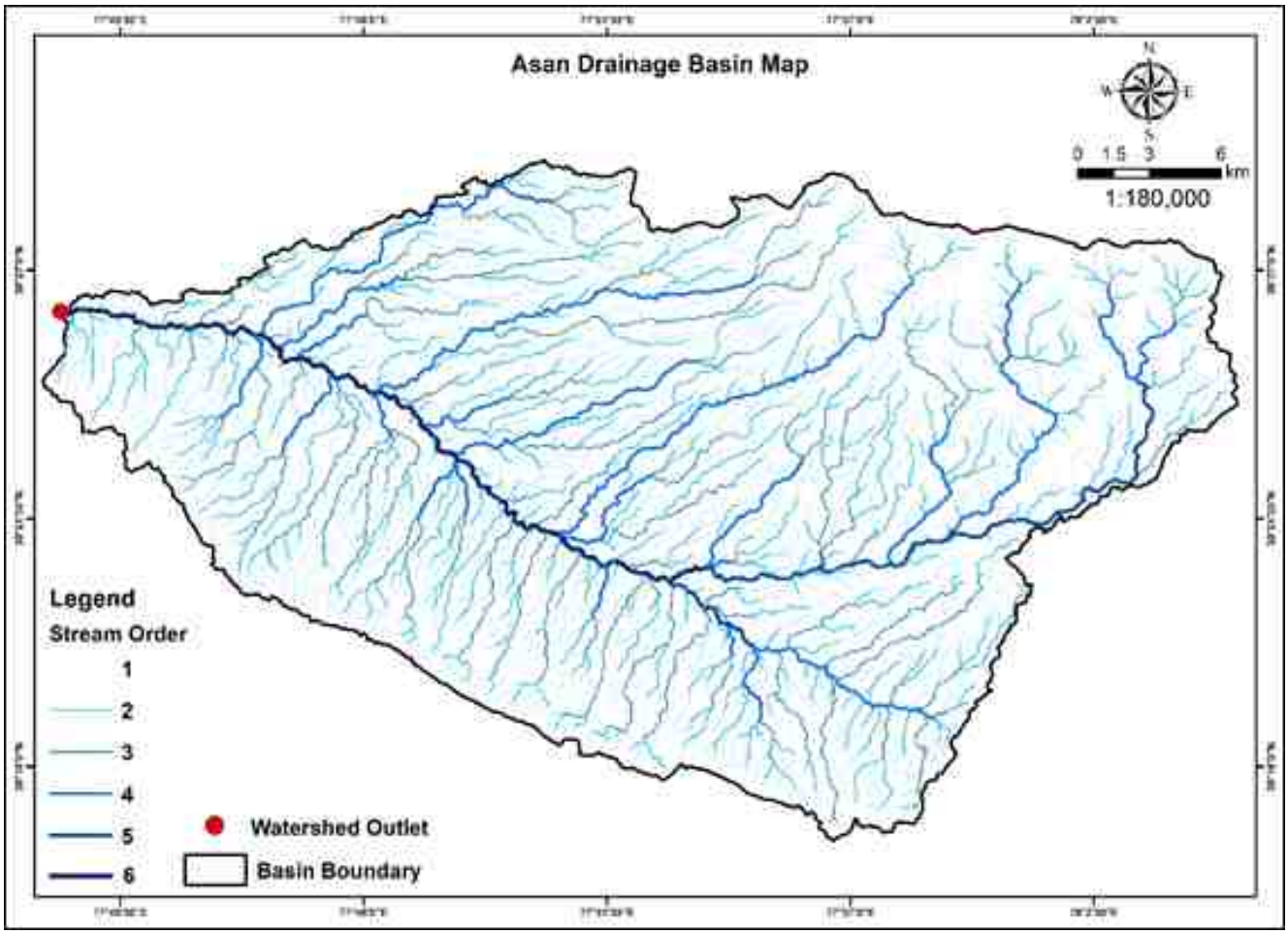

Fig.3 Drainage Basin Map

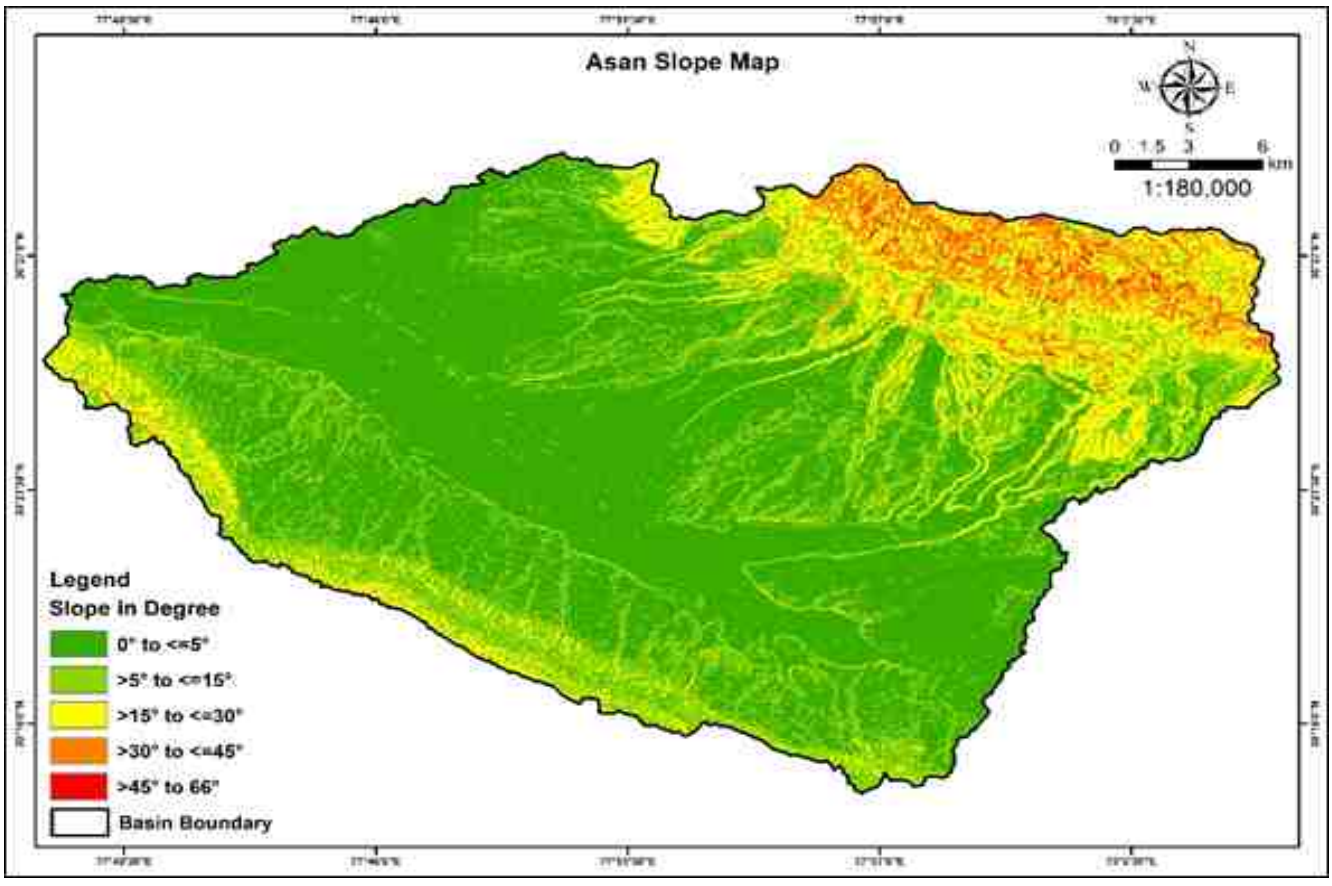

Fig.4 Slope Map

Slope:

Slope defines the steepness of the area. The Asan River basin slope is divided into 5 classes as shown in (Fig.4): (0° to <=5°) is very gentle having 57.52% of the total area, (>5° to <=15°) is gentle having 25.36% of the total area, (>15° to <=30°) is Moderate having 12.14% of the total area, (>30° to <=45°) is steep having 4.62% of total area and (>45° to 66°) is very steep having 0.36% of total area. It is visible from the table and map that most of the basin area is very gentle to gentle. A gentle slope implies that the basin is good for groundwater infiltration having less runoff

Table 6. Slope Table

Sr. No.	Slope Classes	Area in km^2	Area in %
1	0° to <=5°	403.3	57.52
2	>5° to <=15°	177.82	25.36
3	>15° to <=30°	85.13	12.14
4	>30° to <=45°	32.37	4.62
5	>45° to 66°	2.53	0.36
Total Area		**701.15**	**100**

Aspect:

The aspect shows the direction of the slope. The Aspect at (0°-22.5°) is north, at Northeast (22.5°-67.5°) it is east, and so on. For this study, the direction of the slope is west-facing as shown in (Fig.5). This indicates that the slope has higher moisture content and higher vegetation cover as compared with the east-facing slope.

Table 7. Aspect Table

Sr. No.	Aspect Classes	Area in km^2	Area in %
1	Flat (-1°)	2.58	0.37
2	North (0°-22.5°) (337.5°-360°)	91.39	13.03
3	Northeast (22.5°-67.5°)	79.93	11.4
4	East (67.5°-112.5°)	70.67	10.08
5	Southeast (112.5°-157.5°)	75.09	10.71
6	South (157.5°-202.5°)	91.35	13.03
7	Southwest (202.5°-247.5°)	95.09	13.56
8	West (247.5°-292.5°)	97.75	13.94
9	Northwest (292.5°-337.5°)	97.3	13.88
Total Area		**701.15**	**100**

Elevation:

The Elevation of Asan River Basin is classified in 5 classes shown in (Fig.6): (<= 600m) is very low having 43.62% of the total area, (> 600m to <= 900m) is low having 43.15% of the total area, (> 900m to <=1,200m) is moderate having 6.48% of the total area, > 1,200m to <= 1,600m) is high having 3.36% of the total area and > 1,600m to 2,218m) is very high having 3.39% of the total area. The maximum area of the basin is having very low to low elevation value which implies that elevation has a direct relation with slope and indirect relation with drainage density.

Table 8. Elevation Table

Sr. No.	Elevation Classes	Area in km^2	Area in %
1	<= 600m	305.84	43.62
2	> 600m to <= 900m	302.58	43.15
3	> 900m to <=1,200m	45.43	6.48
4	> 1,200 m to <= 1,600m	23.56	3.36
5	> 1,600m to 2,218m	23.74	3.39
Total Area		**701.15**	**100**

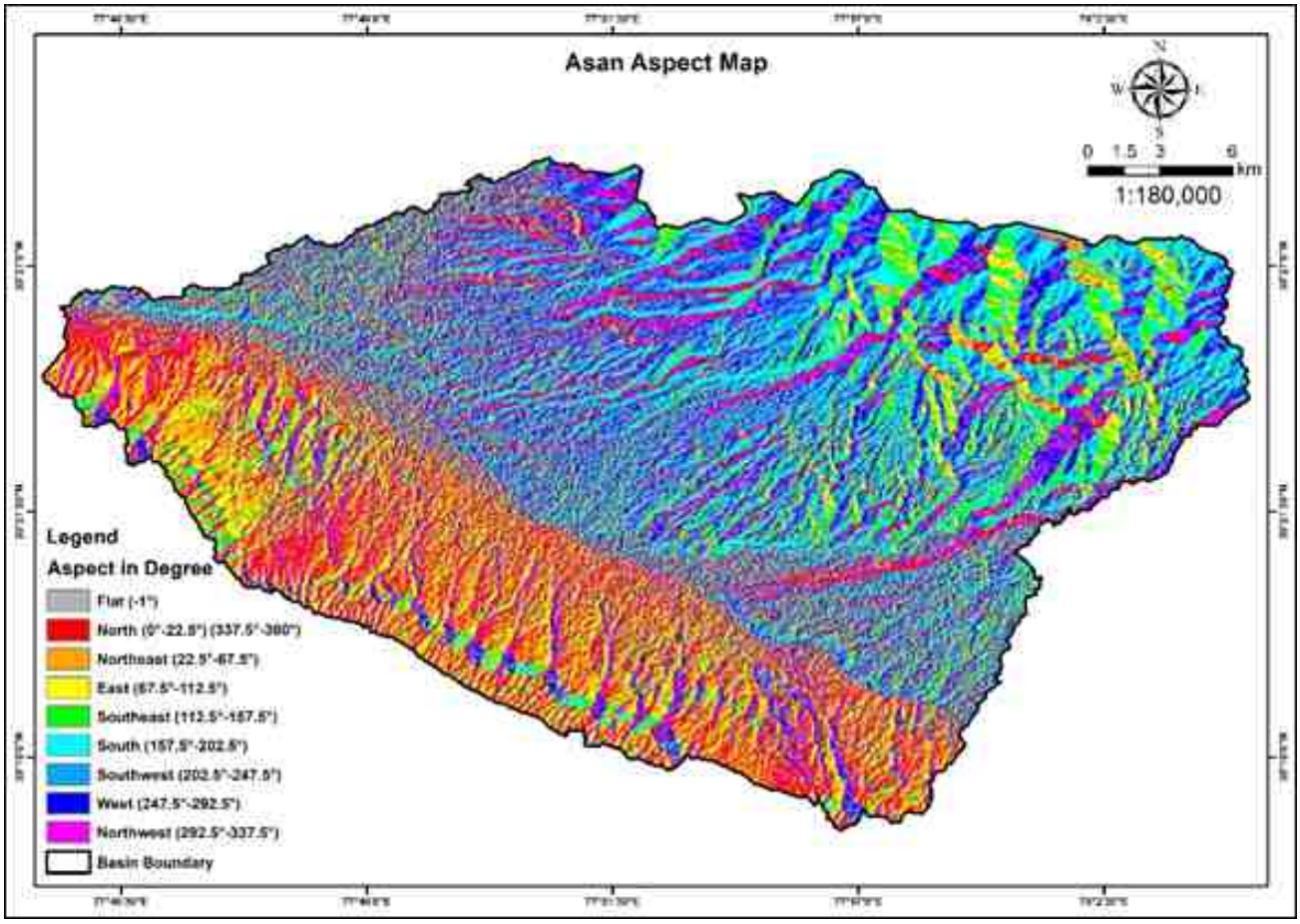

Fig.5 Aspect Map

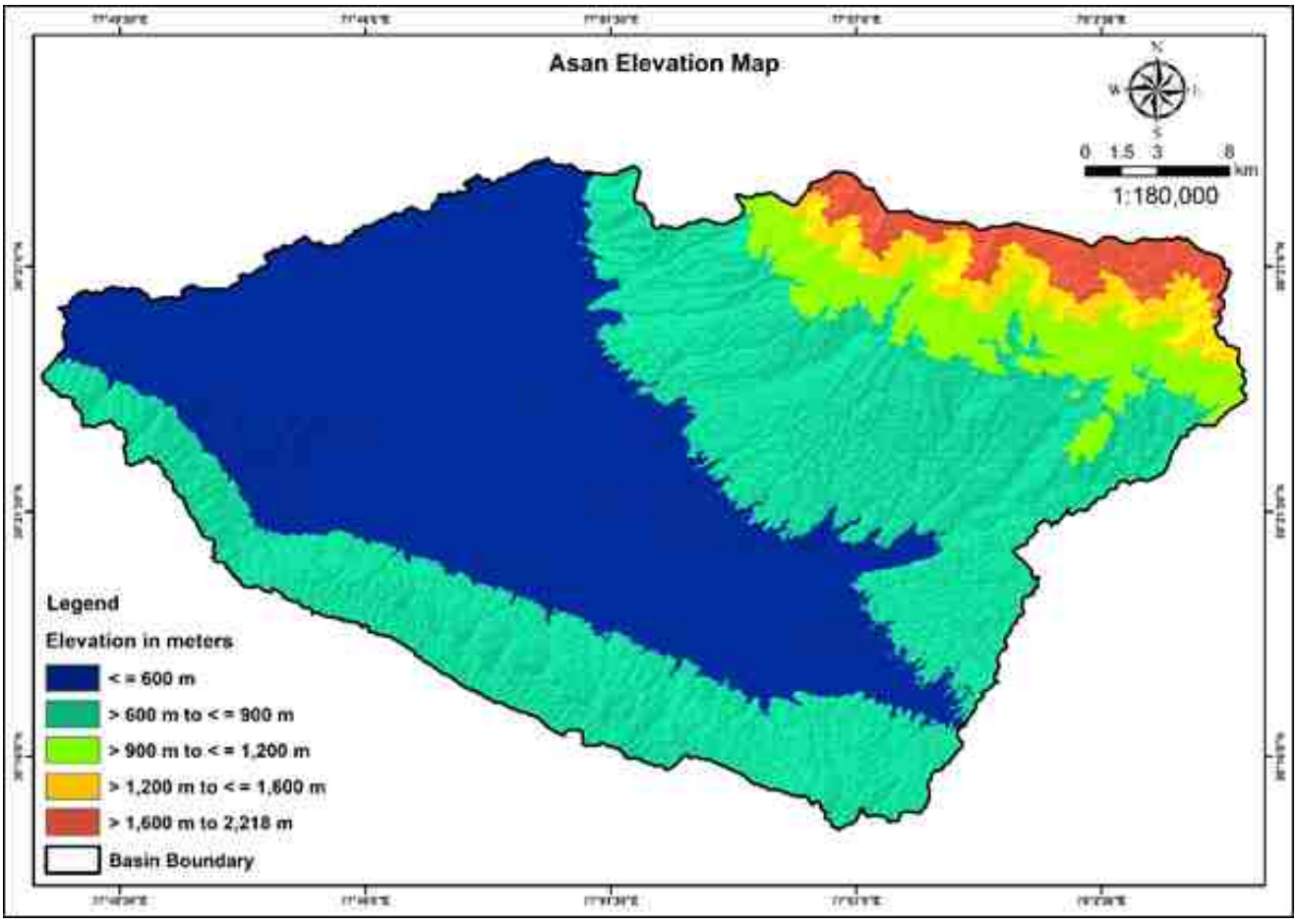

Fig.6 Elevation Map

Drainage Density:

The drainage density of the basin is defined as the total length of streams per unit area. Here, the drainage density is divided into 5 classes as shown in (Fig.7): (<= 3 km/km^2) is very low having 12.1% of the total area, (> 3 km/km^2 to <= 6 km/km^2) is low having 54.35% of the total area, (> 6 km/km^2 to <=9 km/km^2) is moderate having 26.39% of the total area, (> 9 km/km^2 to <= 12 km/km^2) is high having 6.11% of the total area and (> 12 km/km^2 to 14.14 km/km^2) is very high having 1.05% of the total area. Most of the area in the basin is having low drainage density. The highest drainage density represents by the red colour on the map where Selaqui industrial drainage waste is flows into the Asan River which is a major concern on the issue of water quality and water infiltration.

Table 9. Drainage Density Table

Sr. No.	Drainage Density (km/km^2)	Area in km^2	Area in %
1	<= 3	84.85	12.1
2	> 3 to <= 6	381.05	54.35
3	> 6 to <=9	185.04	26.39
4	> 9 to <= 12	42.82	6.11
5	> 12 to 14.14	7.39	1.05
Total		**701.15**	**100**

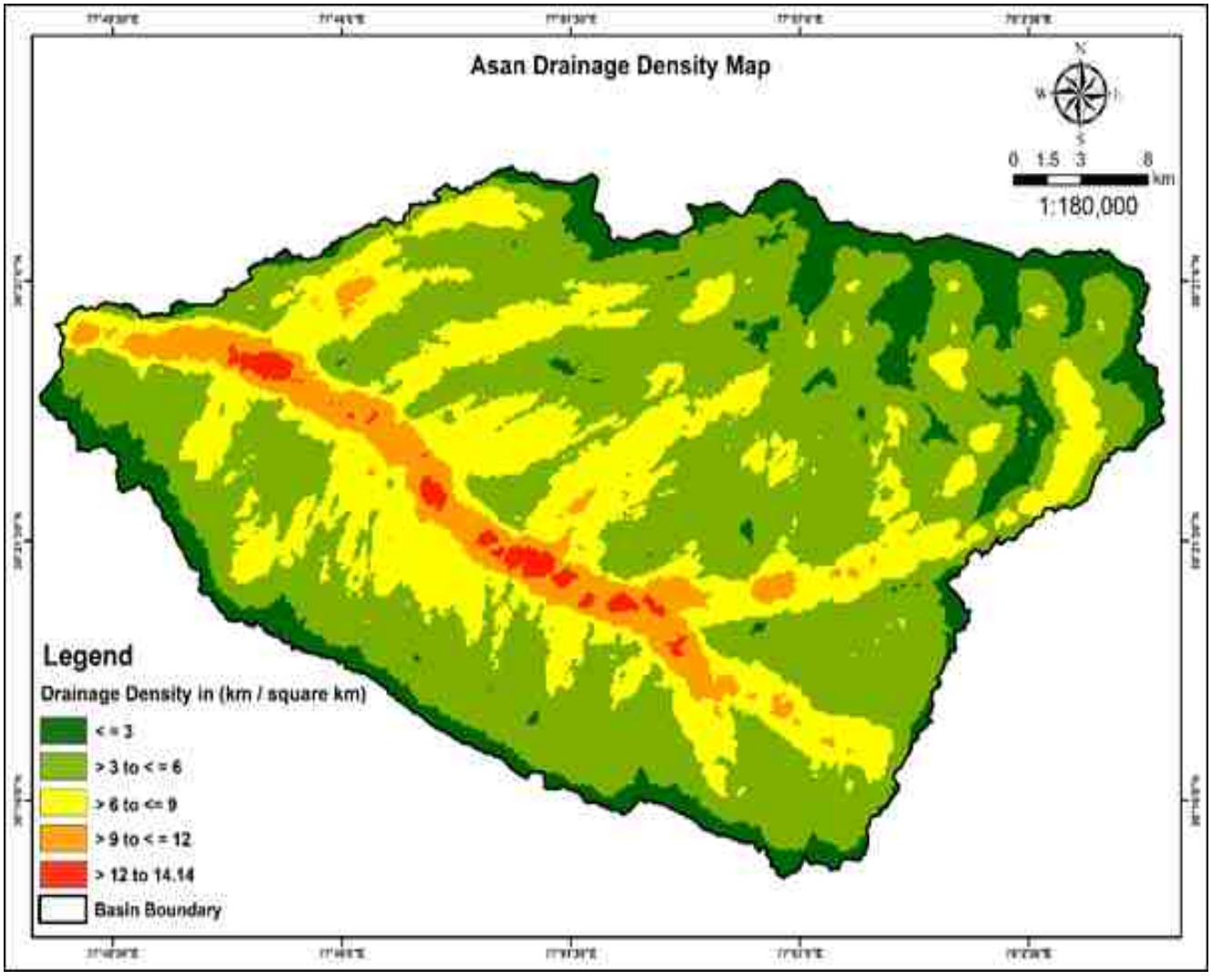

Fig.7 Drainage Density Map

Land Use and Land Cover (LULC)

LULC classification is another important factor for assessment of hydrological condition. of any area. It explains the usage of land resource by anthropogenic activities especially urbanization and agriculture(YanYun et al., 2014).Water resources are always under severe pressure due to climate change and land use practices. The LULC map has been prepared using the Sentinel-2B imagery. The method used for LULC classification is Supervised classification performed in ERDAS Imagine Software. There are 6 LULC Classes viz.: Built-up, Agriculture Land, Forest Area, Wasteland, Dry Riverbed and Waterbodies as shown in (Fig.8). The result from the map depicts that more than half of the area in a basin is forest area (59.72%), followed by agricultural land (15.69%). The basin is surrounded by lesser Himalayas in the north & Shiwalik in the south and has a steep slope, while the central region of the basin is having a gentle slope which means more infiltration and less runoff. This implies that the central part is good for agriculture practices while only (8.23%) of the basin area is under waste land category. The built-up is another dominating class of the basin occupying (12.60%)of the area. This confirmed that the Asan River basin is having huge anthropogenic pressure which will directly affects the river health and its biodiversity. The waterbodies and dry riverbed are two categories occupying least percentage of area in the basin.

Table 10. LULC Table

Sr. No.	LULC Classes	Area in km^2	Area in %
1	Built-up	88.41	12.60
2	Agricultural Land	109.98	15.69
3	Forest Area	418.71	59.72
4	Wasteland	57.69	8.23
5	Dry Riverbed	24.97	3.56
6	Waterbodies	1.39	0.20
Total Area		**701.15**	**100**

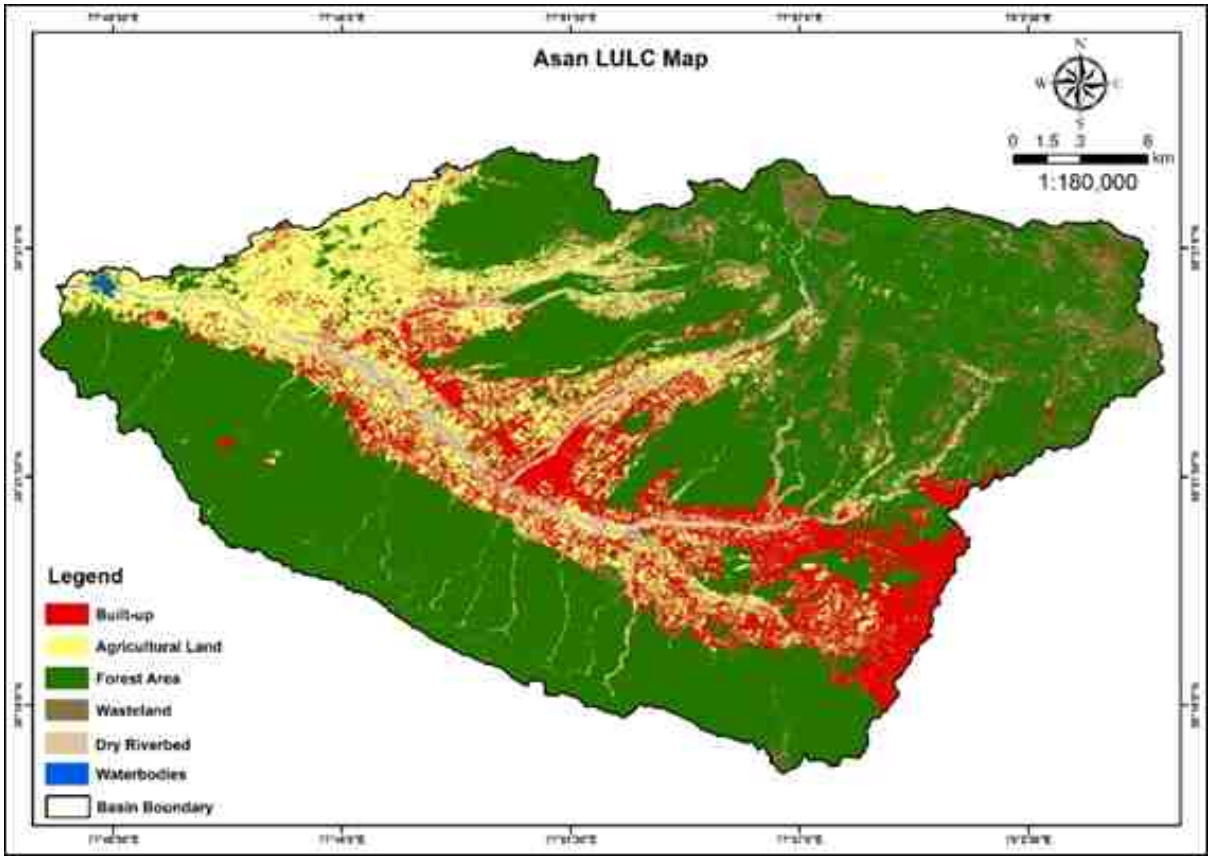

Fig.8 LULC MAP

Normalized Differential Vegetation Index (NDVI)

The NDVI measures the amount of vegetation covering a given area of land. The map in (Fig.9) shows that almost 45% of the area is having (Very High to High) NDVI value which shows that the basin is having a healthy green vegetation. Increasing the amount of green cover in an area is beneficial for carbon sinking, which in turn improves air quality. The NDVI value displayed on the map for the agricultural region of the basin is low.

Table 11. NDVI Table

Sr. No.	NDVI Classes	Area in km^2	Area in %
1	Very Low	36.65	5.23
2	Low	185.25	26.42
3	Medium	162.68	23.2
4	High	173.28	24.71
5	Very High	143.29	20.44
Total Area		**701.15**	**100**

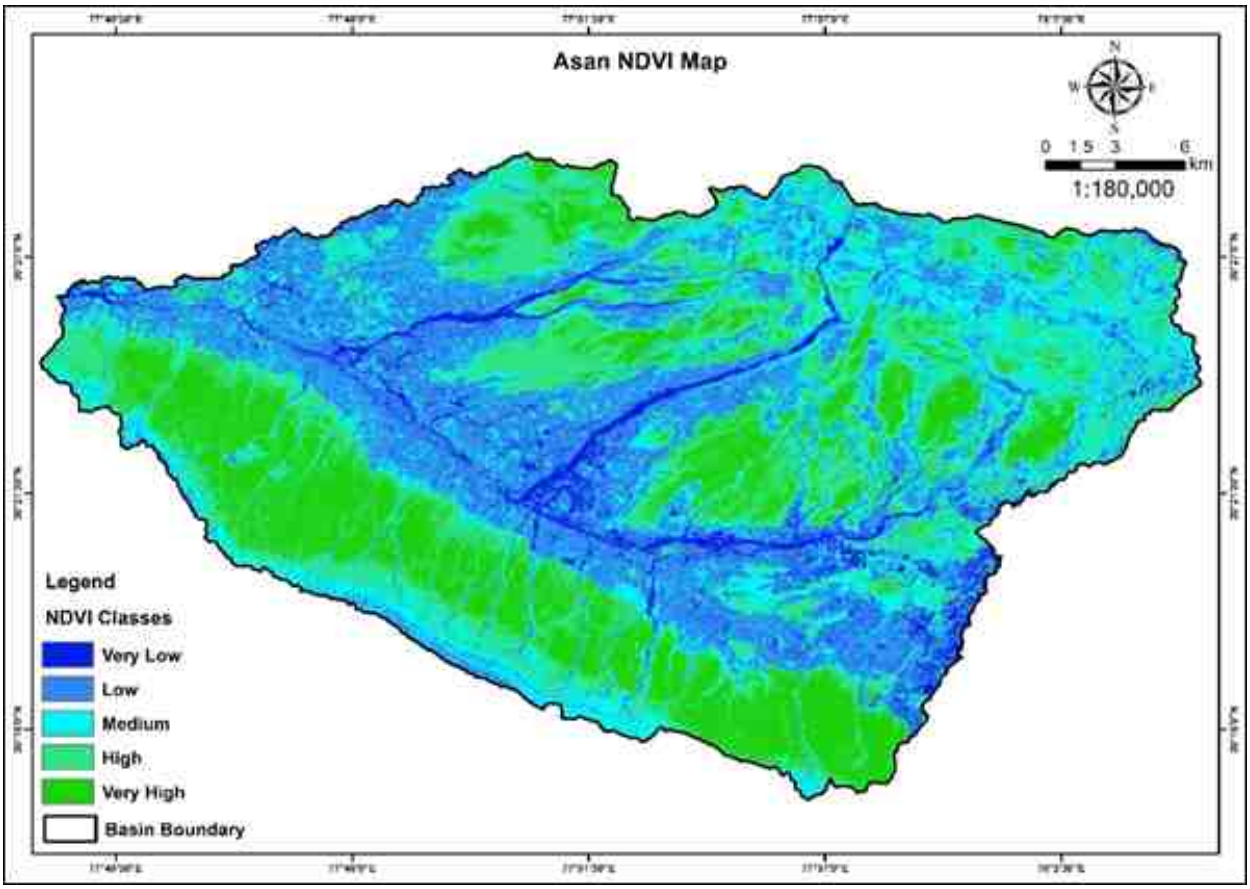

Fig.9 NDVI Map

NDVI relation with Elevation, Slope, and Drainage Density

We found a positive correlation of NDVI with elevation & slope and a negative correlation with drainage density of the basin as shown in (Fig.10). Here, we have taken (+0.3) as the NDVI threshold value. The elevation ranging from 400m to 900m, and slope ranging from 0° to 20°, favoured the vegetation growth. The highest vegetation at drainage density ranging from 1.7 km/km^2 to 9.8 km/km^2.

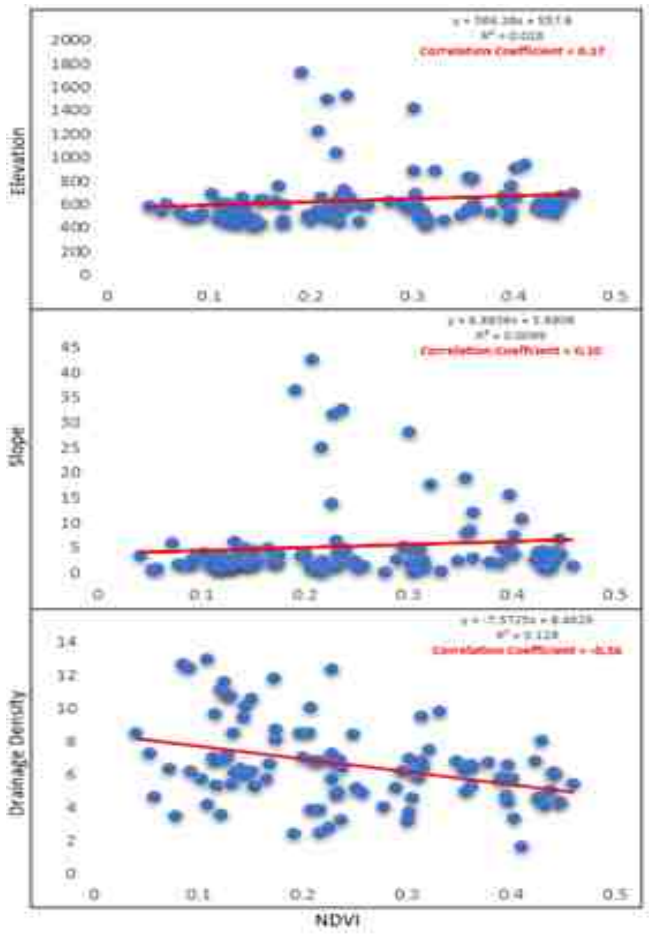

Fig.10: NDVI Correlation with Elevation, Slope and Drainage Density

Conclusions

From this study, we have concluded that the Asan River basin is less elongated in shape with moderate relief. It has been observed that stream segments of the 1st and 2nd order are present in the high altitudinal areas characterized by moderate to steep slopes, while the 3rd to 6th order stream segments occur in relatively gentle to very gentle slope areas wherein maximum infiltration caused by precipitation. Further, the NDVI shows a positive correlation with elevation & slope and a negative correlation with drainage density. The Selaqui industrial area and the households lives on both the banks of the river is having a negative impact on the river water quality. A large amount of dumped industrial waste and polluted urban runoff flows into the Asan River which ultimately merges with the Yamuna River, which is a major concern. Hence, this study demonstrated that GIS and Remote Sensing techniques are competent tools for understanding the hydrological characteristics of drainage basins. The integration of DEM and multispectral satellite data is the solution to the real-world problem. The result from such studies can provide baseline information for city planners especially related to disaster mitigation, watershed management, and urban river management.

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Nautical Cartography – An Extinct Art of Making Charts?

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Abstract

The navigator require navigational chart for steering their ships safely by the shortest possible time. International Hydrographic Organisation's (IHO) special publication S32 (Hydrographic Dictionary) defines "Cartography is the art and science of expressing graphically by Maps and Charts, the known physical features of the Earth or other Celestial Body". A nautical chart is specially designed to meet requirement of marine navigation, showing depths of water, nature of bottom, elevations, configurations and characteristics of coast, danger and aids to navigation. It is a work area on which the navigator plots courses, ascertains positions, and views the relationship of the surrounding area. It assists the navigator in avoiding dangers and arriving safely at his destination. Marine Cartography has slowly evolved over the centuries as the art, science and technology of charting the seas. The Indian Nautical Chart has evolved in its theme format, design, contents, symbology and colour scheme through varied stages of development from hand drawn paper charts to digital Electronic Navigational Charts (ENCs). Traditional nautical charts are printed on paper and the digital charts or electronic charts are displayed on a special display unit called Electronic Chart Display and Information System (ECDIS). The traditional paper charts are made in compliance with International Chart Standards called S4(Chart Specifications) and the depiction of details are to meet the standards of INT1(Symbols & Abbreviations), INT2(Boarders and Graduations) and INT3(Use of INT1 & INT2 on charts). The chart appearance, the depiction of details including symbology, topographic details and navigational aids are maintained uniformly worldwide. Now this art of making charts is going to extinct slowly due to technological developments towards paperless bridge. A recent study on "Future of the Paper Chart" by the IHO's Nautical Chart Working Group (NCWG) revealed that the Paper Chart sales are drastically falling down by 20% every year. Most of the Hydrographic Offices have already announced their plan of action to stop producing paper charts in next 05 years period. Till then paper charts will be printed on user's demand as and when required.

Keywords: Nautical Chart, Hydrographic, Extinct, IHO, ECDIS, ENC, NCWG

Introduction

The Nautical Chart produced by an Authorised Hydrographic Office is not only a tool for safe navigation and also a legal document in case of plea. Now the digital charts named ENCs(Electronic Navigational Charts) are replaced the traditional paper charts. Regulations Related to the use of Paper and Electronic Charts The International Convention for the Safety of Life at Sea (SOLAS), Chapter V, Regulation 19, "Carriage requirements for shipborne navigational systems and equipment," specifies that "All ships, irrespective of size, shall have nautical charts and nautical publications to plan and display the ship's route for the intended voyage and to plot and monitor positions throughout the voyage. An electronic chart display and information system (ECDIS) is also accepted as meeting the chart carriage requirements of this subparagraph." Regulation 19 also states that "An appropriate folio of paper nautical charts [still] may be used as a back-up arrangement for ECDIS." In July 2018, the International Maritime Organization (IMO) mandated requirement for most commercial vessels on international voyages to be fitted with an Electronic Chart Display and Information System (ECDIS) came into full effect. Some national maritime authorities now also allow commercial ships on domestic voyages to navigate entirely with ENCs. It has been sensed that the use of paper chart drastically slows down in the marine community. At this juncture IHO has assigned task to its subordinate body HSSC (Hydrographic Services and Standards Committee) to study the future of the paper chart.

International Hydrographic Organization (IHO) is an International Organization that works to ensure all the world's seas, oceans and navigable waters are surveyed and charted. IHO was established in 1921with its Secretariat in Pricipality of Monaco and coordinates the activities of national Hydrographic Offices (HOs) and promotes uniformity in nautical charts and documents. It issues survey best practices, provides guidelines to maximize the use of hydrographic survey data and develops hydrographic capabilities in Member States. IHO has currently 98 Member States including India. The Hydrographic Services and Standards Committee (HSSC)

is one of the major organs of IHO working with an objective to promote and coordinate the development of standards and guidelines for official products and services to meet the requirements of mariners and other users of hydrographic information. Nautical Chart Working Group (NCWG) is one of the subordinate working group of HSSC which has been developing, revising and maintaining the Chart standards and specifications viz., INT1, INT2, INT3, S11 and S4. This working group has also been working on new symbology to adopt for the new generation S100 series of products. S100 is a universal data model to cater for future demands for digital products and services[1]. The IHO Geospatial Information Registry contains several Registers containing managed lists of concepts, features attributes metadatas and other resources used to develop product specifications. A task has been given to NCWG to study the "Future of the Paper Chart" in the present digital world.

Survey Results

A study was conducted to seek inputs on use of paper nautical chart, from various hydrographic offices. It is noteworthy that only seven member states of the 248 responding to the NCWG survey indicated that only paper charts will meet carriage requirements[2]. Most indicated that either ENCs or paper charts were acceptable. Sales and use of paper nautical charts has declined by about half from 2008 to 2018 (Fig.1), while use of electronic navigational charts (ENCs) has increased about seven fold during the same period (Fig.2). Similar trend observed worldwide in the past two decades (Fig. 3). The effort required to maintain paper and associated digital raster chart formats is now becoming disproportionate when compared to the growing use of ENCs.

Hydrographic offices are now exploring different ways to reduce the burden of paper chart production, such as decreasing the number of charts in their suite of paper/raster chart products, or developing ways to create raster chart products directly from ENC data. Some efforts are also being made to make use of ENCs, or products derived from ENCs, more attractive to mariners and recreational boaters

Current Status

Many recreational boaters have also embraced the use of electronic charts. Although many of these users still keep some paper charts as a back-up or to comply with local regulations, the sales of paper charts has diminished over the past decade while use of ENCs has increased significantly. This, however, varies by country.

Limitations

The United Nations Convention on the Law of the Sea (UNCLOS) defines various maritime limits, over which coastal states have certain rights, such as Territorial Seas, Contiguous Zones, Exclusive Economic Zones, and the Continental Shelf. The convention states the need to publish these limits on charts and deposit them with the United Nations, but the convention does not specify whether the charts are to be paper or electronic. It may be time for more nations to start reporting their maritime limits on ENCs. This would also support the greater use of GIS technology to share information and identify inconsistencies

Alternative Methods of Paper Chart Provision

Chart on Demand technology has several potential advantages when compared to traditional chart production.
Chart on Demand can Reduce the cost associated with paper chart production: Since this type of system uses S-57 ENC data directly and the S-52 Presentation Library, the application of symbols and legends is automatic and standardized.
Eliminate the lag between ENC and paper chart updates: An updated Chart on Demand product can be created as soon as an ENC revision (ER) is published.
Make re-scheming irrelevant to charts: Since the user defines their own chart extent, an agency can scheme their data holdings to maximize their own internal operational efficiency, without concern for pre-existing paper chart footprints.
Harmonize paper and ECDIS visualization: Leveraging the same visualization across both paper and electronic navigational products would mean that mariners do not need to understand two disparate symbology specifications.
A move to harmonize the S-4 and S-52 symbology in S-100 could produce a machine-readable portrayal solution that would also be more human-readable.

Some of the benefits include:
Improve the feasibility of full paper chart automation.
Improve the readability of ECDIS through inclusion of cartographic rules.

Provide a single set of symbols for navigators to learn, regardless of navigational product. Maintain a single visualization standard for all maritime products. The NCWG will continue to work in close co-operation with the other working groups, delivering cartographic advice, to support and enhance the portrayal of ENCs.

Conclusion

The study reveals that the use of paper nautical chart has been decreasing since past two decades since the induction of ENCs. Paper nautical chart got its facelift from the traditional manual compilation methods to the computerized vector products. The set up on the bridge has also been changed from the traditional chart table to the ECDIS (Electronic Chart Display and Information System) and now moving forward to the real time navigation. The art of making maps is not extinct but transformed from raster paper charts to digital vector products. The Hydrographic Offices in the marine world are gearing up to create S100 compliant products by 2024 which is the roadmap defined by the IHO.

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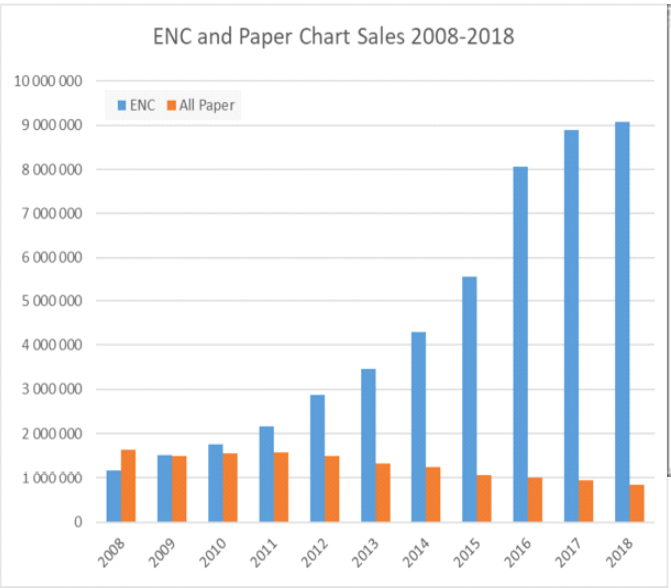

Fig. 1 ENC and Paper Chart sales during 2008-2018 (source: INHO, Dehradun)

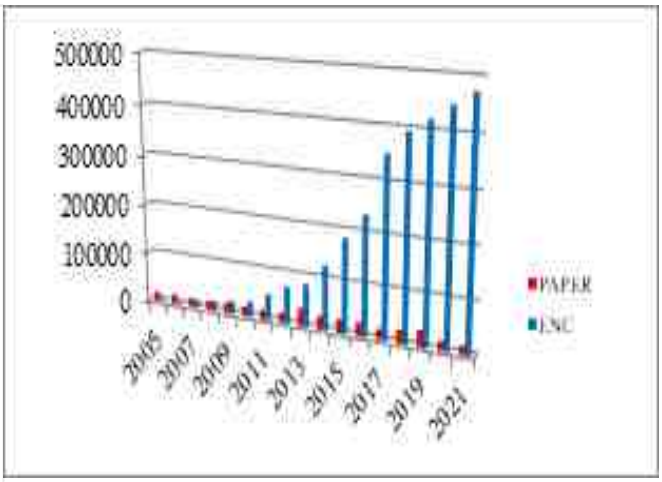

Fig. 3: Paper Chart vs. ENC Sales 005-2021 (source: NCWG Report 17 March 2020)

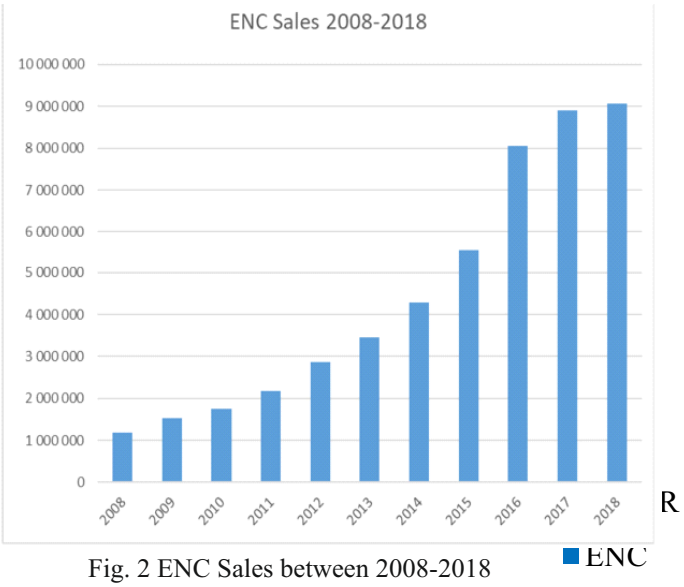

Fig. 2 ENC Sales between 2008-2018 (source: INHO, Dehradun)

Super-Resolution Reconstruction of Remote Sensing Images Using Generative Adversal Networks (MSDGAN)

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Abstract

Due to multiple high resolution sensors are floating in space, coarser resolution satellite data can be modified for better interpretation. Few of the remote sensing satellite have multispectral and panchromatic camera on a single platform. Due to higher amount of solar radiation collected per pixel, panchromatic camera will have better resolution than multispectral. Traditional methods to improve satellite resolution is based on point spread function and statistical methods. Algorithms based on PSF will increase the noise in super resolution image. Statistically based method has limitation that they need multiple iterations and they are time consuming. We propose a deep learning method for super-resolution reconstruction of multispectral image bands using panchromatic image information. Unlike traditional image processing methods that handle each component of image separately, proposed method optimizes all layers of deep learning model. Proposed method learns an end-to-end mapping between the low and high-resolution remote sensing images using a deep Generative Adversal Networks (GAN). GAN model was trained on 2000 datasets of low and high resolution pairs.

New sensors have higher radiometric resolution and dynamic range. Most of the deep learning methods for super resolution converts the image into 8 bit png/jpg to feed the input to the network, which not only change the dynamic range of input but also reduce the radiometric information. To overcome this limitation, proposed deep learning model was directly trained on 16-bit radiometric normalized orthorectified imagery in native format. In proposed method, residual blocks and dropouts was added in network to increase the accuracy and to control the vanishing gradient problem. To achieve trade-offs between performance and speed, different network structures and hyper-parameters settings was explored. Loss function which is mix of MSE and MGE gradient error was used for training the model. Different quantitative analysis matrices like peak signal-to-noise ratio (PSNR) and structural similarity (SSIM) was used to measure the performance of the model. Trained model attained PSNR of 20.04 dB and SSIM of 0.85. Analysis and results are presented in the paper in detail. Proposed deep learning model is a lightweight structure, yet demonstrates better restoration quality. Comparison of the model output with the HRI panchromatic images was done. Finally, it was observed that super – resolution has modified the accuracy of applications like object detection, segmentation and classification.

Keywords: Remote Sensing, Super-resolution, Image-reconstruction, Restoration, Deep convolutional neural networks, Generative Adversal Networks

Introduction

In recent past, multiple high resolution sensors are floating in space like, Worldview, Quickbird, Cartosat etc. Due to availability of high resolution sensors, HRI are favored over coarser resolution satellite data in various application. Coarser resolution data can be modified for better interpretation. Now a day, many applications like change detection, object detection, segmentation and classification etc. are getting developed on high resolution data acquired. Pan sharpening techniques are one of the way to increase the resolution of coarser data, but these techniques need high resolution data to fuse with high resolution data. Image pan sharpening methods aim at increasing the spatial resolution of the Multispectral images while preserving their original spectral content.

In the few decades, efforts have been made to focus on accurately predicting the point spread function (PSF). There are mainly three groups of methods: a) interpolation-based methods, b) refactoring-based methods, and c) learning-based methods. Firstly, in interpolation based methods, value of super resolution pixel is determined by nearby pixels in given resolution image. These techniques are faster and have very low time complexity. In these methods, no new information is predicted and image looks smoother. Secondly, in refactoring based methods, PSF of

the image is modified iteratively to increase the sharpness. In these methods, different information of the same scene is fused to obtained high quality reconstruction results. Thirdly, in learning based methods, PSF relationship between sensors are learned from large number of images. If we have high resolution data with PSF as psf- high and low resolution data with PSF as psf-low, then relationship between psf-high and psf- low can be modeled.

Neural network-based deep learning methods has been in the field of computer vision, due to its advantages for learning a nonlinear function from large samples. In the field of image super-resolution, the super-resolution CNN model was first presented by Dong [1] in 2014. a super-resolution generative adversarial network model (SRGAN) was also presented by replacing the original CNN structure with the generative adversarial network (GAN) [2].

In this study, we propose GAN modified for satellite data (MSDGAN), our work is based on the SRGAN model by modifying the loss function and the structure of the network of the SRGAN to increase PSNR [7] and SSIM [8] values on remote sensing data of less than 1- meter resolution.

As the newest learning model from the deep learning field, the MSDGAN shows many advantages for capturing high-dimensional nonlinear features over large input images. The major contributions of this research work are as listed as follows:-

- We propose the MODIFIED for SATELLITE DATA GAN (MSDGAN) which stabilizes the model training on remote sensing imagery.
- We test the performance of the MSDGAN on remote sensing data of less than 1-meter resolution.
- The proposed method is compared to the original SRGAN methods, and the results show that the MSDGAN achieved the better performance as compare to other learning based methods.

Methods & Workflow

We have used cartosat satellite data of less than 1-meter resolution for the entire workflow. Ortho rectified imageries were taken from march 2017 to march 2021 time period. Two images of the same area were registered with tolerance to +-2 pixels. 2000 pair datasets were prepared using cartosat orthorectified L2 products. Low resolution image and high resolution image as a pair was feeded to the network. We used the MSDGAN to train the deep neural network and obtained the super-resolution model. For the test of whether the model had trained well, we tested model on test set dataset 3 and obtained the Peak Signal to Noise Ratio (PSNR) [7] and Structural Similarity Index Measure (SSIM) [8].

GAN

The GAN is a deep learning model proposed by Goodfellow et al. [3] in 2014. The structure of the GAN is inspired by the two-person zero-sum game in game theory. The framework consists of a generator (G) and a discriminator (D), where the generator (G) learns the distribution of real sample data and generates new sample data, and the discriminator (D) is a binary classifier used to distinguish whether the data is from real samples or generated samples. The structure diagram of the GAN is shown in Figure 1. When the generator and discriminator reach the Nash equilibrium, the optimization process is completed.

We use a generated adversarial network which have two networks, the generator takes a low-resolution image and output a high-resolution image. The discriminator check how real is the generated image. In beginning, the generator produces bad quality high resolution images but as the training converges with multiple iterations, generator starts to produce realistic images. At the end when training is completed, the discriminator can't differentiate between the original high-resolution image and the one created by the generator.

There are few disadvantage of GAN like: - 1. Non convergence of generator and discriminator.

2. GAN is implicit modeling means it will have no probability distribution assumption over data.

SRGAN

The SRGAN is a super-resolution network structure proposed by Christian Ledig [6] in a paper published at the 2017 CVPR conference. But SRGAN was not developed for satellite data. SRGAN uses the GAN network, as base model. The generators use a ResNet structure. The detailed structure of SRGAN generators is shown below in figure 2-

The discriminator adopts the vgg-19 network structure [5], the detailed structure of SRGAN discriminator is shown below in figure 3 including eight convolution layers, where the Leaky ReLu activation

function for the hidden layer is used.

GAN Modified for satellite data (MSDGAN)

Problems in SRGAN

SRGAN was not designed for remote sensing images. It was design for natural images. Remote sensing images are different from natural images in various aspects like view angle effect, high noise and smaller object size. Due to the phenomena of gradient disappearance and mode collapse in the SRGAN training process, the model does not have a good reconstruction ability for remote sensing image super-resolution data of less than 1-meter resolution.

The gradient disappearance, can be explained as follows: -

The training process of the SRGAN, we want the discriminator to be strong enough to distinguish the samples well, and we want to give a result of 1 for the real high-resolution sample image and a result of 0 for the generated high-resolution sample image. In practice, the generated distribution can only be infinitely close to the real distribution, but the two can never overlap completely. Therefore, when using the gradient descent method, the generator cannot get any gradient information, which means it faces the problem of gradient disappearance. The problems stated above led to the unstable performance of the SRGAN in the training process, which led to a poor generalization ability for remote sensing image super-resolution.

MSDGAN - MODIFIED for SATELLITE DATA GAN

We proposed a model inspired by SRGAN, we modified the loss function and the structure of the network proposed the MSDGAN. In this paper we have formulated the loss function with the combination of Mean Gradient Error (MGE) and Mean Square Error(MSE). MGE will provide loss w.r.t. sharpness of edges and MSE will provide the overall content loss. We have taken a lambda (λ) parameter to balance between both types of losses. Value of λ was learned with multiple iterations. Best PSNE and SSIM was achieved with λ as 0.43.

Total Loss function = MSE + λ*MGE

$$\mathrm{MSE} = \frac{1}{n}\sum_{i=1}^{n}(Y_i - \hat{Y}_i)^2$$

Figure 4. Our Loss Function Formula.

Most of the models and research papers will focus on training with 8 bit png and jpg images and Most of the satellite data is not of 8 bit. Down sampling of satellite images to 8bit will reduce not only reduce the dynamic range but also make the image more blur. We have trained the model using 16bit TIFF images, which introduced gradient explosion problem. This problem was addresses by introducing gradient clipping in MSDGAN architecture. Below are the generator and discriminator architecture of MSDGAN which was implemented. We have introduced the skip connections before and after residual blocks, to reduce the gradient vanishing problem.

Modification w.r.t. basic SRGAN model, can be summarized as follows: -

(1) Layers is modified to take 16bit input image and gradient clipping is used in gradient explosion issue.

(2) ReLu was used in the last layer of generator to transform the classification problem into a regression problem.

(3) Max pool layers are removed as second last layer. It was observed that Maxpool layer removal has decreased the overall error and model converges faster.

(4) Pixel shuffler is removed from second last layer to handle miss registration of few pixels.

(5) The convolution kernel of the last layer of the generator was changed to 9 × 9.

(6) Loss function is changed to consider gradient change into account.

Materials and Methods

Study Area - Data Preparation and Datasets Used

Cartosat satellite have high resolution panchromatic camera and low resolution multispectral camera. We have prepared our dataset of LR images using multispectral sensor and HR images using panchromatic sensor less than 1-meter resolution. At the same time, we divided the prepared data set into three parts, namely train dataset 1 (1500 pairs), cross validation data dataset 2 (300 pairs) and test dataset 3 (200 pairs). Both the models were trained and tested on less than a meter resolution. LR data is not created using interpolation from HR data, but it is taken from different sensors and hence prepared data had slight miss registration of +- 2 pixels.

Methodology - Network Parameter Setting and Training

LR images were obtained from courser sensor and HR image was obtained from HRI sensor. LR image was brought to the resolution of HR image using interpolation techniques. During training, the batch size of 64, the ResNet [31] as generator was trained to obtain the mean square error (MSE) and mean gradient error (MGE) between the generated high- resolution image and the real high-resolution image, training 80 epochs in total. We have observed that if number of epochs is increased to 200, quality matrices will have decreased on test data. The learning rate of the generator training was 10^{-2}. Optimization algorithm which was used to update the generator and discriminator alternately until the model converged is RMSProp. The model was implemented in python using the pytorch and CUDA. It was trained on one

NVIDIA GeForce P100 GPU.

Assessment

In this paper, we adopted the peak signal-to-noise ratio (PSNR) [7] and structural similarity index measurement (SSIM) [8] as the evaluation indexes for the experimental results. Usually, after an image is compressed, the image spectrum will change, so the output image will be somewhat different from the original image. We measured the quality of the results using PSNR and SSIM.

PSNR is to measure the similarity between two images first calculate MSE between two images. The unit of the peak signal-to-noise ratio (PSNR) is dB, and the higher the value, the better the image quality. Then fit it in formula of PSNR. Max value represents the maximum pixel value that exists in the input – (L-1) – 255 image (original target image).

$$PSNR = 10 \times log(maxvalue^2/MSE)$$

SSIM method was first proposed by the image and video engineering laboratory of the University of Texas at Austin and then developed in cooperation with New York University. The SSIM algorithm is used to test the similarity of two images, and its measurement or prediction of image quality is based on uncompressed or undistorted images as a reference. The model measures image similarity in brightness, contrast, and structure. The range of SSIM is (0,1); the larger its value, the less image distortion there is.

$$SSIM(X,Y) = \frac{(2u_X u_Y + C_1)(2\sigma_{XY} + C_2)}{(u_X^2 + u_Y^2 + C_1)(\delta_X^2 + \delta_Y^2 + C_2)} \quad (20)$$

where u_X and u_Y represent the means of the gray values of image X and image Y, respectively, and δ_X^2, δ_Y^2 and σ_{XY} represent the variances of the gray values of image X and image Y, respectively.

Generally, $C_1 = (K_1 * L)^2, C_2 = (K_2 * L)^2, K_1 = 0.01, K_2 = 0.03$ and L is the maximum image value.

Results - Super-Resolution Reconstruction of Image using our model MSDGAN.

Based on the MSDGAN super-resolution training model, we tested the MSDGAN on a prepared test dataset. Some test results are shown in table below. Column 2 of Figure 8 shows the super resolution restored of Column 1 Image.

Column 1 of the figure 9 shown the metadata for Column 2 (low resolution image), Column 3 (SR model output) and Column 4 (Ground Truth) of the same row.

We compared the PSNR and SSIM of SRGAN and our model MSDGAN and found that our model performs better values. Below table compares the PSNR and SSIM values of MSDGAN and SRGAN models.

Table 1. PSNR and SSIM comparison of SRGAN and MSDGAN for our data lesser than 1 meter.

Models vs Quality	PSNR	SSIM
SRGAN	20.16	0.82
MSDGAN (our model)	26.04	0.87

Discussion

Both the models (SRGAN and MSDGAN) were trained and tested on less than a meter resolution. In comparison with the SRGAN, the MSDGAN shows better performance for SSIM on remote sensing data. Peak SNR only considers the intensity value of pixels between the two images, but SSIM considers the brightness, contrast, structure, and other information between the images. However, the black color pseudo-textures can be seen in the output of super-resolution.

The reason why black color pseudo-textures was observed is that the deep learning super- resolution algorithms try to reconstruct the nonlinear point spread function (PSF) from a large number of input images. The process of recovering the image details by the super-resolution algorithms is one to many mapping, since the number of pixels needed to be predicted always needs to be larger than the number of known low spatial resolution pixels. The other possible way to recover the image details is by using image pan sharpening technology, the consequences are when the discrepancy between the reference image and the input image goes large or due to sessional effect the land cover changes rapidly, and thus the pan sharpening based method

can fail to predict these changes. In addition, due to the fact that GANs have two networks, which are named the generator and discriminator networks, more parameters than a convolutional neural network need to be optimized during training, so a long training time is needed.

Conclusions

Based on the super-resolution algorithm of the generated adversarial network in the computer vision field, this paper aimed to improve the accuracy of deep learning model for less than 1-meter remote sensing data by combined with the method of minimizing the mean gradient error and mean square error. We also aimed to handle the slight miss registration of +-2 pixels during training time. we modified the original SRGAN architecture and proposed the MSDGAN, mainly for remote sensing images. We solved the problems of gradient disappearance and mode collapse that exist in the training of the generated adversarial network itself. Then we applied it to the super-resolution of remote sensing influence and drew the following conclusions: -

(1) The MSDGAN super-resolution network proposed in this paper is applied to the super- resolution of remote sensing images, and the results obtained are better than other popular learning based super-resolution methods, such as SRGAN.

(2) When LR and HR images are slightly miss registered, removal of max-polling layer and pixel shuffler in last layers of model helps us to cater slight miss registration of few pixels in remote sensing imagery.

(3) Trained the model directly on 16-bit satellite images will increase the training time approximately by the factor of 3,as compare to train the model on 8 bit images. Taking the land use classification as examples, we compared the classification accuracy of the images before and after super-resolution. The K-means clustering algorithm was adopted for the land use classification. The results show that the visual effect and accuracy of the images after super-resolution are modified in the classification, indicating that the super-resolution of remote sensing images is of great application value in resource development, environmental monitoring, disaster research, and global change analysis.

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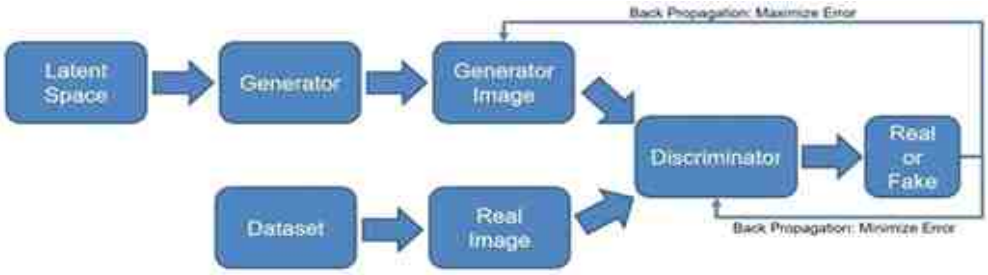

Fig. 1: Structure of generative adversarial nets (GANs).

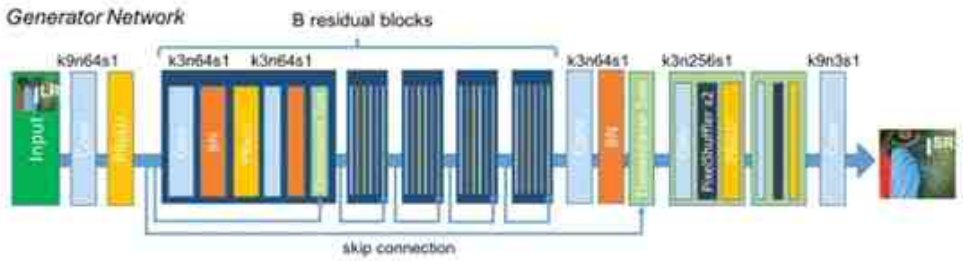

Fig. 2: Structure of generator in SRGAN.

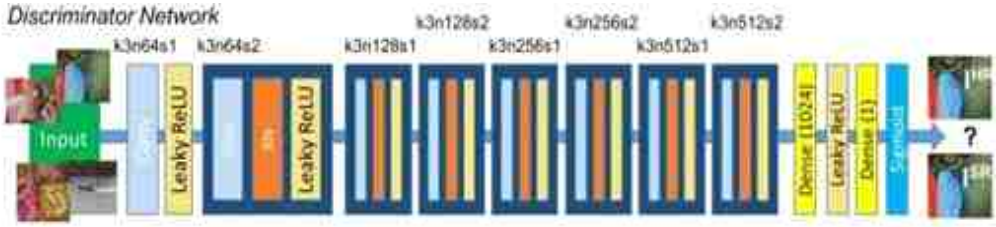

Fig. 3: Structure of discriminator in SRGAN.

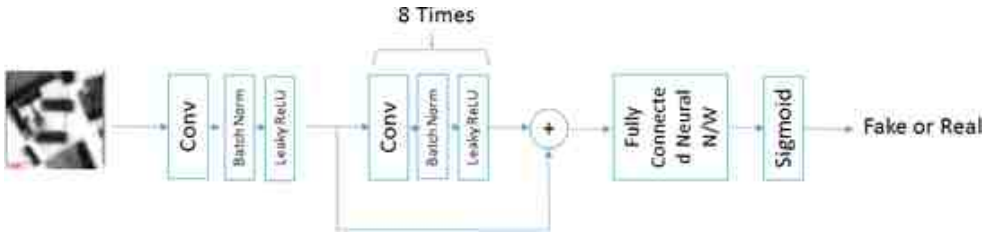

Fig. 5 : Structure of generator in MSDGAN

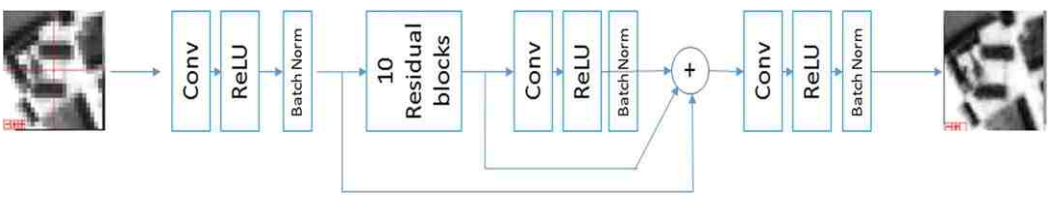

Fig. 6 : Structure of discriminator in MSDGAN.

Fig. 8 : Predicted super-resolution image using our MSDGAN model (**in 2nd column**).

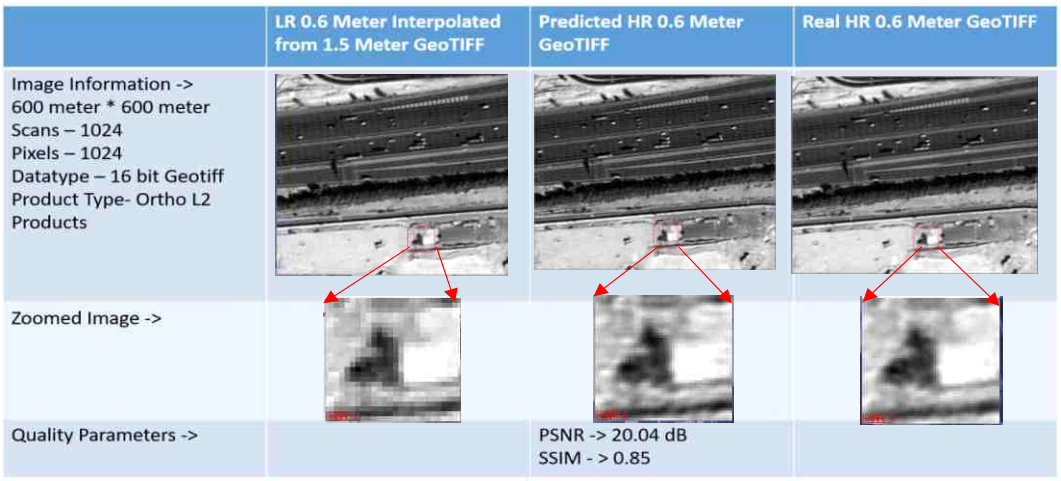

Fig. 9 : Predicted super-resolution image using our MSDGAN model (**in 2nd column**).

Flood Hazard Zonation of Majuli, Assam, India

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Abstract

The traditional methods for recording flood hydrological parameters frequently fail to capture an extreme event. In recent years, remote sensing technology combined with geographic information systems (GIS) has become the primary tool for flood monitoring. In this field, development has progressed from optical to radar remote sensing, which has provided all-weather capability in comparison to optical sensors for flood mapping. The delineation of flood zones and the preparation of flood hazard maps for vulnerable areas are at the forefront of this field. Flood depth is important for flood hazard mapping, and a digital elevation model (DEM) is the most effective way to estimate flood depth from remotely sensed or hydrological data. In flat terrain, the accuracy of flood estimation is primarily determined by the DEM resolution. This paper examines the use of remote sensing and GIS in flood management, focusing on the Brahmaputra River in Assam's Majuli district (largest river island). Majuli's flood zonation map was created using slope, aspect, rainfall, soil, land use, and land cover.

Keywords: Flood hazard, Digital elevation model (DEM), Remote sensing, Flooding, Morphology, Drainage

Introduction

Flood is known as one of the most fatal natural catastrophes that causes huge economic, social and human damages and destroys the infrastructure of any affected area(Doocy et al., 2013). The damages are two kinds-direct and indirect such as destroying houses, roads, crop fields and pasture and loss of lives(Rojas-Downing et al., 2017). Flood is an enduring issue influencing individuals of Majuli consistently during rainstorm season. Majuli gets immersed in extreme floods as well as in typical flood cycles(Jauhari, 2015). Consistently, at any rate three influxes of floods influence Majuli with various forces. The island has been encountering floods for quite a while as it is necessary piece of the dynamic floodplain of River Brahmaputra(I. Pal et al., 2013). Floods here are related with tremendous death toll and property like houses, crops and so forth, spread of pandemic, non-accessibility of fundamental items, fake value rise, nonavailability of adequate drugs, drinking water and so on. On occasion, schools, anganwadi focuses, clinical focuses get totally immersed and are shut for quite a long time together. This makes tremendous immediate and roundabout misfortune all areas of individuals. An extreme flood can make gigantic harm numerous streets, scaffolds and ducts. Remaking of these floods harmed structures requires years together for assent of asset and execution to be finished(Muzamil et al., 2022). Regularly it prompts immense dissatisfaction among individuals bringing about a few lawfulness problems. The late flood situation uncovers that nature of flooding, recurrence, and degree of flood harm has been expanding throughout the long term(Talbot et al., 2018). In spite of the fact that flood is an essential piece of life here, the unfavourable and extreme floods in the new year make the local area exceptionally defenceless and less tough contrasted with before days(Rincón et al., 2018).

The Ganges and Brahmaputra flood plains are two of India's most flood-prone areas(Gangwar, 2013). These rivers originate in the Himalayan ranges and create severe flooding in the plains of Uttar Pradesh, Bihar, West Bengal, and Assam as a result of highwater level.

There are three phases of a flood

PRE-FLOOD MEASURES

Every year, by the 15th of February, a District Relief Committee Meeting is convened to prepare a contingency plan for the upcoming flood season. The maximum number of relief camps that are expected to be established, as well as a survey of appropriate places for relief shelters. The manner in which people and non-profit organisations will be linked to relief efforts. The way Gaon Panchayat will be associated with relief operations. Repairs of roads, embankments, and other infrastructure will be undertaken by many line departments. Estimation of

the number of relief items that may be necessary and submission of proposals to the appropriate authorities. Develop a contingency plan. Repairs of roads, embankments, and other infrastructure will be undertaken by many lines department(S. C. Pal et al., 2021). Maintain a list of jeeps, buses, boats, mar-boats, trucks, and other vehicles required for the relief effort. To get a hold of Gaon Panchayat wise population duly signed by Gaon panchayat president and secretary.

DURING FLOOD

This is the outbreak phase of flood which causes the most devastation of all the phases of a flood. During this phase, affected people should follow the following:

- Boiling water should be consumed.
- Don't eat heavy meals and keep your food covered.
- During diarrhoea, drink raw tea, rice water, tender coconut water, and so on; consult your ANM/AWW for more information.
- Avoid allowing children to eat on an empty stomach.
- To disinfect the area, use bleaching powder and lime.
- Assist officials and volunteers in distributing relief supplies.

POST-FLOOD MEASURES

All departments must assess the flood damage. To get agricultural statistics from the Subdivisional Agricultural Officer regarding the acreage of crops affected by the drought(Swain et al., 2020). Flooding, crop destruction, and farm families are all affected. To submit report on losses and damages in each subdivision to the Revenue Department as soon as possible. After the flood waters receded, the Department communicated with the Deputy Commissioner. Household losses are assessed by Circle Officers. Assessment of losses to fisheries, the handloom industry, and animal husbandry by the appropriate departments(Hadian et al., 2022). Assess the need for and make arrangements for the distribution of-

- Seeds and seedlings(Sameena Banu, 2018).
- Cash and in-kind agricultural loans are available.
- Rehabilitation of people who have been uprooted due to erosion. Provide them with alternative homesteading lands in the surrounding areas.
- Request a suspension or remission of land revenue from the Revenue Department through the Deputy Commissioner. a. In accordance with the requirements of the Assam Land Revenue Manual, request suspension or remission of land revenue from the Revenue Department through the Deputy Commissioner, depending on the severity of the calamity.
- To submit reports to the government when assistance efforts begin and stop. It is critical to collect images both before and after the job is completed for this purpose.

Flood and flood risk

Flood is one of the most common natural catastrophes across the world, produced mostly by high rainfall and wreaking havoc on human existence and societal progress(Muzamil et al., 2022). Floods are grouped into four fundamental varietiesbased on their characteristics: flash flood, standing flood, coastal flood owing to storm surges, and riverine flood. The most difficult to regulate of these four categories is a riverine flood. The Indian subcontinent, which is blessed with abundant natural water resources, is subjected to floods of varying magnitudes on a yearly basis. Because its catchments receive substantial amounts of rainfall, the north-eastern area alone generates one-third of the country's total run-off through the Brahmaputra and Barak River systems. Because India is such a large country, its precipitation varies greatly in both space and time the spatial variation ranges from more than 2800 mm in the Western Ghats, Andaman and Nicobar Islands, Assam, and Meghalaya to about 300 mm in the western part of Rajasthan. The Brahmaputra River, which has a mean annual flood flow of 48,160 m3/sec and a sediment load of 400 million metric tonnes at Pandu, Assam, is ranked sixth in the world in terms of flow. Monsoonal rain (May-October) accounts for 82% of the Brahmaputra's mean annual flow at Pandu. According to the Planning Commission's Working Group on Flood Control Program for India's 10th Five-Year Plan, the country's entire flood-prone territory is assessed to be 45.64 million hectares out of a total geographical area of 329 million hectares (Ministry of Water Resources). Flooding in the floodplains of Indian rivers is a common occurrence that is not cause for alarm until it is linked to major socioeconomic implications. As a result, public perception is an essential factor in determining flood risk. Flood risk is described as the “combination of the possibility of a flood occurrence and the possible harmful implications for human health, the environment, cultural

heritage, and economic activity linked with a flood occurrence" in the EU Floods Directive. Flooding in the country's rural areas is primarily related with large-scale losses in agricultural productivity, animal loss, and occasionally human deaths. Majuli, the centre of Vaishnavite monasteries, was ravaged by numerous huge floods, according to historical sources, causing significant flood inundation and significant bank erosion. In 1735 a terrible flood occurred.

Role of Remote Sensing and GIS in flood monitoring

Earth observations from space and the air provide a unique vantage point for monitoring and assessing floods and other natural disasters(Table 1 and Table 2). Flood mapping and studies in the past were based on traditional surveys and historical flood records(Sanyal & Lu, 2004). In this way, space technology has had a significant impact on every part of life. Preparedness, prevention, and response to flood disasters are all important aspects of flood disaster management(Opolot, 2013).

What are the benefits of GIS?

- Using GIS, create a map of areas where flooding occurs frequently.
- Using geographical factors, sewage drains can be rebuilt to ensure smooth water flow.
- It may be possible to create flood simulation models.
- Using captured imagery, it may be possible to map evacuation routes.

If a weather forecast is available, government officials will be able to make informed decisions based on available maps and location.. For obtaining information about flood inundation areas and flood damage assessment, Indian and other global remote sensing satellites are being used. Satellites from India and abroad that are used for remote sensing(Bera et al., 2012).

Table 1. Indian Remote Sensing Satellite (IRS) in support of flood and disaster management.

SATELLITE	SENSOR	SPATIAL RESOLUTION (m)	REVISITE TIME	SERVICE PERIOD
Bhaskara 1/2	Television camera	1000		June 1979 to 1980 November 1981-83
IRS 1A/1B	LISS I & LISS II	36.5 & 72.5	22	March 1988-1992 August 1991-1996
IRS 1C/D	PAN, LISS 3, WiFS,	5.80, 23.5, 188	22 22 5	December 1995 – 2001 September 1997 – 2005
IRS P3	WiFS	188	5	March 1996-2002
IRS P4	OCM	360	2	May 1999-Operating
IRS P6 (Resourcesat 1)	LISS 3 LISS4 AWiFS	5.8 23.5 56	22 22 5	October 23 - Operating
IRS P5 (Cartosat 1)	Stereopan	2.5	5	June 5 - operating
Cartosat 2	Pan	1	5	January 2007- operating

Table 2. foreign remote sensing satellites in support of flood and disaster management.

SYSTEM	STATUS	CAPABILITIES
AQUA/TERRA (MODIS)	Existing	Optical 36 bands in VIS, IR SWIR, TIR
DMSP	Existing	Optical, IR
ENVISAT	Existing	Radar, optical, IR
IKONOS 1-2	Existing	Optical 1 and 4 m resolution
KVR-1000	Existing	Optical 150 km swath, 2 m
EO-1 ALI, Hyperion	Existing	Optical, VIS, IR, SWIR, TIR 10m to 30 m Multispectral (ALI) to hyperspectral (Hyperion)
LANDSAT 7	Existing	Optical, IR 185 km swath, 30 m, 80m
NOAA-GOES	Existing	Optical, AVHRR
NOAA-POES	Existing	In-situ visible and IR observation
OrbView	Existing	Optical 1, 2 and 4 m
QuickBird	Existing	Optical 1 m resolution
RADARSAT 1	Existing	C-band Radar (SAR) 45-510 km, 9-63 m
TERRASAR-X	Existing	X-band Radar (SAR) 10-510 km, 1-50 m
ALOS (PALSAR)	Existing	L-band Radar (SAR) 40-350 km, 7-100 m
TRMM	Existing	Microwave radiometer, Rain radar, Thermal MI
Resurs-03	Existing	Optical 34-600 m
SeaWiFS	Existing	Optical, IR 1-4 m sea observations
SPOT 1-5	Existing	Optical 60 km swath, 10 m, 30 m

Objective of this study is to prepare a FLOOD ZONATION MAP of the river island Majuli by the process of weighted overlay method by taking parameters like rainfall, slope, soil type data, drainage and land use/land cover of the area.

Study Area

In India's far North-east, home to huge variety of flora and fauna, lies the land of Majuli (Fig 1). The island lies in the middle of river Brahmaputra, which flows in a highly braided manner resulting in immensely unique stream arrangements. The Island is a fluvial landform, a one-of-a-kind geological event and a consequence of the elements of this tremendous stream framework. It is shaped in that stretch of the river where the biggest number of tributaries depletes out and frames their deltas on the Northern and the Southern banks. Majuli is simply an area of fluvial geomorphology. It ascends from the Brahmaputra basin and in course of time transformed into a levelled alluvial plain. The geomorphology of this area is highly related to its physiographic qualities. The tributaries of the river Brahmaputra normally carry flood along with huge amount of sand and clayey silt. The island is formed by the river Brahmaputra in the south and river Kherkutiaxuti, an anabranch of the Brahmaputra, joined by the river Subentire in the North. Majuli island is accessible by ferries from the city of Jorhat. The island is about 300-400 kms east from the state's largest city – Guwahati. Majuli is the abode of the Assamese neo- Vashnavite culture. The island has about 22 Sastras. Furthermore, there are two development blocks- Ujoni Majuli development block-Jengraimukh; Namoni Majuli development block

Kamalabari; 20 panchayats and 246 villages. Description about the study area.

Location of the Area

Between 26° - 25' and 27° - 12' North Latitude and 93° - 39' and 94° - 35' East Longitude, the island is located. The old Brahmaputra stream – the Luit or the Luhit Suti – flows north of the island at 85 metres above sea level, with a modest stream of water today and pitifully detected water reservoirs in general, forming different chaporis along its path. In the east, it is known as KherkatiyaSuti, and in the west, it is known as Subansiri. Subansiri is named after the Subansiri Stream, a Brahmaputra (Luhit) feeder that has fallen to the stream nearly at he centre motive behind the island since the wellspring of the Luhit Suti at its convergence with the Brahmaputra through the KherkatiyaSuti has now been blocked by the Government of Assam by building a massive dam across it, till it forms with the Subansiri River. On the south of the island streams the Brahmaputra which was all at once the course of the Dihing and Dikhow.

Geography of the area

Majuli Island contains a fluvial landform (a riverine delta), which is a unique geographical occurrence caused by the huge river system's dynamics. The island is around 80 kilometres long and 10-15 kilometres wide, with a total size of around 875 square kilometres and an elevation of 85-90 metres above mean sea level. It is formed in a section of the river where the majority of tributaries drain into the delta on the river's northern and southern banks. Wetlands can be found on both the north and south sides of the river Brahmaputra, which is a typical element of the system's hydrology. They're known as Beels in the area, and they're home to a diverse range of flora and wildlife that's unique to this area. The river, its tributaries, the marsh, and the chaporis, as well as the island of Majuli, combine to form the world's largest mid river delta system.

Culture of Majuli

Majuli, an Assamese pilgrimage island, is known for its landscape, culture, and, most importantly, as a site where Vaisnavism has thrived since the fourteenth century. The huge Brahmaputra River nurtures the island's abundance of flora and animal, making it a tropical paradise. Majuli is renowned as the world's largest river island nestled in the lap of the mighty Brahmaputra and also the location of multiple Satra Institutions (Vaisnavite monasteries), some of which are acclaimed as the most legendary Satras of Assam, caring for the history of socioreligious culture, and rich traditions of varied art and literature, distinguishing it from other areas in Assam. Majuli has its own unique characteristics; owing to its topographical circumstances, the island has not been well connected to the mainland, resulting in an isolated water-bounded population zone. During the Middle Ages, the island's people had little contact with the rest of civilization. Majuli rose to prominence after the fifteenth century as a result of Vaisnavite preachers and practitioners who stayed and founded Satras here, particularly following the holy advent of SrimantaSankardeva, the pioneering Vaisnavite Reformer and Saint. Majuli is home to a plethora of ethnic groups, all of which have made significant contributions to the region's rich and colourful cultural legacy. Majuli's population is a mix of Brahmins, Kalitas, Kochs, Naths, Koibartas, Misings, Deori, SonowolKacharis, and Ahoms. Chutiyas, Suts, Nepalis, and Bengalis are all ethnic groups. Mataks with a smattering of Marwaris and Muslims.

Brahmaputra River

The Brahmaputra is one of the largest river systems of the world that flows through China (50.5%), India (33.6%), Bhutan (7.8%) and Bangladesh (8.1%) for a total distance of 2880 km and has a catchment area of 5,80,000 sq. km. In India, it first flows through at a length of 278 km in the state of Arunachal Pradesh and then a length of 720 km in Assam. Flowing through the seismically vulnerable valley in Assam with an average with of about 8km, the Brahmaputra occupies one tenth of the valley. Since the area falls under seismically unstable regions of the world, the island witnesses two severe earthquakes both with a magnitude of 8.7 in the years 1897 and 1950 which are also considered the most severe ones in the recorded earthquake history.

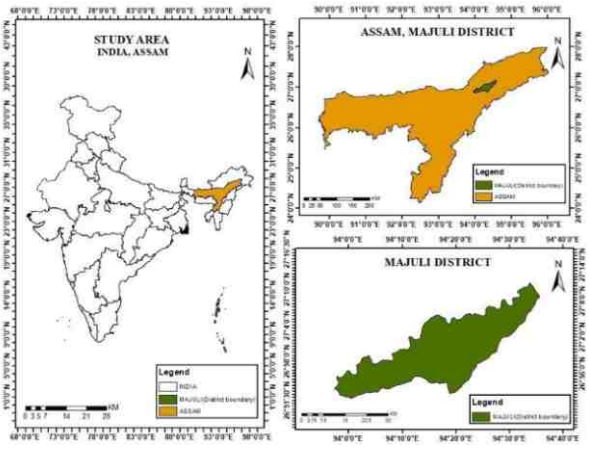

Fig.1 Location of the study area in India map.

Materials & Methods

Majuli district flood hazard zones have been established utilising a geo informatics method that includes remote sensing data and geospatial techniques. The study also made use of secondary sources of information, such as published papers and journals.

Pre-processing of image

Atmospheric correction- The principal target of applying Atmospheric rectification is to acquire genuine reflectance esteem and get physical boundaries on the earth surface including the surface reflectance, that is by expelling the barometrical impacts for the further handling of satellite pictures. There are various methods for applying Atmospheric correction on an image, as the image is processed in Arc Map 10.3, using DOS (Dark object Subtraction) suited the most. Dark Object Subtraction is a straightforward experimental air amendment strategy for satellite symbolism accessible in ENVI which expect that reflectance from dim items incorporates a considerable part of climatic dissipating. Dim article deduction looks at each band for the darkest pixel esteem. Before applying any formulas to run the DOS, we should know the TOA of the bands in the image we are processing, TOA= (0.00002*(BAND)*0.1/Sun Elevation) After obtaining the TOA, we process the formula for DOS and get a particular band Atmospherically corrected, DOS= (BAND- (Minimum Value of the BAND)) Now, after running the above formula in the Arc Map 10.3 tool (Raster Calculator), Surface reflectance values are assumed to be obtained.

Masking- Before applying the parameter's method, we mask and retain the area of interest from the Image. Using the “Extract by Mask” tool in Arc Map 10.3. Shapefile is downloaded from ArcGIS online.The masking process is used to remove the unnecessary pixels and have better contrast. It also eliminates noise which not a part of the area of interest.

Resampling- When altering a raster dataset, resampling is the process of interpolating pixel values. When the input and output do not line up perfectly, the pixel size changes, the data is moved, or a combination of these things happens, this is employed. We have to resample all the datasets into one cell size to extract the final output.

Reclassify- The reclassification tools reclassify or change cell values to alternative values using a variety of methods. You can reclass one value at a time or groups of values at once using alternative fields; based on a criterion, such as specified intervals (for example, group the values into 10 intervals); or by area (for example, group the values into 10 groups containing the same number of cells). The tools are designed to allow you to easily change many values on an input raster to desired, specified, or alternative values. Mainly data from two sources has been used, remote sensing data and secondary data from published reports and journals. Several flood affecting factors have been decided and its corresponding thematic layers have been generated such as slope drainage density etc. Finally, these all maps have been integrated using weighted overlay (fig 2).

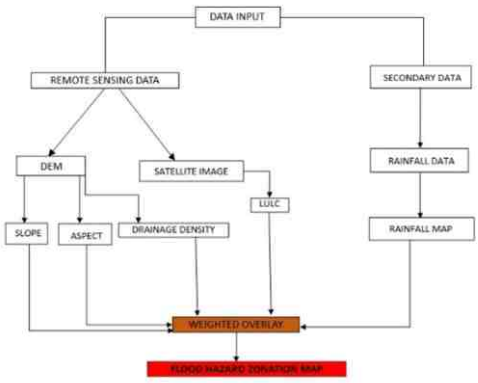

Fig.2 Methodology flow chart.

The Overall weightage of each individual layer are shown in Table 3.

Factor	Percentage	class	value
Rainfall	35	1604.5-2000.7	1
		2000.8-2360.8	2
		2360.9-2721	3
		2721.1-3081.2	4
		3081.3-3441.3	5
LULC	25	Built up	1
		Tree clad	2
		Forest	3
		Agriculture	4
		Waterbody	5
Slope	20	0-0.74	1
		0.75-2.22	2
		2.23-3.21	3
		3.22-4.94	4
		4.95-63.08	5
Drainage	20	0.88-1800	1
		1810-3600	2
		3610-5400	3
		5410-7200	4
		7210-9000	5

Data Used

A sentinel data with 10 m spatial resolution has been used for creating the Land Use Land Cover map and a SRTM DEM data is used to prepare slope and aspect of the area. The same DEM data has been further used for extracting drainage of the area.

Software Used

Arc GIS, ERDAS Imagine, Google earth pro, MS excel were used.

Results and Discussion

NDWI (Normalized Difference Water Index)

NDWIof two different seasons has been calculate using Landsat 8 data in Arc GIS. It can be seen in the given NDWI images (Fig 3) the one before flood has considerably less amount of water flowing only through the main stream of the river. A large area of sand bars can also be seen. Whereas in the NDWI image during flood a large amount of water has been seen flowing through the main stream and also there is overflow of water in the braided channels of the stream. The sandbars are no longer visible as they have been completely submerged by flood.

Fig :Before flood

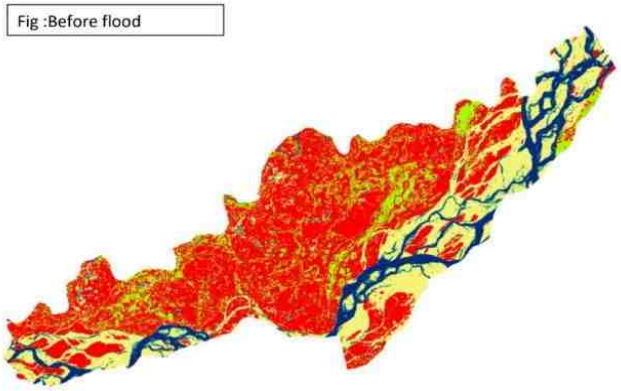

Fig:During flood

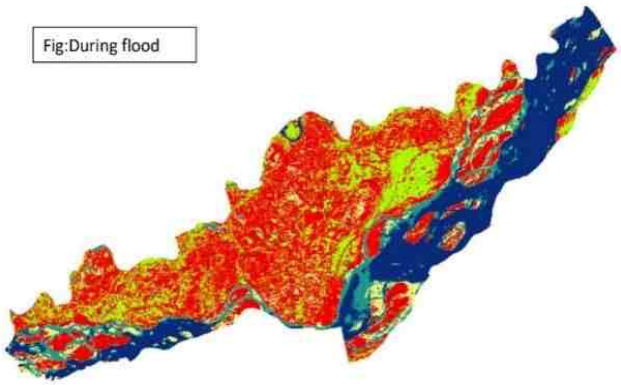

Fig.3 NDWI before and after a flood depiction.

Rainfall

Rainfall is a major contributor to floods in Majuli. Huge monsoonal rains in July, August, and September cause precipitation to overflow on both sides of the river. Flooding is intensified by the continuous sedimentation of the Paleo channel. The minimum and maximum rainfall in the district is around 1501 mm – 5597 mm. In the rainfall map shown below (Fig 4), the average rainfall CSV data has been downloaded from India WIRS website. The data was further processed in Arc GIS and a rainfall map was created using Inverse Distance Weighted (IDW) method. IDW method is used to determine cell values by using linearly weighted values of a set of sample points. The weight is proportional to the inverse distance. The surface being interpolated should be a locationally dependent variable's surface.

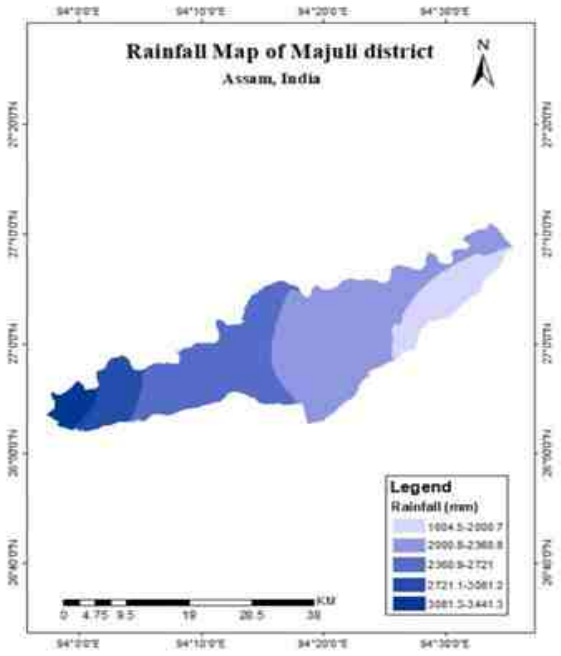

Fig.4 Rainfall in mm of Majuli district.

Drainage

The drainage of the study region was recovered using GIS tools from DEM and an automatic drainage extraction approach. To evaluate the drainage density of the studied area, a focused analysis was performed. The range of values is 0 to 9004.374. The higher the drainage density, the more impervious the surface layer is, and the lower the drainage density, the more pervious the surface layer is in nature. As a result, drainage density determines the surface layer's incidental direction. The higher drainage density could be attributable to the large number of prehistoric channels found throughout the district. Fig 5 has been divided into five different categories. The drainage density in the southwestern part of the area is of a highest class 7201-9000 and the north eastern part of the district has the

has been divided into five different categories. The drainage density in the southwestern part of the area is of a highest class 7201-9000 and the north eastern part of the district has the lowest class 0.88-1800.

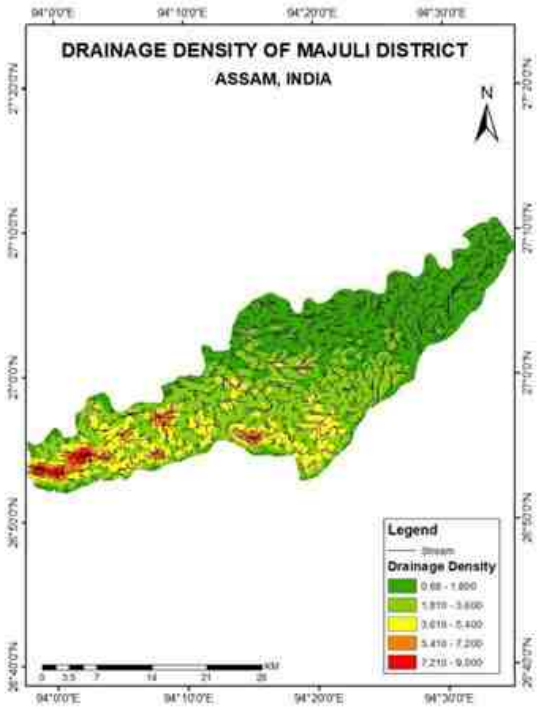

Fig.5 Drainage density.

Slope

Slope is the angle subtended from any adjacent point or the rise or the fall of the ground surface is known as slope. The slope of an area highly affects its vulnerability to flood. The rise or fall of the ground surface is referred to as a slope. It is critical for the farmer or irrigator to determine the land's slopes. In a steep terrain, a slope is simple to spot. This expansion of the slope notion enables for the planning and building of incredibly complex structures that go much beyond static buildings that are either horizontals or verticals, but may vary over time, move in curves, and alter based on the rate of change of other parameters. As a result, the basic concept of slope becomes one of the key pillars of the contemporary world in terms of both technology and telecommunications.

Table 4. Range of slopes commonly referred to in integrated field.

Slope	%	Slope	%
Horizontal	0 - 0.2	Moderate	1- 2.5
Very Flat	0.2- 0.5	Steep	More than 2.5
Flat	0.5-1	-	-

The slope map was created using an SRTM DEM with a resolution of 30m. Overall, the terrain has a mild slope that reaches a maximum of 63 degrees. A minor fraction of the area is subject to slopes more than 40 degrees. As a result, the entire district has a fairly moderate slope, which allows overflowing water to spread laterally and cause flooding during the monsoon season (Fig 6).

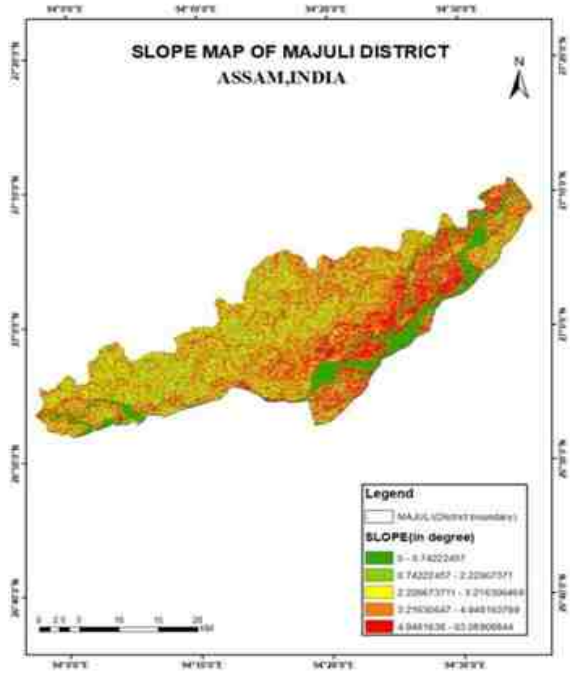

Fig.6 Slope Map.

Aspect

Aspect, in physical geography is the compass direction that a terrain surface faces in physical geography and physical geology. A slope landform on the eastern border of the Rockies toward the Great Plains, for example, is defined as having an easterly aspect (Fig 7). A slope with a westerly face features a steep valley on its western side and a lesser valley on its eastern side. Temperature may be greatly influenced by aspect. This is due to the sun's angle in the northern and southern hemispheres being less than 90 degrees or straight overhead. The northern side of slopes is frequently shaded in the northern hemisphere, but the southern side gets more solar radiation for a similar surface area insolation because the slope is slanted toward the sun and is not shaded. The farther north or south you go and the closer you go to the winter solstice, the more prominent the impacts of this are, and on steeper slopes the impact is larger, with no energy received on slopes with an angle more than 22.5° at 40° north on December 22. (Winter solstice). The aspect of a slope can have a large impact on its local climate (microclimate). For example, because the sun's rays are in the west during the warmest part of the day

in the afternoon, a west-facing slope will be warmer than a protected east-facing slope in most instances (unless large-scale rainfall influences dictate otherwise).

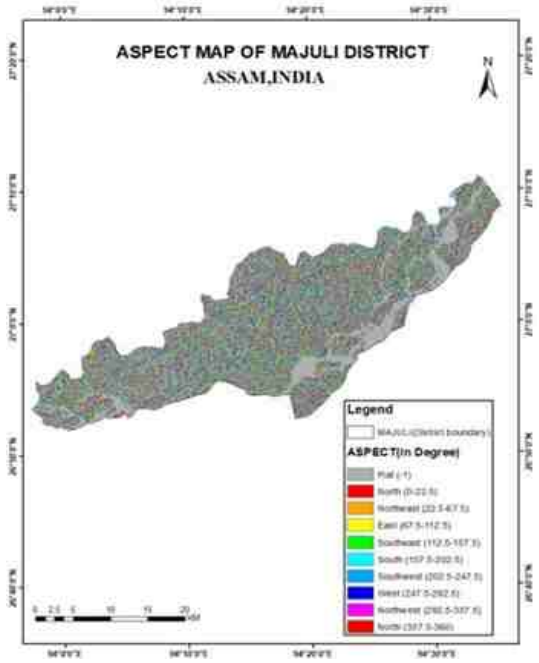

Fig.7 Aspect Map.

Soil

The floodplain morphology and channel conditions, in general, may be thought of as part of a temporal sequence linked by sediment movement and storage from reach to reach. As a result, geomorphological explanations are unsatisfactory unless they include some knowledge of the qualities of the materials used to create the current Majuli island. Brahmaputra loams are deep to very deep, grey to mottled grey, imperfectly drained to well-drained, sandy to silty loam with coarse and/or fine stratification, slightly acidic to neutral with low cation exchange capacity but moderate to high base saturation, and slightly acidic to neutral with low cation exchange capacity but moderate to high base saturation.

Land Use/ Land Cover

Although the phrases land use and land cover are sometimes used interchangeably, each has its own meaning. The surface cover on the ground, such as vegetation, urban infrastructure, water, bare soil, and so on, is referred to as land cover. Land cover identification provides the foundation Fig: Slope Map Fig: Aspect Map 30 for tasks such as thematic mapping and change detection analyses. Land Use / Land Cover (LULC) refers to the categorization or classification of human activities and natural features on the landscape throughout time using recognised scientific and statistical methods of analysis of acceptable source materials. The physical substance on the earth's surface is referred to as land cover. Land use is a description of how humans use land for socioeconomic activity.

An LULC map of the study area had been prepared using Sentinel2 dataset of February 2021. For the purpose of LULC categorization, five primary LULC classifications were identified: agricultural land, water, Tree clads, forest, and built-up area (Fig 8). The agricultural field featured a large crop-sown area as well as cultivable grounds in a pattern of patches and croplands. Waterbody include mainly the river water and water in the bells; some part of the water also includes sandbars covered with shallow water. Agriculture covers most of the area as the village people mainly practice in cropping. Tree clad covers areas in an around the small built-up areas. Remaining area is covered by forest.

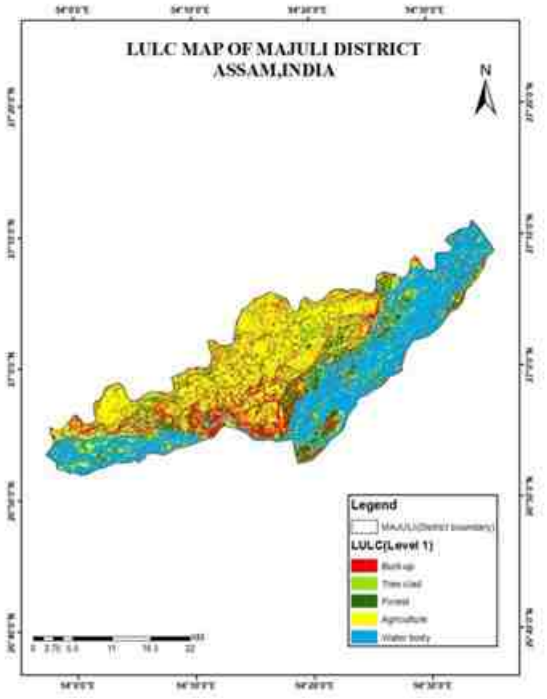

Fig.8 Land Use/ Land Cover Map.

Flood Hazard Zone

A hazard is a condition in which human life and property may be endangered. Any source of possible damage, injury, or bad health consequences on something or someone is considered a danger. A hazard is defined as the possibility of harm or an unfavourable impact (for example, to people as health effects, to organisations as property or equipment losses, or to the environment). Majuli is located in a flood-prone area with a moderate to high risk of flooding. Several blocks of the have been repeatedly inundated. The district's flood danger zone map was created using a weighted overlay approach. Various parameters, as well as distinct classes of each parameter,

repeatedly inundated. The district's flood danger zone map was created using a weighted overlay approach. Various parameters, as well as distinct classes of each parameter, have been assigned varying weightings based on their relevance or contribution to the occurrence of floods. The district as a whole is in the low, moderate, and high flood hazard zones, but only a tiny section of it is in the low danger zone, while the rest is in the moderate to high danger zone. The entire area is prone to flooding because it is a floodplain of the Brahmaputra basin. However, based on the two flood inundation maps, it is clear that the Namoni Majuli (lower half of Majuli) is very vulnerable to flooding due to its location near the confluence zone of the rivers Brahmaputra and Subansiri. After the 1950 earthquake, many structural measures were built to protect Majuli from catastrophic flooding caused by the Brahmaputra River flowing into the higher portions of the region, including damming over the KherkatiaSuti, dykes, embankments, and bunds, among others. A field study was conducted shortly after the major flood event of 2012, in the month of October, to assess the efficiency of these preventative measures. Several breaches in embankments, spurs, and roadways were discovered during the survey. During the field study, a Participatory GIS Mapping was conducted, and it was discovered that the major cause of the large-scale flood flooding in 2012 was a crack in the Tekeliphuta embankment near Haladhibari. During the two major flood disasters in June and September of 2012, this embankment was broken twice. During the survey in the Haladhibari and SonowalKachari villages, a big volume of sand (sand casting) was noticed due to the breaching of the embankment, causing damage to a substantial quantity of agricultural land as well as the inhabitants' residences and properties.

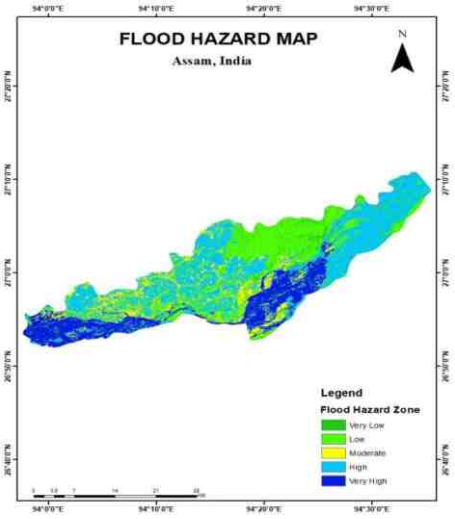

Fig.9 Flood Hazard zone of Majuli.

Majuli has been divided into 5 hazard zones: - Very low, low, moderate, high, very high. As can been seen in the fig 9 shown above mostly southern and south- western part of Majuli falls under very high flood zone therefore maximum attention is required whereas the northern and some 35 parts of eastern falls under very low flood zones and requires trivial attention. The other parts of the district fall under low, moderate and high flood zones.

Conclusion

The Brahmaputra basin in India is prone to a variety of water-related hazards, including floods, flash floods, river-bank erosion, and sand casting (the deposition of large volumes of sand by flood water). Majuli, like the rest of the Brahmaputra floodplains, is no exception. After doing a thorough study of the data and doing a field assessment, it has been determined that the problem of flooding and riverbank erosion in the region is a severe concern. In the years 1962, 1983, 1984, 1988, 1998, 2004, 2008, and 2012, the region was hit by multiple major floods, the worst of which occurred in 1998 and 2012. Despite the fact that no lives have been lost as a result of floods in the region, each flood occurrence has resulted in a significant loss of livestock and agricultural products. Along with the flooding issue, the area is also dealing with issues such as embankment breach, road breach, and sand casting. Flooding caused by river overflow is not a major worry in most regions, according to discussions with stakeholders in the region, because river water generally recedes within 2-3 days. However, when flooding occurs as a result of an embankment or road breach, the situation is exacerbated since the flood water remains stagnant for an extended period of time. Flooding caused by river overflow is not a major worry in most regions, according to discussions with stakeholders in the region, because river water generally recedes within 2-3 days. However, when flooding occurs as a result of an embankment or road breach, the situation is exacerbated since the flood water remains stagnant for an extended period of time. The flood water that enters the villages owing to embankment breaches has a significant deal of force, causing extensive damage to homes and property. It is noted that the region of Majuli is constantly changing owing to active erosion and deposition processes. Majuli's total area was 685.29 km2 in 1972, 510.51 km^2 in 2001, 525.92 km^2 in 2004, 511.88 km2 in 2008, and 521.52 km^2 in 2010. The deposition, however, is not permanent and is eroded during major flood episodes. In most regions, the erosion problem is worsened by flood

In most regions, the erosion problem is worsened by flood occurrences, with the major reason being over-steepening of bank materials caused by the deposition of large volumes of sediments during the flood. As a result of the study's results, an efficient spatial design that considers all elements of flood and riverbank erosion is urgently needed to safeguard this historic monument from future engulfment by the two river systems.

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Flood Vulnerability Assessment in the Adyar Watershed from an Urban Perspective, Chennai Basin, Tamil Nadu– A Geo-Spatial Approach

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Abstract

The study has been carried out with an integrated strategy using remote sensing and GIS techniques to identify flood susceptible locations in the Adyar watershed and preparation of Community based Action Plan for flood risk management activities. As the Chennai and its sub-urban areas are always affected by storm water, the river morphometric analysis has been carried out to understand the hydrological and stream characteristics. Rainfall trend variability has been studied with 20 years' rainfall data of 10 selected rain gauge stations located in the watershed. The MCDA has been carried out to identify the flood susceptible locations by using the physical parameters like slope, elevation, drainage density, rainfall, TWI, NDWI, NDVI, land use-land cover, distance from river, and distance from road etc. The resultant output from the MCDA has been validated with 2005, 2015 and 2021 flood in the watershed. The outcome of the present study will aid planners and decision-makers in formulating strategies to reduce food insecurity in this region.

Keywords: Watershed, River Morphometric Analysis, Flood Vulnerability Map, Flood Susceptible, Multi-Criteria Decision Analysis, Community Action Plan.

Introduction

Floods are considered natural calamities that usually result from heavy rainfall and river discharges which can lead to significant loss of life and damages to infrastructure. All natural hazards are dangerous, but the flood hazard is one of the most dangerous, widespread and frequent in monsoon-dominated tropical and subtropical regions of the world. In monsoon-dominated Asia, flooding is a perennial natural hazard, where over 80% of the population is at risk. Due to heavy rainfall, tidal surges, cyclonic events, dam and barrage discharges, and unscientific human intervention, many flood plains, deltas, and coastal regions of India have been severely affected by flood over the years.

Adyar watershed is vulnerable to flood due to its steep geography and climate characterized by rains and cyclones. These areas are vulnerable to flooding because of cyclone hits in this area. Adyar watershed is an urban area, nowadays urban areas face increased risk of disasters and the potential of economic and human losses from natural hazards and sustainable communities in the urban area, integration between urban planning and hazard mitigation effort is very necessary. Thus, the vulnerability map can be used as one of the strategies for scenario modelling for urban planning. It is a common natural disaster which happens very frequently around the world and it is one of the most destructive and frequent hazards in monsoon dominated tropical and subtropical regions of the world. It refers to water overflows from its channel over the dry area.

Watershed plays an important role in every urban place during flood and high rainfall peak time. Floods generally occurring in the low lying deltaic regions because of the quick accumulation and release of runoff waters from upstream to downstream, which is caused of heavy rainfall. There are many factors for flood which differ from area to area, it depends upon the geographical locations. It is very hard to control floods completely. So, flood vulnerability mapping is one of the most helpful tools for detecting flood susceptible areas.

Study Area

Adyar river watershed is situated in the southern region of India and comes under the Tamil Nadu state (Fig. 1). It is located between 79°50'00"E to 80°15'00"Eand 12°40'00"N to 13°10'00"N. The Adyar River originates from Chembarambakkam Lake in Kanchipuram district of Tamil Nadu and flows through the three districts i.e., Kancheepuram, Tiruvallur and Chennai and it falls in the

Bay of Bengal through Chennai city. Total catchment area of Adyar watershed is 680.0789 Sq.km and the length of this river is nearly 42 Km. Chennai city covers an area of 440 Sq.km of the Adyar watershed and witnessed the flood during the year 1943, 1976, 1985, 1996, 2005, 2015 and 2021. Flood became a common problem in the Adyar river watershed because of receiving the majority of Chennai's sewage water. The climate of the watershed is comes under the subtropical region which receives an average annual rainfall of 1104 mm.

Methodology

Datasets

An extensive use of satellite based remote sensing data for mapping and morphometric analysis was made for the study of flood vulnerability assessment in the Adyar Watershed. ALOS PALSAR satellite data has been analysed and input the derived data for 1D Steady Flow Flood Simulation.

Methods

The flood susceptibility map for the Adyar watershed was created by taking into account several flood-controlling variables. These variables were created using Landsat 8 remote sensing data, Aster DEM data, and rainfall data. Geomorphic features, land use land cover, and other data sets were analysed for information creation. The methodological flow chart has been prepared for the better overview of the research formulations (Fig.2).

Topographic Wetness Index (TWI)

The Topographic Wetness Index (TWI) is a useful tool for estimating where water will collect in a region with varying elevations. It is determined by the slope and the area contributing upstream (R. Sorensen et al. 2006)

$$TWI = ln\left(\frac{\alpha}{tan\beta}\right) \quad \text{....(Eq. 1)}$$

Where, α = upslope contributing area (m^2)

β = slope in radians.

The Compound Topographic Index (CTI), also known as the Topographic Wetness Index (TWI), is a steady-state wetness index. The upslope contributing area (a), a slope raster, and a few geometric functions are all involved. The value in a flow accumulation raster for the related DEM is the value of an each cell in the output raster (the CTI raster). Drainage depressions are represented by higher CTI values, while crests and ridges are represented by lower CTI values.

The Normalized Difference Water Index (NDWI)

The Normalized Difference Water Index (NDWI) is a method for identifying open water features in remotely sensed digital photography and enhancing their visibility. The NDWI employs reflected near-infrared radiation and visible green light to increase the presence of such features while obliterating soil and terrestrial vegetation. The NDWI could also give researchers with turbidity estimates of water bodies using remotely sensed digital data, according to the researchers. The presence of moisture in vegetation cover is determined using the NDWI index for determining fire danger. A high NDWI number suggests enough moisture, whereas a low value indicates water stress. The NDWI product is dimensionless and ranges from -1 to +1, depending on hardwood content, vegetation, and cover. High NDWI values (in blue) indicate a high plant water content and a high plant fraction coating. The NDWI rate will drop during times of water stress.

For water body mapping, the NDWI index is the best option. The water body has a high absorbability and emits less radiation in the visible to infrared wavelength range. Based on this occurrence, the index uses the green and near-infrared wavelengths of remote sensing photos. In most circumstances, the NDWI can effectively improve water data. It is sensitive to developed terrain and frequently leads to overestimation of water bodies.

$$NDWI = \frac{(Green - NIR)}{(Green + NIR)} \quad \text{....(Eq. 2)}$$

Where, *NIR* = reflection in the near-infrared spectrum

Green = reflection in the green range of the spectrum

The Normalized Difference Vegetation Index (NDVI)

The Normalized Difference Vegetation Index (NDVI) measures the difference between near-infrared (which vegetation strongly reflects) and red light to quantify vegetation (which vegetation absorbs). This index ranges from -1.0 to 1.0, essentially depicting greens, with negative values originating from clouds, water, and snow, and values close to zero originating from rocks and bare soil. The NDVI function has very low values (0.1 or less) that correlate to vacant expanses of rocks, sand, or snow. Shrubs and meadows are represented by moderate values (0.2 to 0.3), while temperate and tropical forests are represented by big values (0.6 to 0.8)

$$NDVI = \frac{(NIR - Red)}{(NIR + Red)} \quad \text{....(Eq. 3)}$$

Where, *NIR* = reflection in the near-infrared spectrum
RED = reflection in the red range of the spectrum

Multi-Criteria Decision Analysis (MCDA)

Multi-Criteria Decision Analysis is a strategy that uses a controlled set of approaches to assist decision makers in making key decisions based on a number of criteria. When decision makers must make a decision based on a large number of conflicting evaluations, the MCDA procedures are ideal. T. Saaty (1977, 1980, 1988, and 1995) developed the Analytic Hierarchy Process (AHP), which is the most preferred and appropriate MCDM method. The AHP was created by Thomas Saaty (University of Pittsburgh) and is based on three principles: deconstruction, comparison judgment, and priority synthesis. AHP is a mathematical method for assessing multi-criteria difficult decision problems.

Result and Discussion

Land use/land cover

One of the major issues in flood hazard mapping is land-use and land-cover management, because this is one component that not only reflects the current use of the land, its pattern and kind of usage, but also the relevance of its use in connection to soil stability and infiltration. Land use, such as houses, highways, and slum areas, reduces the soil's penetration capacity and increases water runoff. In other words, land-use types act as water-resistant coverings, reducing the time it takes for water to ccumulate; and, in most cases, they raise the peak discharge of water, resulting in more severe flooding. This means that land use and land cover are important factors in determining the likelihood of floods.

For the year 2021, supervised classification (Fig. 3) using the maximum likelihood classifier was performed on Landsat 8 images (NRSC, 2014). Since Chennai, India's fourth largest metropolitan city, is located in the Adyar watershed zone, the goal of this study was to determine the rapid urbanization that occurred there. This research objective will aid municipal planners and administrators in ensuring the city's long-term viability in newly developed suburbs while also limiting further urban growth. The categories land cover found in the research area as follows built-up, agricultural land, forest, water bodies, scrubland and barren land (Table 1).

Rainfall Variability

Adyar watershed covers Poonamallee, Nungambakkam, Saidapet, Guindy, Meenabakkam, Chembarambakkam, Sriperumbudur, Tambaram and Kattankulathur rain gauges station of three districts of Tamil Nadu. To meet the first objective, mean annual rainfall for 20 years (2001–2020) is examined and interpolated using Inverse Distance Weighting (IDW) to construct a continuous raster rainfall data inside the study area (Fig. 6).

Year wise variation of rainfall data of 2001-2020 of Chennai.

Using data from 2001 to 2020 across the research area, this study evaluates and estimates long-term Spatio-temporal changes in rainfall. The rainfall trend was studied using the Mann-Kendall (MK) test and Sen's Innovative trend analysis. 20 years of monthly and yearly average rainfall has been shown (fig. 4 and Fig. 5).

Elevation

Flooding is influenced by a number of factors, the most important of which is elevation; in general, the likelihood of flooding increases as elevation decreases (Choubin et al. 2019). To extract the elevation map of the research area, an ASTER GDEM with a resolution of 30 m was downloaded from the Earth Explorer USGS data access portal. Adyar watershed covered four of the data tiles that required pre-processing such as mosaicking, no data value elimination, and extraction based on the research area boundary. Finally, the resulting elevation raster, which ranged from 2.57-155.94 m, was reclassified into five elevation classes. The research region is dominated by very low to low elevated areas with elevations ranging from 0 to 30 meters above mean sea level (Fig. 7a). In the research area, one of the key conditioning factors for floods is the low elevation.

Slope

The flow and flooding of a certain area are influenced by the length and steepness of the topographic slope. Low and flat topography, for example, reduces runoff and causes significant infiltration inside the area, resulting in water logging. In addition, during floods, the low-lying area with a low slope angle will be swamped first, as opposed to the high-slope area. When compared to low-lying areas, places with steep slopes have higher peak discharge, causing storage in upstream areas to be depleted.

Flooding is a physiographic trait that is directly related to

slope gradient. Slope impacts flood susceptibility by influencing surface runoff velocity and vertical percolation. The slope map was created in ArcGIS using the DEM layer. The slope in the research region ranged from 0 to 35 degrees, indicating a flat topographic characteristic (Fig. 7b).

Distance from River

River flows are the primary conduits for flood discharge, and regions adjacent to rivers are particularly vulnerable to floods. The multiple ring buffer tool in ArcGIS was used to calculate the distance from the river in this investigation. This distance varied between 300 to 1500 meters.

Drainage Density

The density of drainage has a significant impact on the presence of flood. It has a favourable relationship with flooding since a big number of streams multiplies the flood potentiality. Drainage density, as the name implies, is the concentration of flow. Flood susceptibility is likely to be increased in areas with high drainage density, as for the Adyar watershed it is to be seen in several areas (Fig. 7c) and the Dd values to be seen as 1.08 km/km^2.

Distance from Road

When roads are built, the percentage of impermeable surfaces increases, resulting in decreased groundwater recharge and topographic changes, which affect flow and excessive runoff. The flood susceptibility classes for the raster of road distances were the same as those for "distance from rivers."

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The Compound Topographic Index (CTI), also known as the Topographic Wetness Index (TWI), is a steady-state wetness index prepared for the Adyar watershed (Fig. 7d). The upslope contributing area (a), a slope raster, and a few geometric functions are all involved. The value in a flow accumulation raster for the related DEM is the value of each cell in the output raster (the CTI raster). Drainage depressions are represented by higher CTI values, while crests and ridges are represented by lower CTI values.

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The Normalized Difference Vegetation Index (NDVI)

The Normalized Difference Vegetation Index (NDVI) measures the difference between near-infrared (which vegetation strongly reflects) and red light to quantify vegetation (which vegetation absorbs). This index ranges from -1.0 to 1.0, essentially depicting greens, with negative values originating from clouds, water, snow and values close to zero originating from rocks and bare soil. The NDVI function has very low values (0.1 or less) that correlate to vacant expanses of rocks, sand or snow. Shrubs

and meadows are represented by moderate values (0.2 to 0.3), while temperate and tropical forests are represented by big values (0.6 to 0.8) in the Adyar watershed (Fig. 7f). In the Adyar watershed the NDVI value ranges between -0.4 to 0.78.

Geology

The Adyar basin is occupied by nearly 60% of sedimentary formation and 40% of hard rock formations. Rocks of Archaean, Proterozoic, Jurassic, cretaceous, Tertiary - Quaternary age and alluvium are exposed in this basin (Fig. 7g). The hard rock formations are occupied in the west and south-eastern side of the basin. Biotite Hornblende gneiss and Epidote Hornblende gneiss occur in the western part of the basin whereas Charnockite occupies in the south-eastern part of the basin.

Flood Vulnerability Map

The flood susceptibility map of the Adyar Watershed was created using morphometric data such as elevation, slope, drainage frequency, and other characteristics such as rainfall, NDVI, NDWI, and land use maps (Fig. 8). All of these levels have been classed based on how important they are in terms of flood vulnerability. The flood vulnerability map was created after the strata were reclassified.

Flood vulnerability zones are depicted in the figure are divided into four categories: very high, high, medium, low. Table 5.9 shows that very high flood-vulnerable zones cover 42.85% of the watershed, high flood-vulnerable zones cover 29.41%, moderate flood-vulnerable zones cover 9.88 percent and low flood vulnerable zone covers 17.86 percent. The lower portion of the Adyar watershed, it might be established, is extremely vulnerable to flooding.

Conclusion

Due to the abundance of sand and silt in the Chennai district, geological factors do not contribute to flooding. Geomorphological landforms such as alluvial plains, coastal plains, flood plains, and Pedi-plains caused the district's majority of land to be classified as highly vulnerable. In terms of LULC, the majority of the district is built-up land, with water bodies, cultivable land, and waste land covering the remainder, resulting in the district being classified as high susceptible. After the validation and scenario of water surface levels from various incidents clearly reveals that the river overflows the majority of its accessible buds, demonstrating the need for engineering facilities such as dykes and levees along the river channel. Prior to the monsoon season, water bodies must be desilted. In order to avoid future flood-related destruction, the state government must take proper actions. In any future infrastructure design, the Chennai district should not be viewed as a single geographical region. The government should regard the districts of Thiruvallur, Kanchipuram, and Chennai as a single planning entity. Because rivers that run through these districts carry a lot of water after heavy rains and discharge it into Chennai, these districts are flooded.

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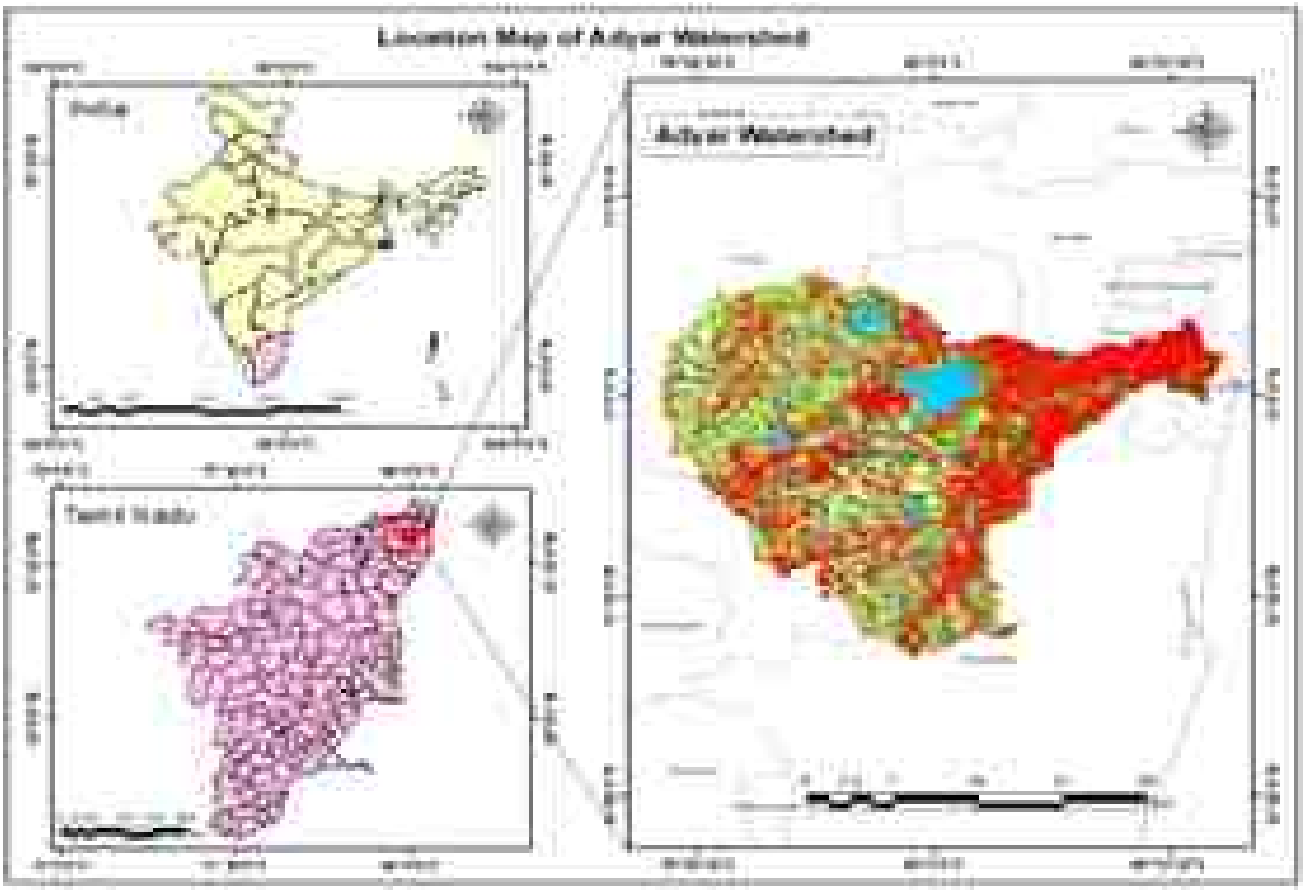

Fig. 1: Adyar Watershed study area

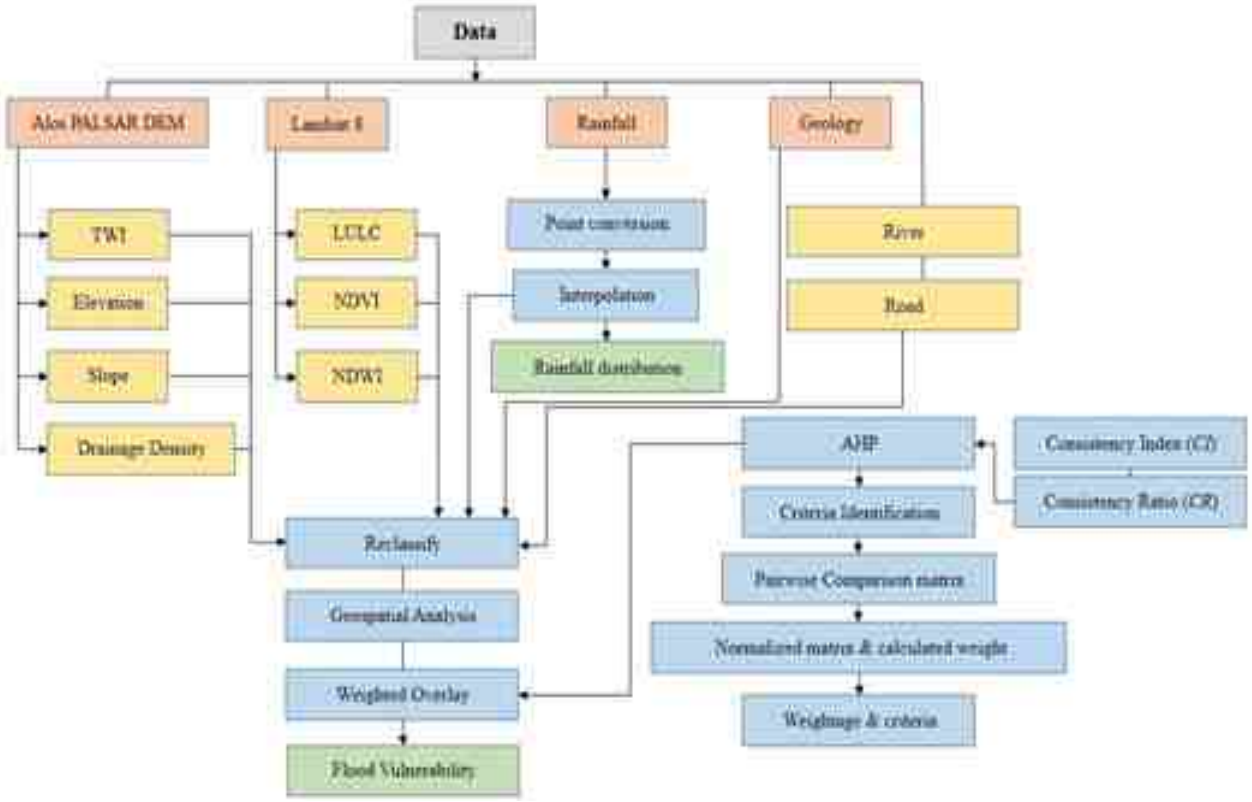

Fig. 2: Methodological flow chart

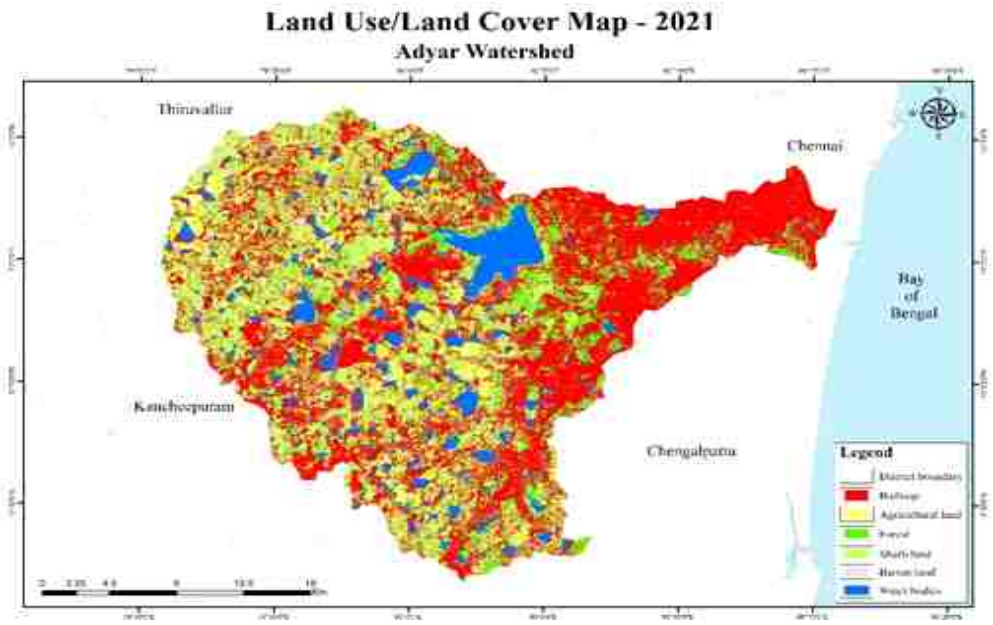

Fig. 3: Land use Land cover map of Adyar Watershed

Table 1: Land use Land cover classification area.

Class names	Area in km^2	Percentages
Agricultural Land	44.70	13.07
Barren Land	0.41	0.05
Built-up	291.70	35.29
Forest	163.50	15.00
Scrub Land	259.30	29.00
Water Bodies	66.80	8.09
Grand Total	826.50	100.00

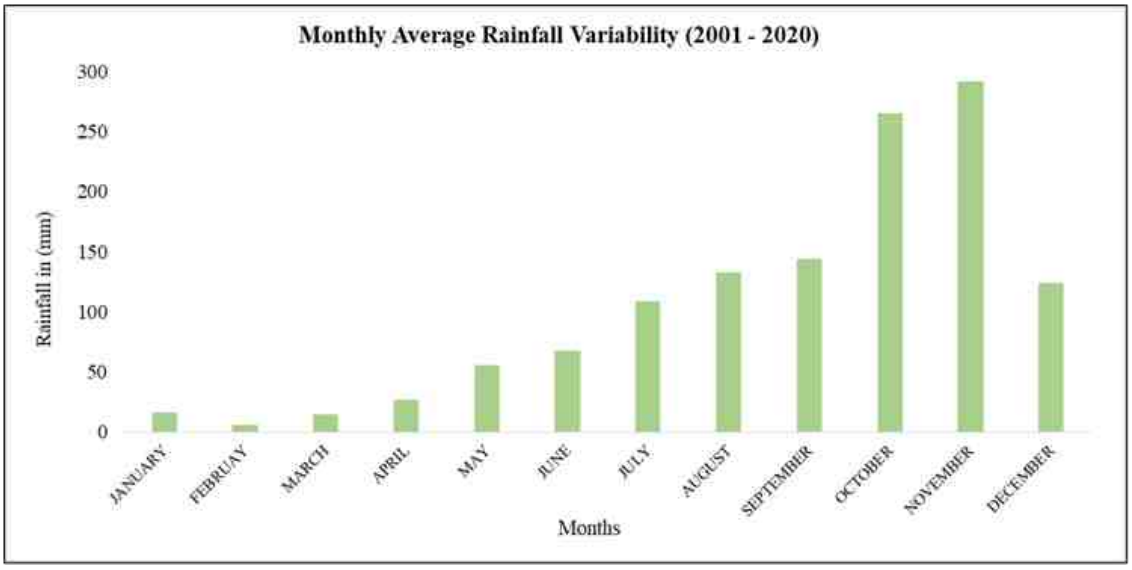

Fig. 4: 20 Years of Annual Average Rainfall of Chennai District (2001-2020) (Source: Indian Meteorological Department)

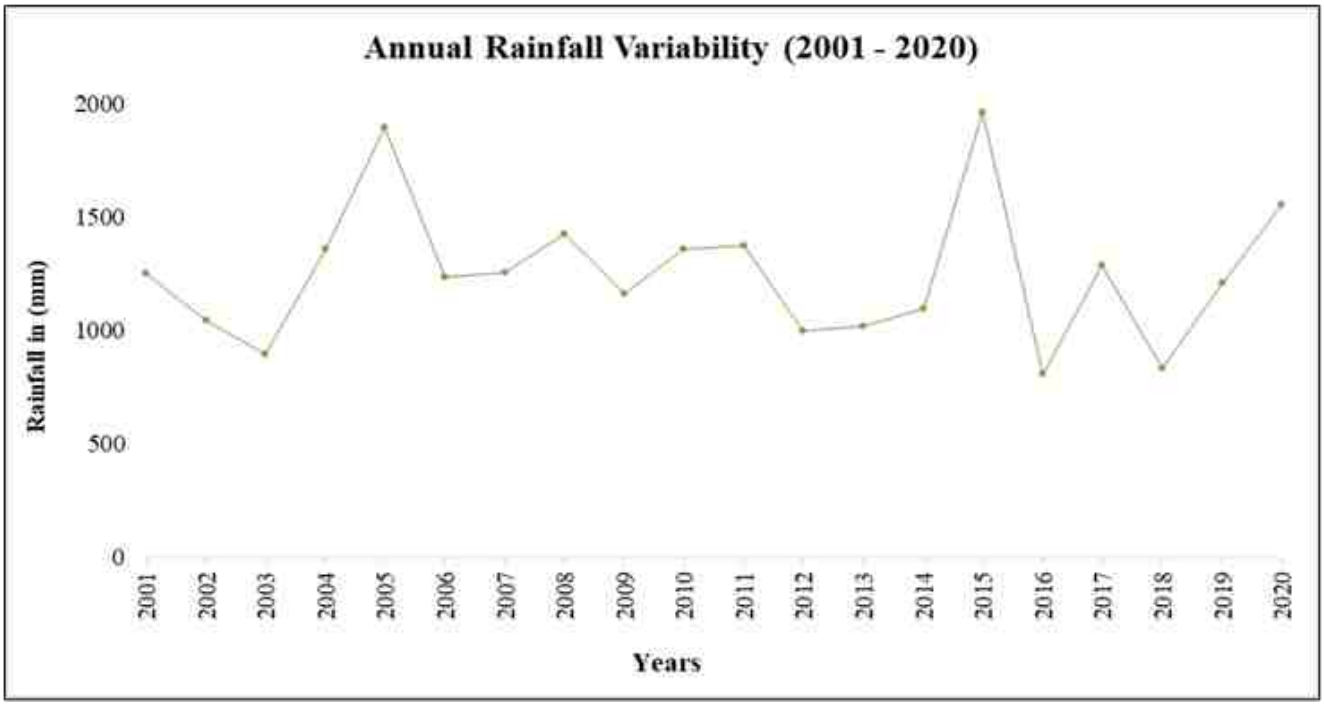

Fig. 5: 20 Years of Annual Average Rainfall of Chennai District (2001-2020)

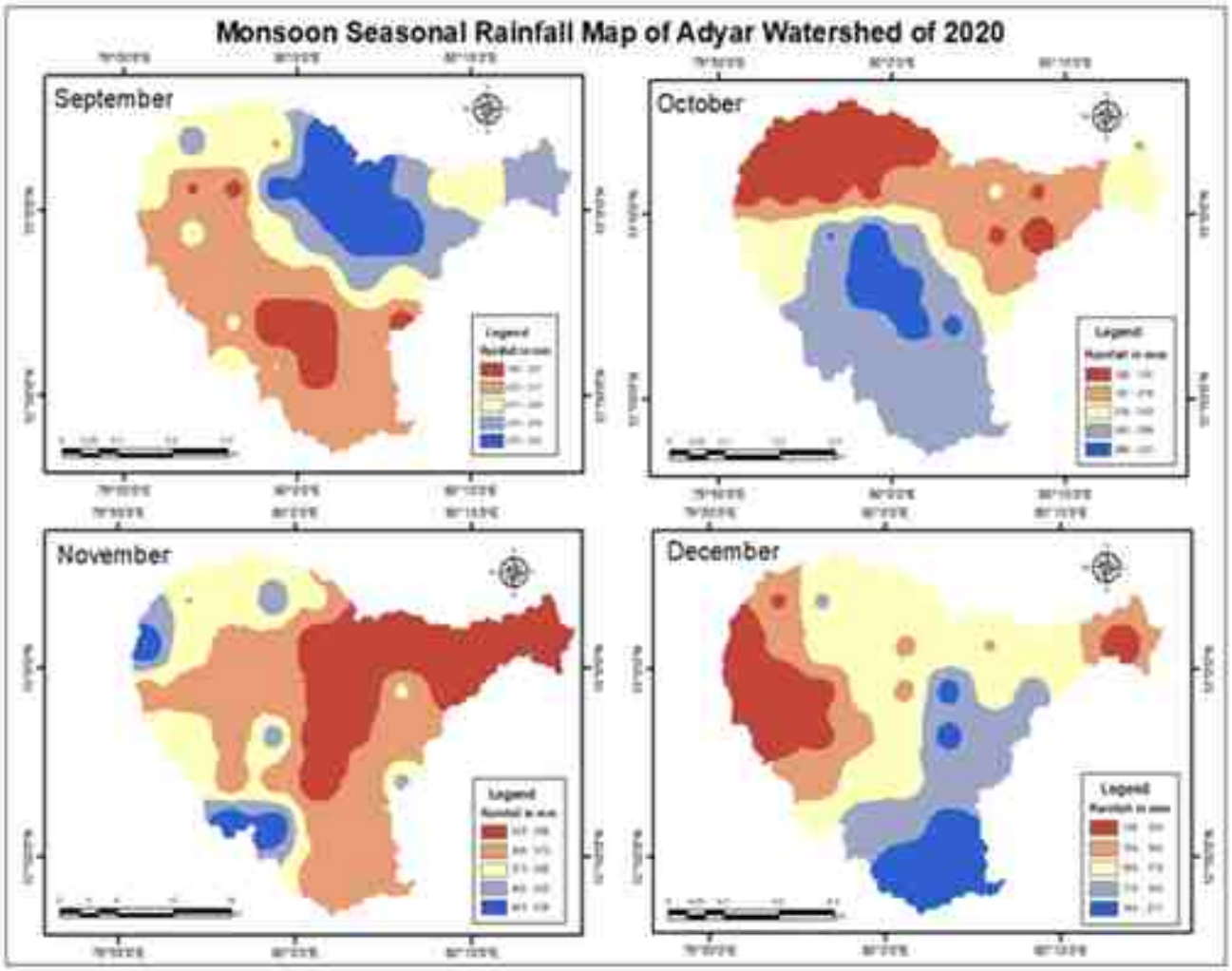

Fig. 6: Spatial distribution of rainfall in the watershed during the monsoonal season, 2020

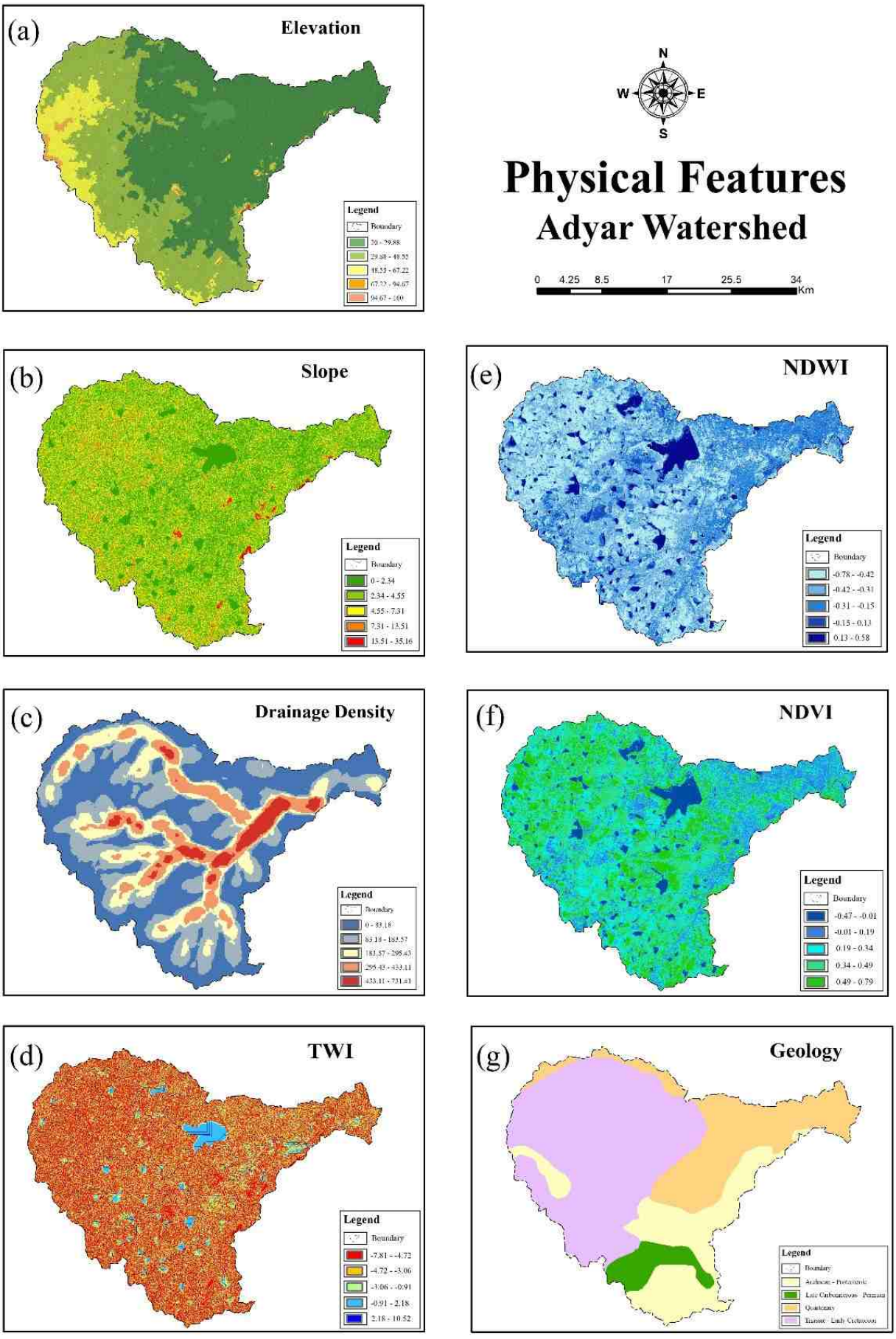

Fig. 7: Physical features of Adyar Watershed, (a) Elevation, (b) Slope, (c) Drainage Density, (d) TWI, (e) NDWI, (f) NDVI, (g) Geology.

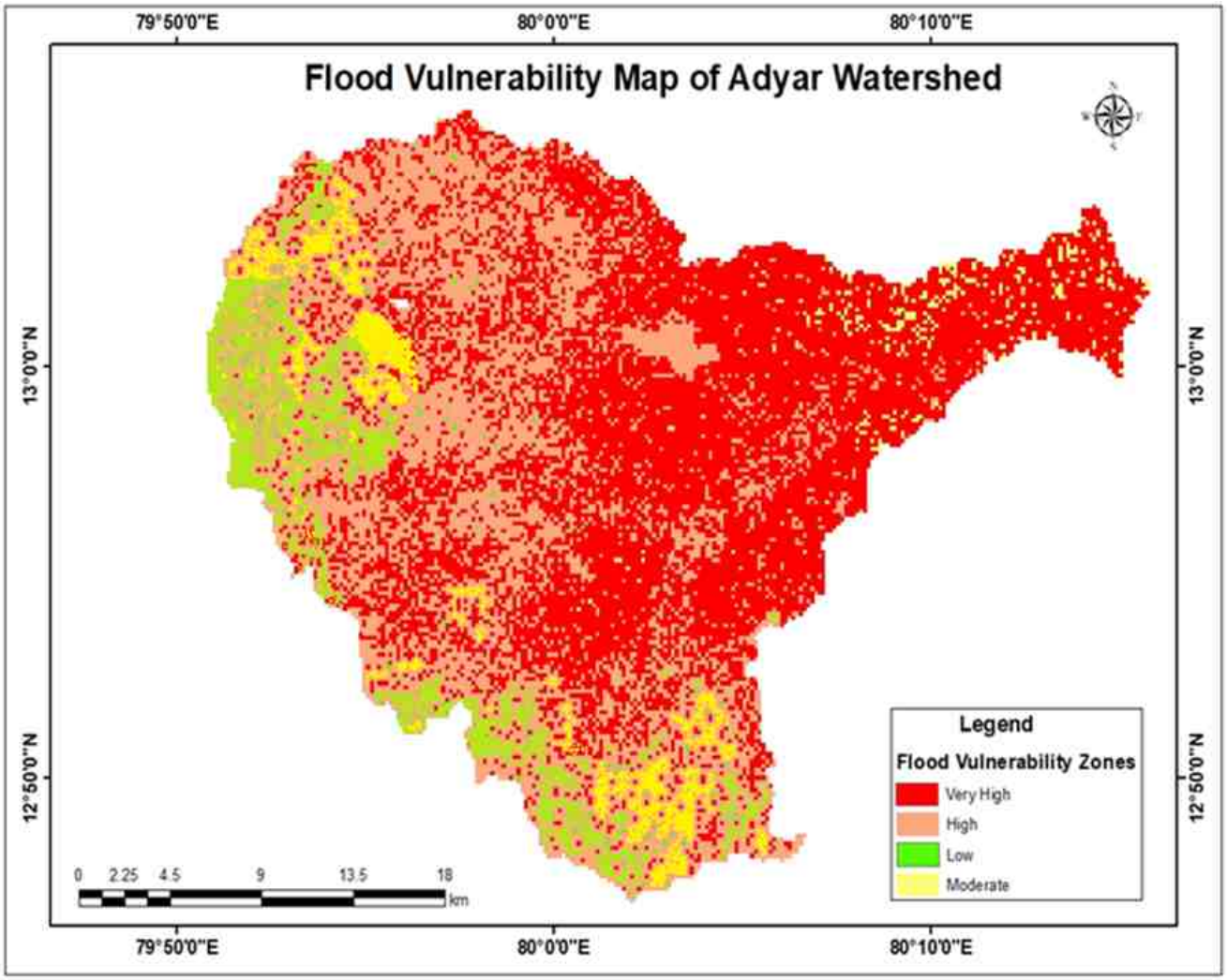

Fig. 8: Flood Vulnerability Map of Adyar Watershed

Mapping: Climatic Vulnerability of Drought-Prone area of Palamu Division, Jharkhand.

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Abstract

Drought is defined as an extended period of abnormally dry weather that causes water shortage and crop damage. Drought is the result of the shortage of total rainfall well below average for several months. Other signs of drought include visually low river flows, low groundwater and reservoir level, very dry soil, reduce crop ills or even crop failure. Water is of paramount significance for all biotic life and for the extended killing of agricultural products. It is very much related to the timing and effectiveness of the rain. An attempt has been made to study the climatic vulnerability of the drought of the Palamu division which is severely prone to drought. Its intensity is very high in the Jharkhand state. The district has a minimum number of dams in the state and reeling from severe drought and acute drinking water shortage. The average temperature in a Palamu division is around 44°C in summer. Vegetation contrast, soil moisture, crop production and precipitation have been considered as the major parameters for drought studies. For the present analysis, three indices (NDVI, NDWI & NDVI) are used to predict the severity of droughts. The resultant indices, crop production data and drought index are used to repeat the intensity of the crop. This study will be highly useful for the planner to work out a strategy to mitigate the severity and vulnerability of drought.

Keywords: drought, vulnerability, damages, crop failure, water shortage, Palamu division

Introduction

Climate variability is among the major phenomenon occurring worldwide which has caused major changes in climate variables such as precipitation, air temperature, relative humidity, and solar radiation (Haskett et al., 2000, Bates et al., 2008, Yu et al., 2013). Because of these alterations, there is a consistent warming trend which is clearly reflected by the increasing occurrence of extreme climate events like droughts, floods, and heat waves (Meehl et al., 2007). Natural disasters worldwide are a result of extreme events rather than just a variation of the mean climate (Plummer et al., 1999). According to the fifth report of the Intergovernmental Panel on Climate Change (IPCC, 2013), the average maximum and minimum temperatures over land have increased worldwide by an excess of 0.1 °C per decade since 1950, including in India, thereby affecting agriculture, water demands, and more rapid melting of glaciers. The report also stated that extended intervals of monsoon failures and dry spells have struck India and southeastern Asia, in the last few years leading to prolonged and intense droughts, which are a recurring feature of Holocene paleoclimate, also, the frequency of heavy precipitation events is increasing while light rain events are decreasing. The climate variability has led to increased evapotranspiration rates, the decline in soil moisture, socio-economic consequences with longer dry periods, and a greater number of extreme events (Izrael et al., 1997, Cruz et al., 2007, Ramos et al., 2012). Higher or lower rainfall or changes in its spatial and seasonal distribution influences the spatial and temporal distribution of runoff, soil moisture, and groundwater reserves, and thereby affect the frequency of droughts and floods (Kumar et al., 2010, Jhajharia and Singh, 2011).

The changes in climate extremes have drawn the attention of researchers worldwide because of their critical impacts on human society, economic development, natural ecosystem, and the environment (Vincent and Mekis, 2006, Torma et al., 2011, Ji-Yun et al., 2012). Indices for climate variability and extremes have been used for a long time, by assessing days with temperature or precipitation observations, which provide insight into local conditions, physically based on relative thresholds that describe features by examining the distributions of meteorological parameters through well distributed meteorological stations over the study area (Moberg and Jones, 2005, Zhang et al., 2011, Dutta et al., 2015). Amongst all the climate change indicators, the indicators for temperature and precipitation or their derivative quantities are widely used in monitoring and quantifying the extreme meteorological and hydrological climatic events (floods and droughts) (Wang et al., 2011). Researchers like Frich et al. (2002), found an increase in warm summer nights, a decrease in the number of frost days, and a decrease in intra-annual extreme temperature ranges, while extreme

globally, and significant increases were seen in the amount derived from wet spells and the number of heavy rainfall events.

The climatic variability over the state of Jharkhand has been analyzed in the present study as it follows a similar drift of global warming scenario as reflected worldwide. The northwestern region of Jharkhand like Palamu and Garhwa in particular has been suffering from an extended dry spell which has led to a number of severe impacts in the region. Thus, detailed monitoring and assessment of climate trends over Jharkhand requires to be evaluated for analyzing the impact of rainfall and temperature on society, agriculture, and the environment

Study area

The study was conducted for the entire area of the Palamudivision of Jharkhand, which lies between 23°50′ N to 24°8′ N latitude and 84°10′E to 84°30′E longitude covering an area of 4393 sq km where most of the districts come under the Chota Nagpur Plateau. Climatically, the Palamu district weather is significantly varied with the northwest and west central parts of the district being hot with less rainfall and the southwest receiving more rainfall. The three most prominent seasons in the palamu division re characterized by summer, winter, and rainy season, wherein the summer season comprises the months from March to June with May being the hottest month and the winter season consists of the months of November to February and is the most pleasant part of the year. The southwest monsoon precipitation from mid-June to October is primarily responsible for the state's annual rainfall where most of the precipitation falls in July and August. The annual precipitation ranges from about 1000 mm in the west-central part of the district to more than 1500 mm in the southwest (www.jharkhand.gov.in). The agricultural land and forest cover 33.25% and 31.9899% of the total geographical area of Palamu district respectively. The location map of the study area is shown in Fig. 1.

Material and methods

The data recorded at Zonal Research Station, Chianki, Palamu has been used for the analysis. The average annual, seasonal and monthly temperature, evaporation, water balance and humidity have been presented and the comparison has also been done. The changing nature of climatic classification for understanding its pattern and ecological condition so that estimation of agricultural potential may be done by the using formula as suggested by Thornthwaite. This formula is based on PE index which are:

PE index (precipitation of effectiveness index) =

P / E X100

Where, P = annual precipitation, E = annual evaporation

Based on the PE index.

Based on The Thornthwaite classified the climate into five groups as shown below

Table PE index according to Thornthwaite climatic classification

Symbol	Humidity provinces	PE index
A	Wet	128
B	Humid	64-127
C	Sub-Humid	32-63
D	Semi-arid	16-31
E	Arid	Less than 16

Results and Discussion

Rainfall pattern: According to Sah et al., (2008) a drastic reduction in annual rainfall during the last ten years (1997-2007) was observed. It has reduced to 830.4mm as against to1304.4mm (1958-67) and 1467.9mm during 1968-77.

Impact of change in nature of climate: The study clearly revealed that the climate of Palamu region has changed from sub-humid to semi-arid. This remarkable change is due to impact of climate change. During 1976-85, PE index was 41.4 and 56.5 during 1986-2003 periods but during 2004-2020 periodictime it has a remarkable change, 26.38 it is very low PE index comparison to before time. (Table 2)

Temperature: A rise in mean annual maximum temperature by 2.9°c during 1981-2003 has been observed. Similarly, the mean annual minimum temperature has also reduced by 3.6oC. Thus, the gap between mean annual maximum and minimum temperature has been widen (Table 2). The mean maximum temperature for all months has gone up whereas the mean minimum temperature for months has been reduced. The highest rise in mean maximum temperature has recorded in the month of May (4.7o C) and the maximum decline in mean minimum temperature has recorded in the month of November

(-6.2oC) (Table 3). This is a typical example of impending impacts of climate change. The study also revealed that there is 4.6oC increase in maximum temperature during February month which is very important for wheat crop. The high temperature, even for short period affects the crop growth in wheat by reducing the growth of shoots and in turn reduces root growth. The higher temperature during booting stage resulted in pollen abortion. In case of wheat the temperature higher than 27oC causes under development of anthers and loss of viability of pollen resulting reduction in yield of wheat. The higher temperature (39.4oC) during March and April are causing the forced maturity in wheat and chickpea whereas the low temperature lesser than 10oC are affecting the flowering and pod initiation stage in chickpea resulting in poor pod set and ultimately the yield is reduced.

Evaporation: Temporal analysis showed that the mean annual evaporation has increased drastically during 1986-03. It was 4170.6mm during 1986-03whereas during 1976-85 it was only 2899.0mm meaning thereby there is1271.8mm (43.9%) increase in mean annual evaporation during 1986-2003. Similarly, during the same period 92.4mm (7.7%) lesser amount of mean rainfall was also observed (Table 4).

The result revealed that evaporation has increased in all seasons during 1986-2003. It has increased from 1115.7mm to 1656.3mm, 386.4mm to 679.7mm, and 183.4mm to 259.2mm and 1213.0mm to 1597.3mm during monsoon, post monsoon, winter and Pre monsoon season, respectively (Table 4). Evaporation has also been increased in all the months (Table 5).

Impact on water balance: The annual water deficit has increased during 1986-2003(3063.6mm) in comparison to 1976- 85(1700mm). All seasons and months also received the lesser amount of rainfall than ET and creating water deficit. The seasonal and monthly water deficit has also been increased during 1986-2003 in comparison to 1976-85 (Tables 4 and 5).

Humidity: The normal value of annual humidity at 7.00 am and 2.00 pm and daily is 74.3%, 42.6% and 58.4%, respectively. During 1991-2003 daily humidity has increased by 1.1% in comparison to its normal value and by 2.5 % in comparison to value during 1967-90 (Table 2). The humidity (daily) has also been increased during 1991-2003 in comparison to 1967-90 in all seasons. It raised from 55.0%, 45.3%, 66.0% and 58.0% to 56.8%, 47.0%, 68.9% and 61.2 % during winter, pre-monsoon, monsoon and post-monsoon season, respectively. During 1991-2003 it has also increased by 0.9%, 0.8%, 1.5% and 0.2% during winter, pre-monsoon, monsoon and post-monsoon season, respectively in comparison to normal value (Table 6). The analysis showed that humidity at 7.00am reduced in all months except May, June and December month whereas humidity at 2.00pm increased in all months during 1991- 2003 in comparison to 1967-90 (Table 7). The daily humidity increased in all months (Table 7). Therefore, increase in RH may enhance the incidence of insect-pest and disease. The high RH favors easy germination of fungal spores on the leaves of plant whereas under high humidity the grain yield of maize, wheat is decreased due to adverse effect of RH on pollination and high incidence of pests. Similarly increase in RH during panicle initiation to maturity is increased the yield of sorghum. Changing climate in the Palamau region of Jharkhand have brought forth myriad new problems and new questions, the solutions to which will be generated by combining farmers, ingenuity, new technologies and several trial and-error efforts. There is need to re-orientation of planting time of crops particularly of wheat and chickpea, selection of short duration and drought tolerance varieties, inclusion of new cropping system and crop diversification. Similarly, there is need to ensure collective action at the personal, corporate and political levels by improved energy efficiency, alternative energy sources, forest conservation and eco-friendly.

Conclusion

From the above discussion, it is concluded that the whole Palamu division in the Jharkhand district is drier than the other district and neighboring state. It comes under dry triangle and grooved under a drought prone area of the Jharkhand district. The division is prone to drought and its vulnerability may be seen on the different aspect of the socio-economic condition in the district. This division is under three tops severe climatic vulnerability has the district receive less than 100 cm of rainfall. In 5 decades, the area under agricultural decreasing due to climatic vulnerability. The net shown area and fellow land more than 2 years and 5 years have increased. As a whole due to climatic extremity the vulnerability may be seemed up as

- The Palamu division is a drought prone area as the division receives less 100 cm rainfall even during the monsoon season.
- Dryness is a common feature of a climatic vulnerability as the whole division depends on underground water for drinking purpose. The whole ground water table has a lowered such an extent that during summer season, wells and tube wells becomes dry and remaining water are found to be heavy fluoride.
- The fauna and flora of the division has been highly affected by the climatic vulnerability.
- The climatic vulnerability may be seen as the tiger reserve project of the Palamu division have been deserted, there are no tiger and no other wild animals.
- From the table no 1, it is evident that the amount of rainfall is continuously decreasing in the division.

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Fig.1: Location Map of the study Area

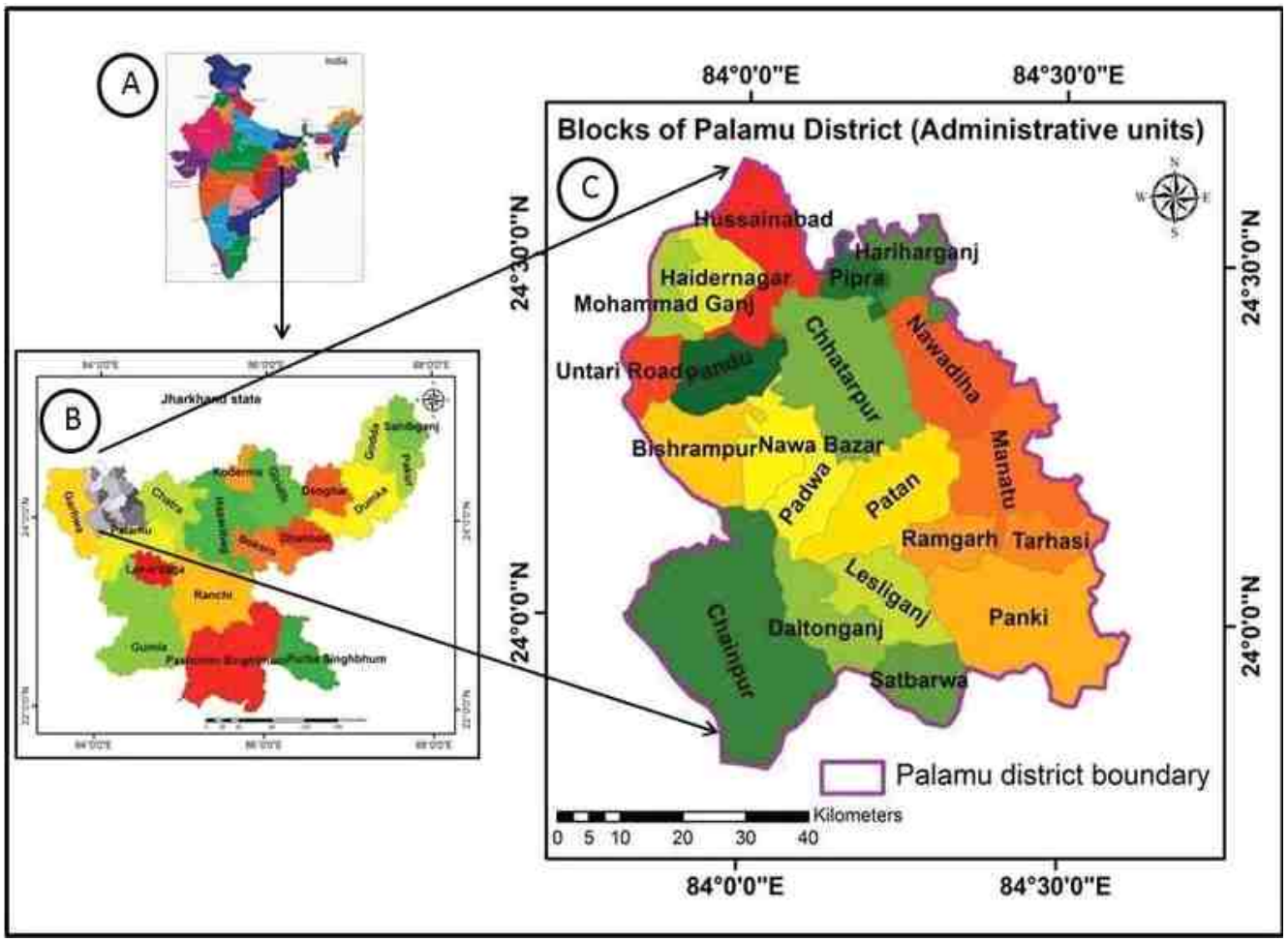

Table.2 PE index

Year	Evaporation(mm)	Rainfall(mm)	PE index
1976-85	2899	1199	41.4
1986-03	4170.6	1107	56.5
2004-2020	4150.5	1095	26.38

Table.3 Changing in annual temperature (^{O}C)

Temperature(^{o}C)	1967-80	1981-03	2004-20	average
Max.	29.4	32.3	34.2	31.96
Min.	21.6	18.0	22.0	20.53
Gap between max. and min. temperature	7.8	14.3	14.2	

Table. 4 Changing in monthly temperature (^{O}C

Month	Temperature(^{o}c)							
	1967-80		1981-03		Normal		Av.Difference between1981-03and1967-80	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
January	20.3	11.8	24.7	7.2	23.1	9.0	4.4	-4.6
February	23.2	14.8	27.8	10.4	26.0	12.1	4.6	-4.4
March	28.4	19.3	32.1	14.9	30.7	16.6	3.7	-4.4
April	35.8	24.8	39.5	20.4	38.1	22.1	3.7	-4.4
May	35.8	29.0	40.5	25.0	39.9	26.5	4.7	-4.0
June	38.8	28.5	38.9	26.5	36.8	27.3	0.1	-2.0
July	30.8	26.2	33.0	24.7	31.3	25.4	2.2	-1.5
August	30.9	25.8	32.5	23.3	31.9	25.0	1.6	-2.5
September	31.1	25.3	32.3	23.9	31.9	24.4	1.2	-1.4
October	29.9	22.7	32.2	18.6	31.4	20.2	2.3	-4.1
November	26.2	18.2	29.2	12.0	28.1	14.4	3.0	-6.2
December	21.6	12.4	25.4	8.0	23.9	9.7	3.8	-4.4

Table .5 Annual and Seasonal distribution of evaporation (mm) and water balance (mm) over time

Season	1976-85			1986-03		
	Evaporation on (mm)	Rainfall(mm)	Water balance(mm)	Evaporation (mm)	Rainfall (mm)	Water balance(mm)
Annual	2899	1199	-1700	4170.6	1107	-3063.6
Monsoon	1115.7	1011.6	-104.1	1656.3	922.9	-733.4
Post monsoon	386.4	69.8	-316.6	679.7	58.0	-621.7
Winter	183.4	52.0	-131.4	259.2	24.0	-235.2
Summer	1213.0	66.1	-1146.9	1597.3	31.8	-1565.5

Table.6 Monthly distribution of evaporation (mm) and water balance (mm) over time

Month	1976-85			1986-03		
	Evaporation(mm)	Rainfall(mm)	Water balance(mm)	Evaporation(mm)	Rainfall(mm)	Water balance(mm)
January	80.6	20.9	-59.7	100.6	9.4	-91.2
February	102.8	31.1	-71.7	158.6	14.6	-144.0
March	235.9	16.5	-219.4	331.3	10.8	-320.5
April	418.1	22.8	-395.3	518.2	5.2	-513.0
May	560.0	26.8	-533.2	747.8	15.8	-732.0
June	493.0	142.1	-350.9	674.7	167.3	-507.4
July	294.8	356.8	-56.0	358.3	286.9	-71.4
August	175.2	289.1	-113.9	329.9	286.2	-43.7
September	152.7	223.6	-70.9	293.4	182.5	-110.9
October	162.6	53	-109.6	261.3	37.4	-223.9
November	135.0	9.2	-125.8	217.7	9.2	-208.5
December	88.8	7.6	-81.2	200.7	11.4	-189.3

Table.7 Comparison of annual and seasonal humidity (%)

Time / Year		7.00am	2.00 pm	Daily
1967-90	Annual	74.6	39.4	57.0
	Winter	77.4	32.7	55.0
	Summer	64.3	26.3	45.3
	Monsoon	79.1	52.9	66.0
	Post monsoon	76.9	39.2	58.0
1991-03	Annual	74.0	45.0	59.5
	Winter	76.3	37.3	56.8
	Summer	62.5	31.4	47.0
	Monsoon	78.8	59.0	68.9
	Post monsoon	77.3	45.0	61.2
Normal	Annual	74.3	42.6	58.4
	Winter	77.0	34.8	55.9
	Summer	63.7	28.7	46.2
	Monsoon	79.0	55.8	67.4
	Post monsoon	77.1	44.8	61.0

Table.8 Comparison of monthly humidity (%)

Month	Time	1967-90	1991-03	Normal	Av.difference in daily humidity between1991-03 and1967-90
January	7.00am	79.4	78.9	79.2	
	2.00pm	34.9	39.4	37.0	
	Daily	57.2	59.2	58.1	2.0
February	7.00am	75.4	73.7	74.8	
	2.00pm	30.4	35.1	32.6	
	Daily	52.9	54.4	53.7	1.5
March	7.00am	69.2	66.8	68.4	
	2.00pm	25.3	29.9	27.5	
	Daily	47.3	48.4	48.0	1.1
April	7.00am	61.9	59.0	60.9	
	2.00pm	25.5	31.1	28.1	
	Daily	43.7	45.0	44.5	1.3
May	7.00am	61.7	61.7	61.7	
	2.00pm	28.2	33.2	30.6	
	Daily	45.0	47.5	46.2	2.5
June	7.00am	67.8	68.8	68.1	
	2.00pm	38.9	44.8	41.6	
	Daily	53.4	56.8	54.9	3.4
July	7.00am	81.2	80.4	80.9	
	2.00pm	56.7	61.9	59.2	
	Daily	69.0	71.2	70.1	2.2
August	7.00am	84.3	83.7	84.1	
	2.00pm	59.4	66.2	62.6	
	Daily	71.9	75.0	73.4	3.1
September	7.00am	83.0	82.2	82.7	
	2.00pm	56.6	63.2	59.7	
	Daily	69.8	72.7	71.2	2.9
October	7.00am	79.4	78.9	79.3	
	2.00pm	45.4	53.5	49.2	
	Daily	62.4	66.2	64.3	3.8
November	7.00am	76.6	75.5	76.2	
	2.00pm	36.9	44.3	40.4	
	Daily	56.8	59.9	58.3	3.1
December	7.00am	74.7	77.5	75.7	
	2.00pm	35.3	37.1	36.5	
	Daily	55.0	57.3	56.1	2.3

Spatio-Temporal Analysis of Heat Waves in Dehradun City, Uttrakhand: Causes and Effects

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Abstract

After Dehradun became the capital in 2000, the city had a substantial influx of immigrants. As a result of the unplanned growth of urbanization and to meet the demand of increasing dwellers, the land cover of grey infrastructure has increased over a period. Concretization behaves as heat receptors and leads to temperatures rising rapidly. The RMC reported the highest temperature of 40.2° C on June 7, 2022, in Dehradun. As a result, humans and plants suffer from a variety of ailments. In this paper, an attempt has been made to identify a relationship between land use land cover classes and the Heat index in the city for the period of 2000 to June 2022. The results indicate an increasing trend intemperature for Dehradun because of its heavy grey area. As a result of this study, a strong correlation was observed between the LST with land-use dynamics as indicated by NDVI and NDBI.

Keywords: GIS, Concretization, LST, Land use dynamics, Population density, Grey infrastructure

Introduction

Urbanization changes the natural landscape into an artificial one, which affects the surface's radiative, thermal, roughness, and moisture qualities as well as the atmosphere above it. Urban areas are experiencing heat island effects. And is generating discomfort to flora and fauna in general. If the trend continues it could create climate disaster. As a result, the study of urban climate is receiving a lot of interest today. According to studies, there is a difference in the rate at which the temperature changes in urban and rural areas, and the warming trend is more pronounced in urban areas than in the nearby rural areas– (1). Assessing how changes in land use and urbanisation affect mean surface temperature is a complex task. Remote sensing has enabled us to quantify and analyse these tasks.

Statement of the problem- Studies demonstrate that one of the key causes of the city's rising temperatures and their effects on changes in humidity are land use dynamics. And concretization behaves as heat receptors and lead to temperatures rising rapidly. The regional meteorological centre (RMC) reported that the highest temperature of 40.2° C on June 7, 2022 in Dehradun. As a result, humans and plants suffer from a variety of ailments. Changes in land use and land cover and decrease in the percentage of vegetative area, andan increase in building construction activities (roads, buildings, reservoirs, etc.) need to be assessed scientifically to establish a relationship between these factors.

Explanation of themes-The main goal of this study was to use GIS and RS to examine urbanisation, urban expansion, and urban sprawl in the city and the surrounding area in order to address the causes of urbanisation and heat waves in the city.As, temperature is the main component of the heat wave,an attempt has been made to find NDVI, NDBIand LST with Remote sensing images using GIS tools.

The Specific Objectives of the study are-

This study focuses on Dehradun region in Uttarakhand for the following:

- To create NDVI, NDBI and LST by using the ArcGIS tool
- To analyse a correlation between the land surface temperature (LST) with land-use dynamics as indicated by NDVI, NDBI.

The Study-Area

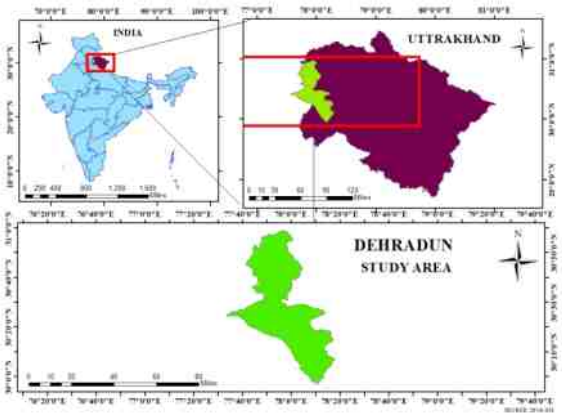

Fig 1. Study area Map

Historical Background

The name Dehradun is a combination of two words "Dehra" which means Camp and "Dun" which means valley. Its history goes back to the 17th century. It was annexed by the British in 1815 and had been one of their favourite places due to its location and climate. Dehradun is the administrative centre and the capital of the new state of Uttarakhand since 2000. Dehradun is situated at the Himalayan foothills in the fertile Doon Valley. The valley is well known for its salubrious climate and natural beauty. It is due to this reason Dehradun has been one of the favourite residential cities. Dehradun is one of the most beautiful resort centres and also an important educational centre of the country. After the formation of the capital, Dehradun is experiencing growth in built-up area due to rising population and administrative pressure. This has been impacting the climate of the city

Location-

Biodiversity Profile of Uttarakhand: Uttarakhand the 27th state of Republic of India lies between 28° 44' & 31° 28' N Latitude and 77° 35' & 81° 01' East longitude. It was carved out of UP on 9th November 2000.Dehradun district is situated in the North-Western part of the state at 30° 19' N and 78° 04' E. The height above sea level is 640m.The district total area is 3088 sq kmand the city Dehradun has a total area of 196.5 km². As total area of city is smaller as compared to district hence study area of Dehradun district has been taken to view the heat island difference for the city

Climate

The climate of the state of Uttarakhand is changing quickly as a result of land use dynamics. This has an impact on the weather, which in turn affects people and vegetation. The Climate of the district varies greatly from tropical to severe cold depending upon the altitude of the area. The district being hilly, temperature variations due to difference in elevation are considerable. In the hilly regions, the summer is pleasant, but in the Doon, the heat is often intense, although not to such degree as in the plains of the adjoining district. The temperature drops below freezing point not only at high altitude but even at places like Dehradun during the winters, when the higher peaks are also under snow. The area receives an average annual rainfall of 2073.3 mm. Most of the annual rainfall in the district is received during the months from June to September, July and August being rainiest.

Selection criteria of the study area –

After Dehradun became the capital in 2000, the city had a substantial influx of immigrants. With a total area of 196.5 km^2, the current metro area population of Dehradun in 2022 is 967,000, a growth of 2.55 % year on year basis.

Materials & Methods

Present paper is an attempt in the direction where it analyses the normal difference indexes like NDVI, NDBI for Green and Grey infrastructures respectively to identify a relationship between land use land cover classes and the Heat index in Dehradun for a period of about 22 years (2000 to June 2022).

Data Source

The primary source of information for this study is a satellite image. The specifications of the satellite data, including the date of data acquisition, spectral resolution, and spatial resolution, are provided in Table 1. The Normal Difference Vegetation Index (NDVI), Normal Difference Built-up Index (NDBI), are all analysed using only four bands (Green, Red, NIR, SWIR). Below are the bands, wavelengths, and resolutions of the Landsat 5 and Landsat 8 data. These satellite pictures are ones that the United States Geological Survey (USGS) provided for download.

The following flow chart 1 depicts the methodology adopted:

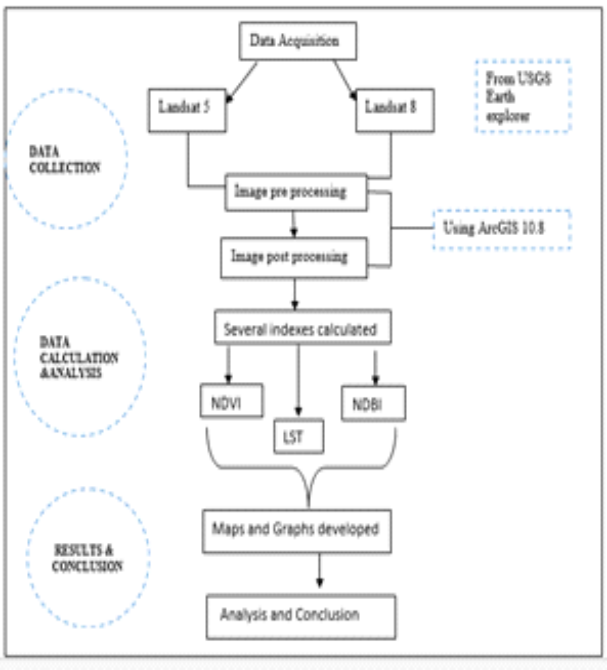

Chart 1: Flow chart of Methodolgy

Data Evaluation-

The NDVI (Normalized Difference Vegetation Index), NDBI (Normalized Difference Built up Index) and surface temperature maps and graphs were created in order to distinguish between vegetation, built-up, and water index. Several ArcGIS 10.8 tools were used to analyse and prepare the graphs.

The first requirement is to determine whether the research area's urbanisation has caused the vegetation to decline over time. In order to accomplish this, NDVI and NDBI calculations and comparative maps were developed. The study area's urbanisation, which causes temperature to rise with time, is the second requirement. Utilizing ArcGIS software, surface temperature was determined for that purpose.

Table 1. Details of Bands specification in Landsat 5 and Landsat 8

S.N.	Landsat 5 Enhanced Thematic Mappers plus			Band
	Resolution (meter)	Wavelength (micrometre)	Band name	
1	30	0.45-0.52	Blue	Band 1
2	30	0.52-0.60	Green	Band 2
3	30	0.63-0.69	Red	Band 3
4	30	0.76-0.90	NIR	Band 4
5	30	1.55-1.75	SWIR 1	Band 5
6	30	10.40-12.50	Thermal	Band 6
7	30	2.08-2.35	SWIR 2	Band 7
8			Panchromatic	Band 8
	Date of data acquisition 19.02.2000			

Lnadsat 8 operational land imagers (OLI) & Thermal Infrared Sensors (TIRS)			
Band 1	Ultra-blue	0.435-0.451	30
Band 2	Blue	0.452-0.512	30
Band 3	Green	0.533-0.590	30
Band 4	Red	0.636-0.673	30
Band 5	NIR	0.851-0.879	30
Band 6	SWIR 1	1.566-1.651	30
Band 7	SWIR 2	2.107-2.294	30
Band 8	Panchromatic	0.5030.676	15
Band 9	Cirrus	1.363-1.384	30
Band 10	TIRS 1	10.60-11.19	100X (30)
Band 11	TIRS 2	11.50-12.51	100X (30)
Date of data acquisition20.04.2022			

Results

Identification of Vegetation and vegetation growth by NDVI

NDVI is used to quantify vegetation greenness and is useful in understanding vegetation density and assessing changes in plant health. NDVI is calculated as a ratio between the red (R) and near infrared (NIR) values in traditional fashion:

(NIR - R) / (NIR + R)

In Landsat 5, NDVI = (Band 4 – Band 3) / (Band 4 + Band 3).

In Landsat 8, NDVI = (Band 5 – Band 4) / (Band 5 + Band 4).

The vegetation status has been determined using these bands. As a result, it was found that there is now more urbanisation as a result of higher population density. The increase in population and human activity caused the vegetation index to decline.

The map (Fig.2) below displays the vegetation status by year. To highlight the clear distinction, two distinct maps from the years 2000 and 2022 are displayed. The green colour shows the maximum vegetation in the year 2000 and the purple colour shows the less vegetation in the year 2022 comparatively.

The total area covered by vegetation was decreased from 834.134 sq km in 2000 to 504.873 sq km in 2022 (till April). The overlap maps and their graph below

Fig 3. NDVI Overlap Map

display the study area where the significant difference was seen.

Identification of Urbanisation and urban growth by NDBI

NDBI analysis was used to track the change in land cover using a number of Landsat multi-spectral photos. From 2000 to 2022, urbanisation has increased most quickly. This is because Dehradun has a higher population density and an unequal distribution of tourists since it became the state capital. The second phase, from 2011 to 2022, has seen developments that were not apparent during the first phase from 2000 to 2010.

The NDBI is calculated by using the formula:

For Landsat 5 data, NDBI = (Band 5 – Band 4) / (Band 5 + Band 4)

For Landsat 8 data, NDBI = (Band 6 – Band 5) / (Band 6 +

Identification of Urbanisation and urban growth by NDBI

NDBI analysis was used to track the change in land cover using a number of Landsat multi-spectral photos. From 2000 to 2022, urbanisation has increased most quickly. This is because Dehradun has a higher population density and an unequal distribution of tourists since it became the state capital. The second phase, from 2011 to 2022, has seen developments that were not apparent during the first phase from 2000 to 2010.

The NDBI is calculated by using the formula:

For Landsat 5 data, NDBI = (Band 5 – Band 4) / (Band 5 + Band 4)

For Landsat 8 data, NDBI = (Band 6 – Band 5) / (Band 6 + Band 5)

Also, the Normalize Difference Build-up Index value lies between -1 to +1. Negative value of NDBI represents water bodies whereas higher value represents build-up area (4).But sometimes the above formula does not give proper results, thus this study has used another formula to analyse built up (BU), i.e.

BU= NDVI-NDBI

The following maps (Fig.4 & 5) showing the total built-up area in Dehradun district and Chart no. 3 and 4 showing built-up status in some selected area

Land surface temperature

According to study, Dehradun experiences an average high temperature of 34.8 °C (94.6 °F) and low temperature of 23 °C (73.4 °F) in June. The average heat index for June is calculated to be 47.4°C (117.3°F), which indicates how discomfort the climate has become.

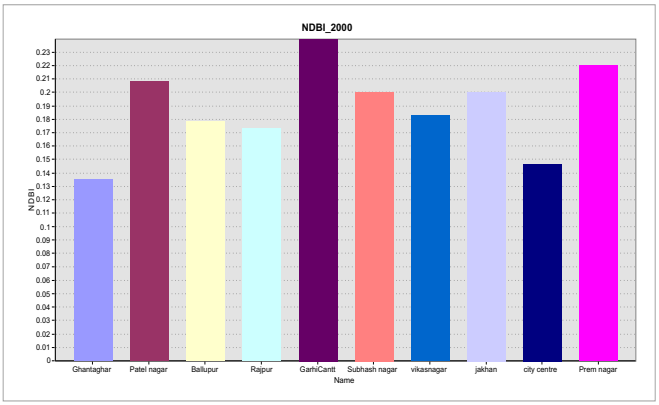

Chart 3. Selected built-up areas showing the growth in year 2000

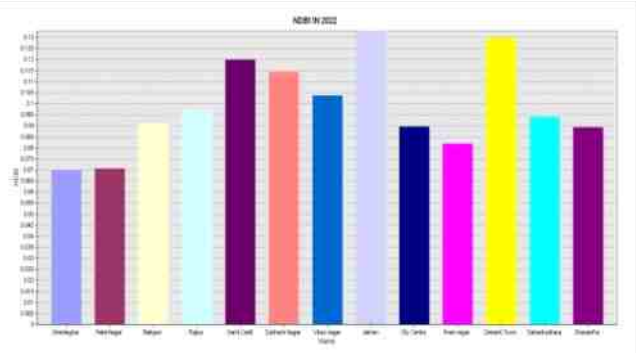

Chart 4. Selected urban areas showing the variations in built-upin year 2022

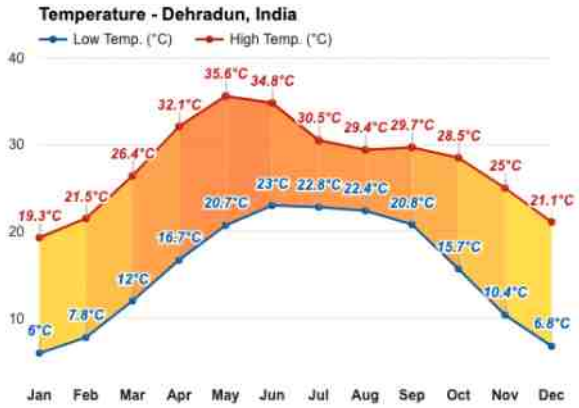

Fig 6: Average Temperature, Source: weather-atlas.com

According to Indian Meteorological Department (IMD) heat waves are when 'The maximum temperature varies by 4 to 5 °C or more in regions where the typical maximum temperature is greater than 40 °C and by 5 to 6 °C in areas where the normal maximum temperature is less than 40 °C. A heat wave is only considered to be present when a station's peak temperature reaches at least 40°C for plains and at least 30°C for mountainous regions.

Regardless of the normal maximum temperature, it is also considered as a heat wave if the actual maximum temperature is 45°C or higher. (5)

The process of land surface heat exchange, which is essential to the study of environmental change, is reflected in land surface temperature (LST). This study finds the reasons for urban heat island (UHI) are anthropogenic activity, the fabric of a city, the lack of vegetation, and the close arrangements of buildings. Here in this study, the Landsat 8 satellite imagery has been used to analyze the LST. According to studies, Dehradun's temperature has recently increased, which was never before seen.

The following maps (7 & 8) are showing the comparison of land surface temperature in the years 2000 and 2022:

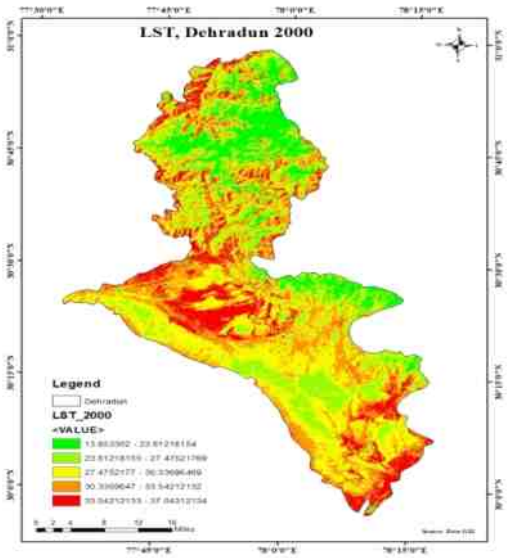

Fig. 7 Land Surface Temperatures, 2000

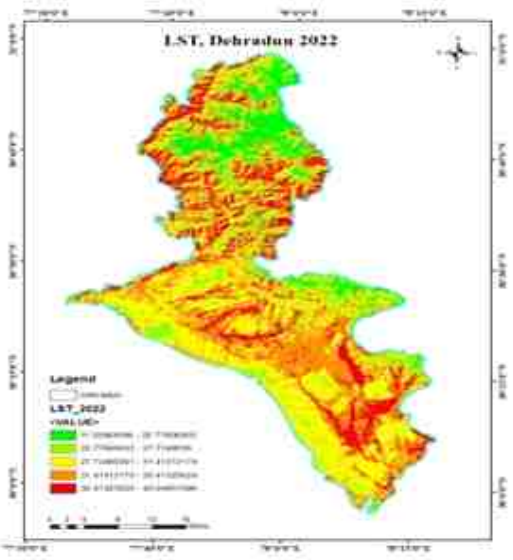

Fig. 8. Land Surface Temperatures, 2022

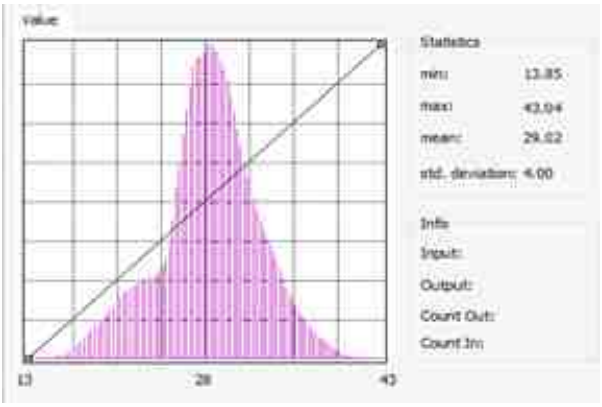

Chart 5: Statistics of LST, 2000

It has been observed that the land surface temperature (LST) of Dehradun district has increased from 33 to 42 during the period 2000 to 2022 which is an increase of more than 4-5 degrees and hence can be called as heat wave. The following charts are showing the statistics values of LST :

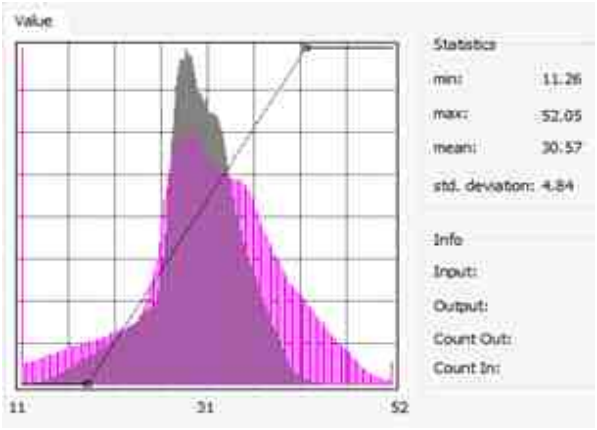

Chart 6: Statistics of LST, 2022

Conclusion

Results show that LST builds a positive relation with NDBI and a negative relation with NDVI. These relationships are stronger in the area below mean LST and weaker in the area above mean LST. It indicates that the values of LST are largely influenced by the different land surfaces, like vegetation, water, soil, and built-up area. Decreasing vegetation and increasing built-up area is causing more absorption of heat and resulting into the rising temperature in the city when there is peak summer days with full sunlight.NDBI values ranging from -1 to +1, positive value indicates urban land area and negative value indicates non-urban land. Area of positive value of NDBI has been calculated by using GIS software and is shown in the following Table 2:

Table 2. Results of LST, NDVI and NDBI in Dehradun

Location	LST		NDVI		NDBI	
	2000	2022	2000	2022	2000	2022
Dehradun	33.3 degree Celsius (Max Avg. Temp)	45.05 degree Celsius (Max Avg Temp)	834.134 sq km	504.873 sq km	215.345 sq km	457.028 sq km

A strong correlation between LST, NDVI and NDBI has been noticed. The research reflects how the vegetation in Dehradun and the surrounding areas has changed during the past 20 years.NDVI, NDBI, and LST changes have been detected utilizing satellite pictures and an integrated remote sensing technique. The majority of the changes are unfavourable to the health of the climate and they are directly related to the study area's growing urbanization. Due to the shift in this region's socioeconomic conditions during the previous years, urbanization has had a

:

significant negative influence on climate. And is the main cause of the heat waves. In Dehradun, the lowest and highest LST have increased in correlation with the decline in vegetation. These alterations also serve as a reminder of how quickly Dehradun city and the surrounding areas have urbanized.

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Web-links

1. https://earthexplorer.usgs.gov/
2. https://www.weather-atlas.com/en/india/dehradun-weather-june

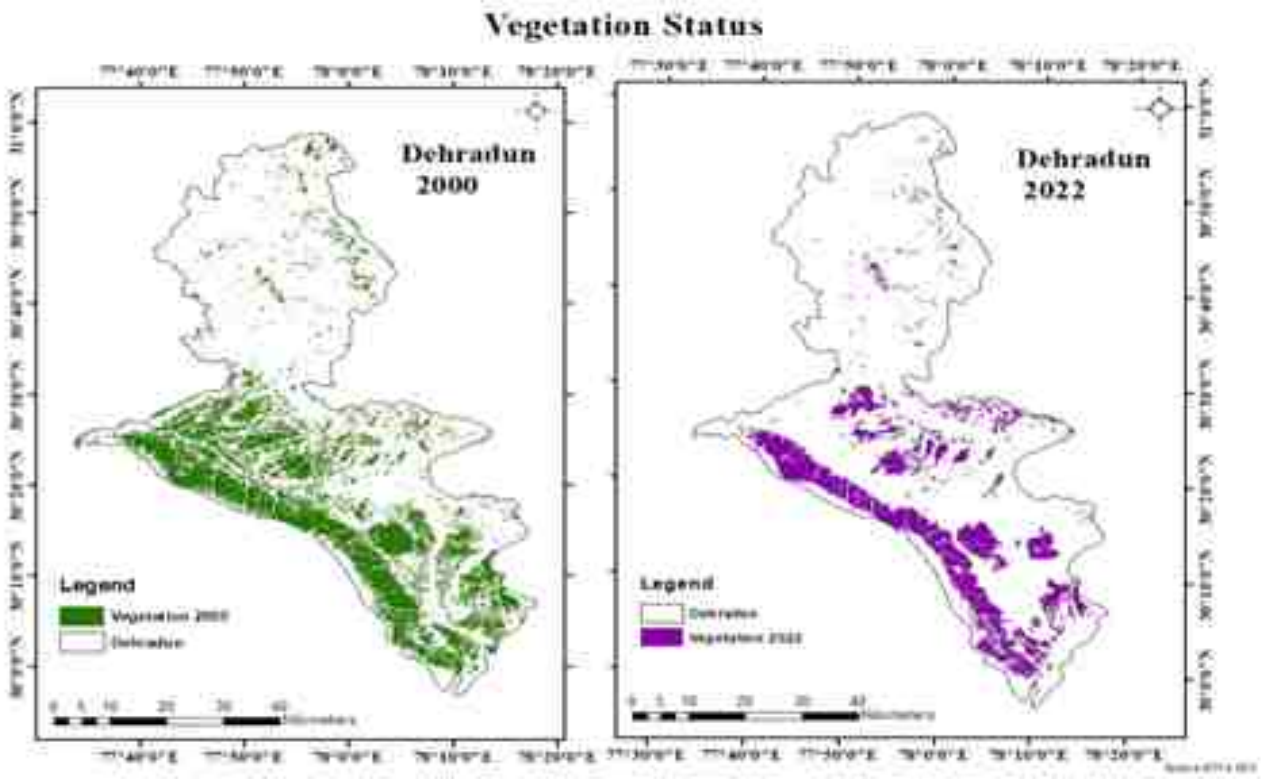

Fig 2 . Vegetation status in 2000 and 2022

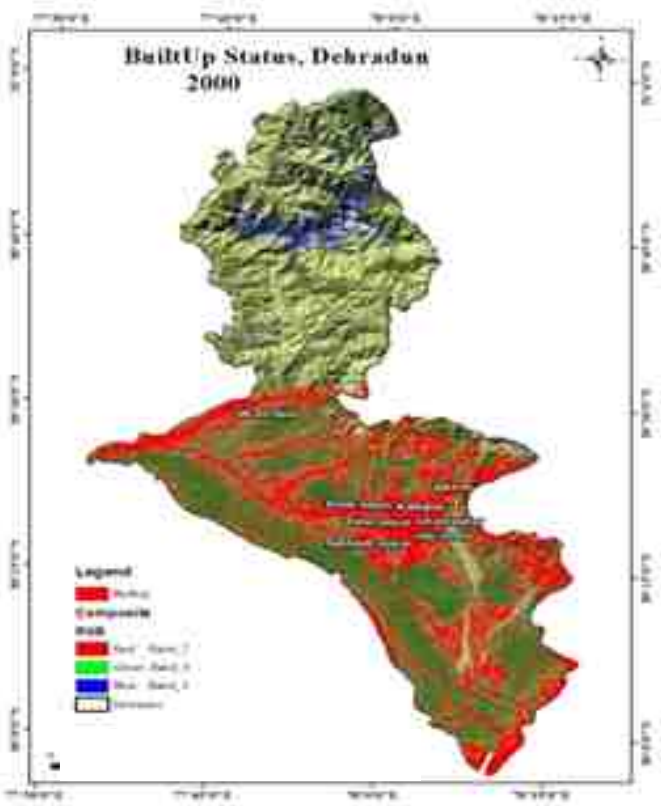

Fig 4 . Built-Up status in 2000

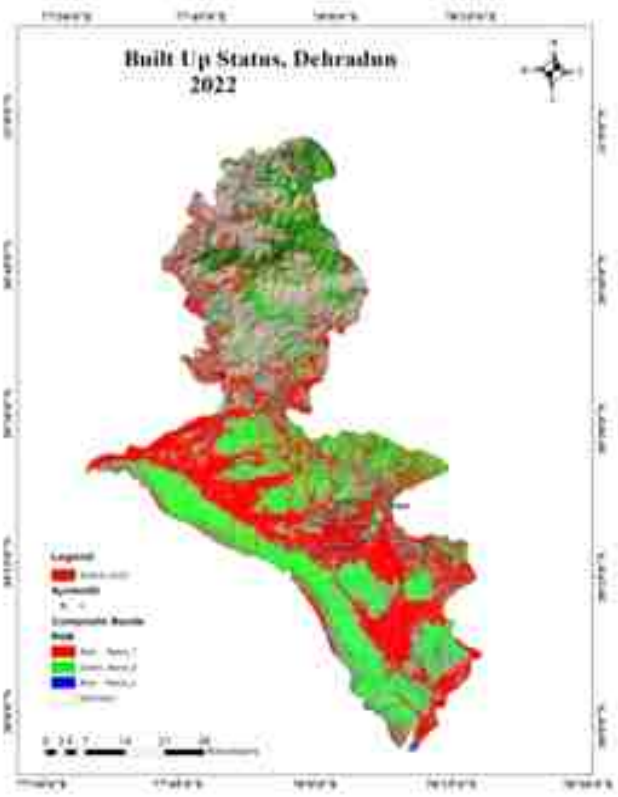

Fig 5. Built-Up status in 2022

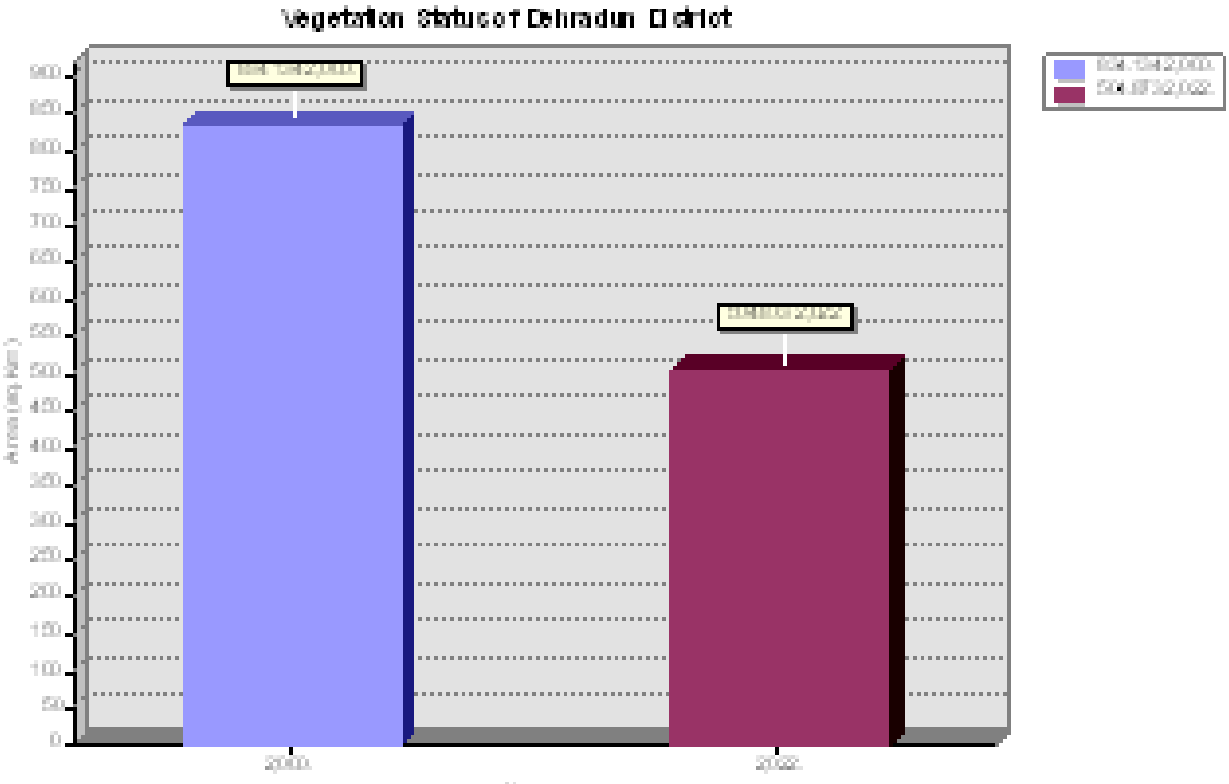

Chart 2: Total area covered by vegetation in 2000 and 2022

Mapping: Impact of Climatic Variability on Crop Productivity in The Coastal Area of Indian Sundarban: A Case Study of Kultali Block, South 24 Parganas, West Bengal

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Abstract

Climate variability and the continual occurrence of cyclones, floods, and storm surges have greater implications on the fragile ecosystem of the IndianSundarbansBiosphere Reserve. Centurial meteorological data were used to assess the climate variability in the Reserve. Multivariate principal component analysis was performed to identify the consistency among the conditioning parameters of climate. Cyclones, severe cyclones, storm surge height, salinity intrusion, pH, and surface water temperature were assessed to figure out the overall consequences of climate variability. Field investigation from 600 households from coastal and inland blocks (an administrative division of the district) was carried out to reaffirm the variability in climatic conditions and it's their environmental, economic, and social consequences in the coastal area of the Sundarbans block. The study revealed wide spatiotemporal variation in temperature and rainfall. Rise in sea level, flood and high storm surge height and salinity intrusion were inducing vulnerability in the coastal blocks. Communities in Gosaba, Kultali, Kakdwip, Sagar, Patharpratima, and Namkhana blocks largely showed a high level of agreement for climate variability. Hence, the study calls for effective adaptation and mitigation strategies.

Keywords: Sundarbans, Climatic variability, coastal, Cyclone, Salinity.

Introduction

Hazards and disasters are unevenly distributed in time and space. The terms like 'earthquake prone', 'drought prone', or 'flood-prone areas are used to describe the distribution effect of the concerned hazards. People living in such areas are vulnerable to hazards and disasters of varied types. This vulnerability is the extent to which an individual or a community or an area is exposed to the impact of a hazard. According to the National Institute of Disaster Management (formerly National Centre Disaster Management), vulnerability is defined as the extent to which a community, structure, service, or geographic area is likely to be damaged or disrupted by the impact of particular a hazard on account of either nature, construction and proximity to hazardous terrain or disaster-prone area. Thus, vulnerability implies a measure of risk combined with the level of social and economic ability to cope with the resulting event to resist major disruption or loss. In other words, vulnerability is "a set of prevailing or consequential conditions of physical, socio-economic and/or political factors which increase a community's susceptibility to calamity or which adversely affect its ability to respond to events.

The Sundarbans coastal region, in South Asia, is prone to cyclones, storms, erosion, and storm surge flooding. Coastal areas are the most productive and transitional areas between land and sea. In these areas, the ecosystems are more vulnerable to climate change-induced natural hazards like coastal inundation, stormsurges, tsunamis, shoreline change, sea level rise, cyclones,typhoons, etc. The concept of vulnerability is a holistic approach and it navigates across the ecological and socio-economic systems of a region. The ecological and socio-economic vulnerability of a region can effectively be assessed using multi-hazards. To understand the ecological and socio-economic vulnerability to climate change of any region, it is essential to find out the intensity of climate change. This paper makes attempts to analyze Spatio-temporal weather and climate variability in Sundarbans Biosphere Reserve and especially the kultali block, south 24 Parganas, west Bengal.

Coastal areas are the most productive and transitional areas between land and sea. These ecosystems are more vulnerable to climate change-induced natural hazards like coastal inundation, storm surge, tsunamis, shoreline change, sea level rise, cyclones, and typhoons globally (Torresan et al., 2008; Nicholls and Cazenave, 2010). The Sundarbans coastal region, in South Asia, is prone to cyclones, storms, erosion, and storm surge floods (Chaudhuri AB, Choudhury A 1994). It is intensively

affected by extreme weather events among all the surrounding rims of the Bay of Bengal (Chittibabu, 1999; Gonnert et al., 2001). Several geophysical and geo-hydrological factors such as tidal drainage system, estuary, deltaic shape, shallow coastal water, tidal creeks, the convergence of the bay, high astronomical tides, and inlets have been the main drivers of disastrous storm surges in Sundarban (Dube et al., 2009).

The concept of vulnerability is a holistic approach and it navigates across the ecological and socio-economic systems of a region. The ecological and socio-economic vulnerability of a region can effectively be assessed using multi-hazard events. The concept of vulnerability has been addressed by academicians, scientists, environmentalists, ecologists, economists, social scientists, and policymakers from different points of view. To understand the ecological and socioeconomic vulnerability to climate change in any region, it is essential to find out the intensity of climate change. This paper attempts to analyze Spatio-temporal and climate variability in Sundarbans Biosphere Reserve.

Study Area

Kultali is a community development block in the South 24 Parganas district of West Bengal, India. it is situated 22°05′12″ N and 88°35′37″ E, an average elevation of 7 meters (23 feet) above sea level. The Kultali CD block is bordered by 4 different blocks which are Jaynagar I and Canning I CD blocks in the north, the Basanti CD block in the east, and the Jaynagar II CD block in the west. The total area covered by the kultali block is 870 km^2 (335.909 square miles). There are nine-gram panchayats, 120-gram salads (village councils), 46 Mouzas, and 43 inhabited villages in the panchayat samity. The two police stations service the entire block, the Maipith police station serves the coastal part of Kultali, and the Kultali police station serves the majority of the area. Jamtala is the CD Block's headquarters.Kultali is unique in that it is a component of the Indian Sundarbans. This area consists of approximately 30 large and small islands separated by numerous tidal streams and rivers. Matla and Bidyadhari are two important rivers that flow from the two sides of the Kultali Block.

Objectives

The objectives of the study are-

i. Analyze the climatic variability condition.
ii. To investigate the climatic variability and impacts the crop productivity in the coastal area of the Sundarbans.
iii. To analyze the impact of frequent severe cyclone on crop production system.
iv. Recovering time of crop yield.
v. Disaster protection and recovery recommendation.

Data Base and Methodology:

Both primary and secondary data are used to support this investigation. The secondary data was gathered from a number of Bangiyo Bhugol Mancha publications from various years, as well as from the District Census Book, Bureau of Applied Economics & Statistics, Government of West Bengal, Economic Review, Human Resource Development Report, and Bureau of Applied Economics & Statistics. The primary data was primarily gathered using structured questionnaires from the inhabitants of nearly all the villages in the Kultali Block in order to improve and develop the secondary data. Generally speaking, the investigation was carried out during my two-month stay in the South 24-Parganas region's Kultali Block of the Sundarbans during the post-Aila period.

Result and discussion:

Kultali is a community block. Climatically this block is very vulnerable. Frequently occurrence of various climatic events affects the all over block and also impact in the crop production in the block. Table no. 1 shows that various climatic hazards effect the agricultural land and damage property.

Threats due to climate change

The Sundarbans are located in a region of the world where powerful tropical cyclones frequently occur. These hurricane-like storms pose a threat to both human survival and the habitats of several animals, particularly in Sundarbans low-elevation zones. As wind speeds and precipitation amounts keep rising, it is predicted that the rising sea levels and temperatures will worsen these storms. One of the species that resides in the Sundarbans is the Bengal Tiger, and because their prey supply has decreased, they are also disturbed and impacted by storms. Furthermore, the availability of habitat for migratory and resident water birds as well as other animals is anticipated to be significantly impacted by the loss of intertidal mudflats. There is evidence that climate change is creating warmer temperatures. The Sundarbans are located in a region of the world where powerful tropical cyclones

frequently occur. These hurricane-like storms pose a threat to both human survival and the habitats of several animals, particularly in Sundarban's low-elevation zones. As wind speeds and precipitation amounts keep rising, it is predicted that the rising sea levels and temperatures will worsen these storms. One of the species that resides in the Sundarbans is the Bengal Tiger, and because their prey supply has decreased, they are also disturbed and impacted by storms. Furthermore, the availability of habitat for migratory and resident water birds as well as other animals is anticipated to be significantly impacted by the loss of intertidal mudflats. There is evidence that climate change is creating warmer temperatures.

AILA Cyclone

Kultali block is situated on the bank of Matla River and was highly affected by cyclone Aila. All 43 villages of the block were adversely affected by Aila. Though there was no loss of life agricultural land was heavily damaged because of gushing saline water and the loss of livestock was also huge. The extent of damages in the Sundarban area and Kultali block is depicted below in table 6 and table 7 respectively.

AMPHAN:

Assessment Area: BTS volunteers conducted their assessment in their field area of 3 blocks in Sundarban - Kultali, Patharpratima, and Basanti in South 24 Parganas district, West Bengal. In this area, they assessed 8 Gram Panchayats, 27 villages, and about 4800 families. The overall summary is as follows (see detailed report for individual summaries):

- No. of Households affected: 4,800
- No. of people affected: 180,000
- No. of people died: 4
- No. of Houses damaged: 2100
- Length of River Embankment breached: 15 Kilometers in 11 villages
- Area of standing agriculture crops damaged: 3700 bighas (around 950 hectares)
- Betel leaf vines damaged: (No. of plots) 218
- Ponds with water salinized: 530 ponds in 13 villages
- Mangrove Forest destroyed: Huge
- No. of trees fallen on both community plantation and household's plantation: Uncountable
- No. of cows died: 100
- No. of goats died: 260

Cyclones and storm surge

Tropical cyclones of different intensities (63–120 km/h) are a regular and recurring phenomenon in the SBR during July and September almost every year. Based on the intensity and the periods of occurrence of the tropical cyclones in the Bay of Bengal, these can be classified into two types: “cyclonic storms” with a wind speed between 63 and 87 km/h and “severe cyclones” with wind speed between 90 and 120 km/h. The historical records of the occurrence of cyclones in the study area revealed that the cyclone which occurred in 1976 and the 'Aila' cyclone which occurred in 2009 were the most destructive cyclones during the periods 1891-2010. Historical data of 120 years was used for analyzing cyclonic storms, severe cyclones, and storm surge height in the study area. The result revealed that the SBR has registered a 26% increase in tropical cyclones during the last 120 years. The frequency of tropical cyclones has further increased during the last 10 years. The number of tropical cyclones making landfall on the different blocks of SBR and their return periods has been shown in Figure. Gosaba, Kultali, Patharpratima, Namkhana, and Sagar were found to be the most severe cyclone-affected blocks in SBR with less than 10 years of return periods. The storm surge during cyclone Aila (2009) reached inland up to 120 km. The blocks situated in the northern part of the SBR are less affected by severe cyclones. The maximum surge height over 120 years return periods was found to be 15.6 meters in the study area. The surge height was recorded to be the maximum during severe cyclones. Sagar, Gosaba, Namkhana, Patharpratima, and Kultali blocks have recorded more than 12 meters of surge height. The blocks situated in the northern part of the reserve have recorded less than 4 meters of surge height during the last 120 years.

Agriculture status in the Kultali block:

The Tebhaga campaign, started by the Communist Party of India in 1946, was heavily influenced by the South 24 Parganas. Operation Barga then sought to protect the peasants' tenancy rights. A total of 5,859.51 acres of property were purchased and vested in the Kultali CD block. 95.95 percent of the vested land was allocated from these 5,621.97 acres. There were 10,375 patta (document) owners in all.

In the South Twenty-four Parganas district, agriculture is a significant source of livelihood, according to the District Human Development Report. Only 0.41 hectares are arable land per agricultural worker in the

district. Additionally, the irrigation infrastructure has not been expanded to a satisfactory degree. Most of the agriculture is still monocrop Ped.

Conclusion

The agricultural system of the kultali block has been massively damaged by Aila, josh and Amphan due to a lack of proper embankment management, and a lack of drainage system. Surge water could not flow back into the river and hence leaving a thick layer of salt on the top soil over agricultural plots and fertility was markedly reduced to increase the fertility of the agricultural land soil must be frequently plowed and the use of fertilizer with organic matter for root development necessary. Soil management and irrigation management is very much needed for plant growth and mineralization of organic matter and irrigation system should be developed or increased production.

From the above discussion, it is mentioned that changing climate or increasing climatic vulnerability is very much effective on crop production all over the block. The majority percent of villager (about 90%) in this area, belongs below the poverty line (BPL) and their livelihood depend on land-based crop yield agriculturally activities. But frequently occurring climatic events that are storms, floods etc. natural calamity totally damaged their crop field. It's a very pathetic situation all over the block area.

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Table 1. Snapshot of Sundarban and Kultali Block

(Source: Census Reports, 2011; Block Development Office & Author's Survey)

Particulars	Sundarbans	Kultali Block
Geographical location	21º12' and 22º44' North Latitudes and between 80º05' and 89º00' East Longitude	21°54' North Latitudes 88°24'East Longitude.
Total number of blocks	19	Kultali is one of these 19 Blocks having 46 Mouzas and 43 inhabited villages
Total Area	9630 sq. km	239.48 sq. km
Total number of households	6,69,669	45,099
Average family members	6.60	5.08
Total Population	44,22,038(22,75,418 are males and 21,46,620 are females)	2,28,988 (1,17,775 are males and 1,11,213 are females)

.***Table 2*** *Features of the different climatic events in the Kultali Block*

Year	Cyclonic storm name	Hazard type	Total affected area (%)	% o f the damaged agricultural land
27 May 2009	**Aila**	**Cyclone +flood**	**80**	**90**
2019	**Fani**	**Cyclone**	**30**	**25**
16 May 2020	**Amphan**	**Cyclone+ flood + covid 19 (lockdown period)**	**70**	**60**
2021	**yaas**	**Cyclone + covid 19 (lockdown period)**	**45**	**35**

Table 3. The extent of total damages due to Aila on May 25, 2009, in the Sundarbans area. (Source: Unpublished Records of the Government of West Bengal (2009-10))

Sl. No.	Particulars	Extent of Damages
1	The number of villages affected	4249
2.	Size of the affected population	25,62,442
3.	Number of people missing	8,000
4.	Number of deaths	70
5.	Length of embankment breached	400 Kilometers
6.	Number of cattle lost	2,12,851
7.	The total area of agricultural land affected	1,25,872 hectares
8.	Estimated financial loss in agriculture	Rs. 337 Crores
9.	Number of houses partially damaged	1,94,701
10	Total loss	Rs. 1,495.63 crores

Table 4. The extent of total damages due to Aila on May 25, 2009, in Kultali Block (Source: Author's Survey and Block Development Office)

Sl. No.	Particulars	Extent of Damages
1	The number of villages affected	43
2.	Size of the affected population	1,35,567
3.	Number of people missing	10-15 approx.
4.	Number of deaths	Nil
5.	Length of embankment breached	20 Kilometers approx.
6.	Number of cattle lost	17,954
7.	The total area of agricultural land affected	12,256 hectares
8.	Estimated financial loss in agriculture	Rs. 15 Crores
9.	Number of houses partially damaged	6000 approx.
10	Total loss	Not available

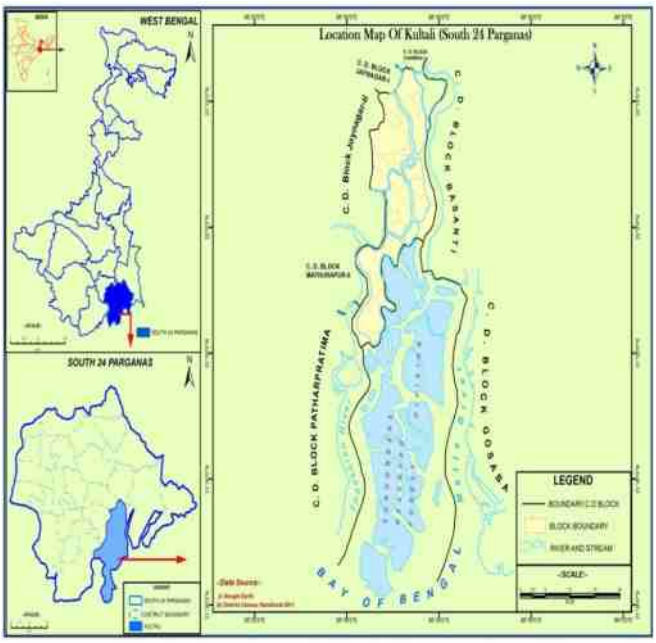

Fig. 1 Location map of the study area

Fig. 2 Inundation of agricultural land after Aila

Fig. 3: Flood by Amphan

Technology-Enabled Risk Mitigation and Preparedness for Lightning in Bihar

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Abstract

Bihar is prone to multiple disasters, wherein lightning is a serious threat to life and property in the state. With the onset of the southwest monsoon, lightning strikes increase manifolds. More than 60% of the deaths occurring due to lightning in the country are reported from Bihar. To facilitate risk mitigation and preparedness for lightning, the Disaster Management Department, Government of Bihar has launched an app called Indravajra a technology-enabled initiative, other than intensifying the information, education, and communication activities for awareness and outreach to the masses. The paper captures the purpose, process, and benefits of the lightning mobile application for the people and how far it has been helpful in risk mitigation and preparedness for lightning in the state. It highlights the areas where further work could be taken to facilitate better lightning preparedness.

Keywords: Lightning, Mitigation, Preparedness, Early Warning, Technology, Mobile Application

Introduction

Bihar is a multi-hazard prone state which witnesses natural as well as man-made hazards. Among the various types of disasters, the number of deaths due to lightning strikes are on a rise in recent years. According to Annual Lightning Report 2021-22, released by Lightning Resilient India Campaign, Madhya Pradesh, Uttar Pradesh and Bihar remains as three states incurring more than 60% losses of national toll due to lightning.

Lightning can strike the ground, the air, or inside clouds. As per the information from MetMatters of Royal Meteorological Society, there are roughly 5 to 10 times more cloud flashes than cloud-to-ground flashes.

The incident of mass casualty on 25 June 2020 in Bihar, had large flash lengths,, which are highly lethal. Lightning even today is not notified as a National Disaster. It has been declared state specific disaster by 16 states as per MHA guidelines wherein 10% of State Disaster Response Fund may be committed to state specific disasters.

Preparedness is being emphasised globally as the key step in disaster risk reduction, wherein Early warning Systems play a significant role. Even in case of lightning, there is a need for Early Warning System (EWS) for Risk Mitigation and Preparedness. Therefore, presenting an opportunity for Bihar to benefit significantly from accentuating its early warning system. EWS can play a critical and vital role in Disaster Risk Reduction (DRR), especially in case of increasing deaths due to lightning in Bihar. There are many studies that investigated how to strengthen disaster risk reduction strategies by policy, strategy, innovations as well as other actions *(UNICEF and Disaster Risk Reduction. 2011*). Disruptive technologies can spread critical information more quickly, improve understanding of the causes of disasters, enhance early warning systems, assess damage in new ways and add to the knowledge base of the social behaviours and economic impacts after a crisis strikes **(***Disruptive technologies and their use in disaster risk reduction and management, UNDRR 2019).*

In 2020, an app called Indravajra was launched by the Disaster Management Department, Govt. of Bihar to give alert messages 45 minutes prior to a lightning strike. But the challenge that remains for the department is to ascertain the accessibility, usability, accuracy and the convenience for the community. However, the mobile application has been designed to facilitate user interface with access to easy and accurate information and content with regards to lightning. Satellite visual (by Google Earth) of Bihar, India is shown in Figure 1.

Methodology

The study involves interactions with respondents in person and over telephonic surveys. The in-persons interaction was conducted in the three districts of Bihar- Saran, Jamui, and Patna, with the families of the lightning victims. Telephonic survey was conducted with a sample of users of the Indravajra mobile application living in different

users of the Indravajra mobile application living in different parts of state. A total of 120 respondents have been contacted for the study, 80 individual surveys in person and 40 over the telephone. The in-person interaction has played a primary role in collecting data for the study, but the emergence of new methods (telephonic survey) widen the reach of the study to every possible location where the team could not reach due to resource constraints. The scope of the study is (1) to assess the awareness and usability of the Indravajra mobile application (2) to modify/update the application to benefit the people with enhanced user interface (3) to facilitate in building a culture of risk mitigation and preparedness amongst the community in terms of lightning.

It was emphasized that the Mobile Application is not merely an Early Warning System, but it is also an educational tool to promote Information Education & Communication (IEC) for risk mitigation and preparedness. Hence, it is also important that its contents are integrated to support Community Based Disaster Risk Reduction (Community Based DRR). The numbers of application downloaded in the past six months is shown in figure 2.

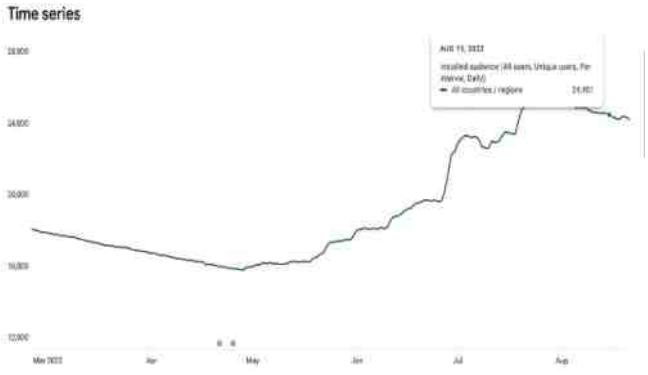

Fig 2: The number of applications downloaded in the last six months

Fig 1. Satellite visual (by Google Earth) of Bihar, India

Out of the 120 respondents surveyed, 45 respondents (Group 1) belonged to the rural areas of three districts- Saran, Jamui, and Patna, wherein 10 respondents (Group 2) belonged to the tribal communities. The tribal communities are primarily predominant in the Jamui district in Bihar. The 25 respondents (Group 3) represented district and state level officials, academicians, and urban communities. While 40 (Group 4) respondents who have downloaded the Indravajra mobile application, were contacted over the telephone. The response analysis is significant in improving the Mobile Application to benefit the people. Figure 3 shows the interaction with the respondent.

Fig 3: Interaction with the respondent

Results and Discussions

In the year 2020, 459 people were killed due to lightning in Bihar (highest till now). Later on in the year 2020, Disaster Management Department of Bihar launched the application 'Indravajra' for the benefit of people in the state. The mobile application was built by Qihou Solutions which later became Hydenmet Solutions (Reseller partner of Earth Networks) in 2020. The mobile application can be downloaded free of cost. It is available on Google Play store for android users and App Store for iPhone users. The interface of the Indravajra app is shown in figure 4.

Fig 4: User Interface of Indravajra Application

The users receives alert 45 minutes before the lightning strike giving them enough time to find a shelter or safe space. It is also found that the user may also receive an alert whenever not connected to the internet or when the phone is switched off. However, the application is not available for use on basic mobile phones, PC and Laptops. It was found that more than 90 percent of Group 1 and Group 2 respondents did not know about the Indravajra application prior to the interaction with the study team. However, the majority of respondents in these groups are involved in agriculture activities. They spend most of their time in open spaces which makes them vulnerable. Their level of education and lifestyle is also the factor that exposes them to the consequences of lightning. The rest 9 percent of the respondents got to know about the application through social media platforms or in some interactions. However, only 50 percent of these respondents were having the Indravajra mobile application in their mobile phones. The others know about the application, but were facing issues in downloading or registering in the application. Those having the application shared that they get alerts of lightning through the mobile application.

More than 60% of the respondents of Group 3, have the application installed on their phone. All the respondents have smartphones. In this group, respondents were able to understand the feature and disseminate the alert amongst their circle. They were aware of the information. However, they did raise their concern regarding the inaccurate alert issued by the application. The application issues alert whenever there is a lightning strike within a radius of 20kms. Because of this large area coverage of the application, its accuracy is at stake and leads to multiplicity of results making the usability of the mobile application redundant for users.

One of the respondent shared “This application issues alerts even when there is sun outside and the weather is good. It is very disturbing. The false alerts makes the application less dependable”.

Of the respondents who have used the application, 62.3% of Group 3 have faced issue in installing the application but it was 47% of Group 4. Most respondents (70%) from Groups 1 and 2 recommended that the community should be widely informed about the application.

95% of the respondents stated that the availability of the information in hindi in the mobile application makes it easy to use.

Preparedness is an important aspect of community- based DRR. Hence, whenever many people in the community have enough information and are alert by an early warning system, the risk gets mitigated to a great extent. It is obvious that the Indravajra application can be used as an effective information, education and communication tool for Risk Mitigation and Preparedness to spread awareness about lightning and to issue lightning alerts. Figure 4 shows the dos and don'ts given in the Indravajra mobile application in hindi.

Fig 4: do's and don'ts in Hindi

With a few modifications in the application and awareness generation programs, the usability of the application could be enhanced. There is no feedback option available for the users. Having a mechanism to receive feedback will help in making regular improvements in the application.

There is high scope to improve the effectiveness and user interface of the Indravajra mobile application for further benefit the people in the state. It also has the potential and possibility of use in other states which are vulnerable to lightning in India.

Conclusion

There is a need to utilize the application to its full potential. However, there are some shortcomings that needs to addressed. Indravajra application is effective to give alerts and knowledge as an early warning system. As an effective early warning system and IEC tool, this application is necessary to be taken to farmers in the rural areas who are highly vulnerable to lightning.

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Air Quality Index Mapping from Satellite-Derived Aerosol Optical Depth over the Jharkhand State, India

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Abstract

Air quality in Jharkhand, especially the concentration of suspended particles in the atmosphere is gradually affecting Jharkhand's climate and the health of communities. This study used moderate resolution imaging spectrometer (MODIS) data at 550 nm to investigate the variation in AOD over the entire Jharkhand. The present work deals with the application of a statistical model to retrieve the concentration of RSPM over the entire Jharkhand state. In this study, an attempt has been made to quantify air quality index from satellite-derived AOD, ground-based Respirable Suspended Particulate Matter (RSPM) and relative humidity using a multiple linear regression model. A strong positive correlation (R^2 = 0.76 in pre-monsoon and the R^2 = 0.64 in post-monsoon) observed. It shows high correlations among AOD, relative humidity and RSPM in pre-monsoon than the post-monsoon over Jharkhand. In case of pre-monsoon, the air quality of Jharkhand from the West to the East gradually varies from good (RSPM<50 μg/m^3) to very poor (RSPM 251 to 350 μg/m^3) air quality whereas, in the post-monsoon season, a poor air quality pattern was observed over the Northern and Eastern boundaries (RSPM> 251 μg/m^3) and in Western and Southern boundaries a good air quality (RSPM<101 μg/m^3) prevailed. So, the Satellite-derived AODs provide an alternative resource for analysing large-scale aerosol variations over the entire Jharkhand, thus overcoming the limitations of the scant network of ground-level measurements.

Key words: Air Pollution, Aerosols, Multiple Linear Regression Model, MODIS-AOD, Respirable Suspended Particulate Matter, Pre-monsoon, Post-monsoon

Introduction

Environmental pollution turns into increasingly more serious due to today's development all around the world. Environmental pollution is more concerning these days since all everyday exercise is connected with the climate. Air pollution is one of the utmost significant environmental problems. To have an improved knowledge of aerosol dynamics and its impact on global and regional climatic conditions, sufficient knowledge of its spatial and temporal dispersals along with its variations is very significant (Kaufmann et al., 2002; More et al., 2013; Bandyopadhyay et al., 2021). For this persistence, different ground and satellite-based sensing techniques are provided that a systematic retrieval of aerosol optical properties on the global and regional scale (Kaufmann et al., 2005; Kahn et al., 2010; More et al., 2013). Ground observed and satellite-based remote sensing are the two ultimate tactics being widely deployed for measuring AOD (Guleria et al., 2011; Guleria et al., 2012; Ramachandran et al., 2012; Mehta et al., 2021 Kaur et al., 2020). Though, ground observed aerosol remote sensing techniques cannot deliver a global analysis of AOD, however satellite-based aerosol remote sensing techniques can deliver a wide-ranging global investigation (Dubovik et al., 2002; Kaufmann et al., 2005; Kahn et al., 2010; More et al., 2013; Alam et al., 2014; Mohammad et al., 2022).

Still, satellite-based observation also has limits like snow-covered surfaces, bright land surfaces and cloud masks. For these limitations, the error in AOD quantity differs from region to region and is one of the thought-provoking matters. As a result of the speedy change of geographic land features, the error in the retrieval of MODIS AOD over land (±0.05 ± 0.15_AOD) is more than the error (±0.03 ± 0.05_AOD) over the oceans (Reimer et al., 2005; Guleria et al., 2012; Alam et al., 2014). Therefore, intending to recover the exactness of the MODIS data, it is significant to equivalence and validates the MODIS data with the autonomous ground observed measurements (More et al., 2013). AOD value less than 0.1 specifies a clean sky with extreme visibility, whereas the value of 1 postulates a hazy condition (NASA Earth Observations., 2021). The AOD value of more than two specifies severe atmospheric pollution.

All the previous studies focused on bivariate simple regression analysis of AOD and ground observed Particulate Matters (PM10 or PM2.5). Remer et al., 2014, Equated the MODIS aerosol data with ground observed AERONET measurements of aerosol optical depth

(AOD). They established that Collection 5 MODIS aerosol products estimate AOD to within anticipated accuracy greater than 60% of the time over the ocean and greater than 72% of the time over the land. Zhang et al. examined the relation among MODIS AOD and PM2.5 over the 10 U.S. Environmental Protection Agency (EPA)-well-defined geographic areas in the United States based on a 2-yr (2005-2006) match-up dataset of MODIS AOD and hourly PM2.5 measurements (Zhang et al., 2009).

The AOD retrievals determine a geographical and seasonal disparity in their correlation with PM2.5. ood correlations are typically detected over the eastern United States in summer and fall. The southeastern United States has a maximum correlation coefficient of more than 0.6. The southwestern United States has the lowermost correlation coefficient of around 0.2. The seasonal regression relations measured for each region are used to estimate the PM2.5 from AOD retrievals, and it is revealed that the valuation using this method is more precise than that using a fixed ratio among PM2.5 and AOD. Throughout the ICARTT field operation in the summer of 2004 over eastern North America, investigators use an ensemble of ground observed, satellite (MODIS), and aircraft-based aerosol observations (Drury et al., 2010). They observed that the Inference of ground PM2.5 from MODIS AOD retrieval demonstrates a good correlation to the EPA-AQS data (R = 0.78). The ensemble of the surface-observed, MODIS and aircraft data are reliable in indicating a model overestimate of sulphate in the mid-Atlantic and an underestimate of organic and dust aerosol in the southeastern United States.

Particulate Matter (PM10) and Relative Humidity (RH) data for pre-monsoon and post-monsoon seasons in 2017 over the entire Jharkhand.

Study Area

Jharkhand was established on the 15th.November 2000 as the 28th State of the Republic of India. The geographical area of Jharkhand is about 79,714 sq. km (Bhatt et al., 2002). Jharkhand is located at the centre of Chotanagpur Plateau towards the Northwest of Kolkata at about 160 km radial distance and about 770 km in the Southeast from Delhi. Both Delhi and Kolkata reveal high air pollution almost through the year. This state is the part of Indo-Gangetic Plain (IGP), which is known for its aerosol hotspots (Srivastava et al., 2013; Kumar et al., 2015b; Sen et al., 2017; Mhawish et al., 2017; Mhawish et al., 2018; Ramachandran et al., 2020; Mohammad et al., 2022).

Different anthropogenic activities in Jharkhand have increased especially mining, highly polluting industries, thermal power plants etc. On the other hand, forest fires are a common phenomenon in the state, which is a very important factor for air pollution. The geographical extent of Jharkhand State is between 21° 55 to 25° 35' North Latitude and 83° 20' to 88° 02' East Longitude (Figure. 1). It encompasses the Chotanagpur Plateau, which is a part of Deccan bio-geographic domain.

Materials & Methods

Data Used

In this study, we have used remote sensing data along with the different types of ground data or surface data for

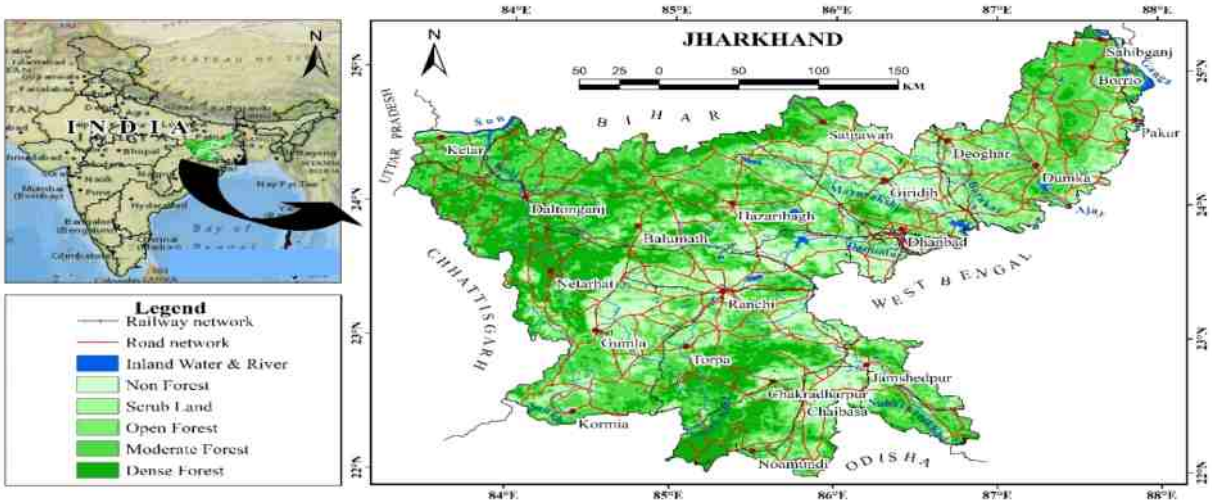

Fig.1 : Geographical distribution of the study area, Jharkhand state, India.

In this study, we have tried to perform the multiple linear regression model to estimate the ambient Air Quality Index from satellite-measured Aerosol Optical Depth using field observed Respirable Suspended estimating the Air Quality Index (AQI) over the study area for the year 2017 in pre-monsoon (March, April and May) and post-monsoon (September, October and November) seasons. These data are from different sources and have

a consistent projection, structure, spatial resolution and also definite time duration.

MODIS is a satellite-based global imager that can quantify visible and infrared radiation in the 0.4 to 14.4 µm spectral range for land, atmosphere, and ocean applications. MODIS data has 36 spectral bands. Nine bands are in the visible and near-infrared (NIR) spectral regions, have wavelengths of 412 nm to 869 nm and have the enhanced radiation sensibility essential for ocean color applications (Esaias et al., 1998; Franz et al., 2007, Mohammad et al., 2022). MODIS data takes measurements at three spatial resolutions, the MODIS imagery has a spatial resolution of 250 m, 500 m, and 1 km (Kahn et al., 2009; Zhang and Reid, 2009; Shi et al., 2012; Acharya and Sreekesh, 2013), The repetitive, extensive coverage permits MODIS data to produce an extensive electromagnetic image of the globe every two days (Miller, 2003). The MODIS aerosol data monitor the ambient aerosol loading and some other cloud-free aerosol properties on the ocean and land surfaces. It is provided by the different types of spectral bands, and spatial monitoring in different algorithms has been used to get the aerosol properties over the atmosphere (Kaufman et al., 1997; Levy et al., 2013; Hsu et al., 2013).

On the other hand, we have considered the ground observed relative humidity of the Pre-Monsoon and Post-Monsoon seasons of 2017 from the Automatic Weather Station Network (AWS) Jharkhand Space Application Center (JSAC, 2017) over 16 ground monitoring stations. According to the Central Pollution Control Board, Government of India the Respirable Suspended Particulates Matter (PM10) is the major air pollutant of immediate human concern which when in higher concentration affects the health and well-being of the people. For assessing the ambient air quality, we have considered the ground observed relative humidity and Suspended Particulate Matter (PM10) along with the satellite measured AOD over the study area.

Methodology:

We have computed the relative humidity (%) over the entire state using kriging interpolation techniques. We performed a multiple linear regression model to compute the satellite-based Respirable Suspended Particulate Matter (RSPM) or PM10 for the assessment of ambient Air Quality Index (AQI) over the study area using satellite-derived AOD, ground observed particulate matter (PM10) and relative humidity using R statistical software.

Extraction of MODIS AOD

In this study, Terra-MODIS C6 AOD at 550 nm with recommended quality assurance (QA), for DT is at 10 km (retrievals flagged QA = 3), DB is at 10 km (QA ≥ 2) and merged DT-DB at 10 km are at the same time considered (Kaufman et al., 1997; Levy et al., 2013; Mhawish et al., 2017; Mohammad et al., 2022). For this study, the daily overpass time (~10:30 local time, ±60 minutes), of average Terra-MODIS C6 AOD at 550 nm with recommended quality assurance (QA) data was used for estimating the Aerosol Optical Depth over the Jharkhand state. AOD is retrieved from the MODIS product (MOD04_L2) using the AOD_550_Dark_Target_Deep_Blue_Combined Algorithm. We have considered a spectral signature of 550 nm from the MODIS Terra aerosol dataset (MOD04_L2). Using the ENVI/IDL 5.2 software we extracted the MODIS AOD after being geo-referenced. From the retrieved AOD, we have reprocessed the AOD using resampling techniques and generated mean AOD for the pre-monsoon and post-monsoon seasons of 2017 using ERDAS IMAGINE 2014 software over the entire Jharkhand state (Figure. 2).

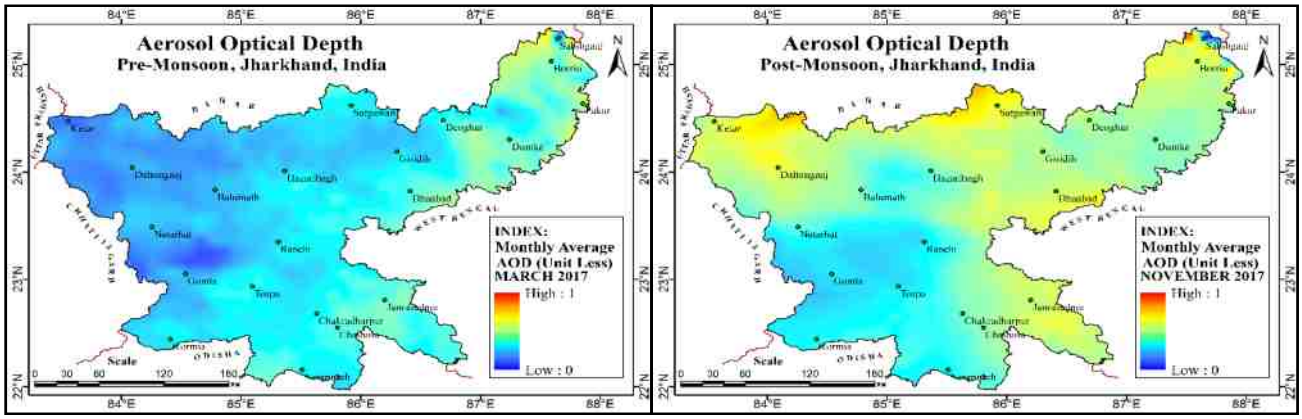

Fig. 2: Seasonal Average Aerosol Optical Depth over Jharkhand State; (a) Pre-Monsoon and (b) Pre-Monsoon of 2017.

Preparation of Relative Humidity Maps

Relative Humidity (RH) is a ratio, quantified in percent, of the quantity of moisture present in the atmosphere relative to the quantity that would be present if the air were saturated. Relative Humidity is measured from the accompanying Temperature and Dew Point for the specified hour (National Weather Service, NOAA) (Equation: 1)

$$Relative\ Humidity = \frac{Actual\ Vapour\ Density}{Saturation\ Vapour\ Density} * 100 \quad (1)$$

A.M. time space and created a seasonal average relative humidity. Then we interpolated the data using kriging interpolation techniques in ArcGIS 10.4 software to get the relative humidity map over the study area (Figure. 3).

Estimation of Respirable Suspended Particulates Matters (PM_{10})

Respirable Suspended Particulates Matter (RSPM) or PM_{10} from 8 different ground stations in the study area were collected from the Jharkhand State Pollution Control

Table 1: Seasonal Average Relative Humidity (%) over 16 different ground monitoring stations over Jharkhand State, India for pre-monsoon and post-monsoon seasons in 2017

Name of the Stations	Latitude	Longitude	Seasonal Average Relative Humidity (%)	
			Pre-Monsoon	Post-Monsoon
ISRO0957_15F3BD(BDO-D.C.Office-Hariharganj-)	24.56	84.28	41.01	59.04
ISRO0931_15F3A3(BDO-Dhumka-D.C.Office-)	24.28	87.26	48.52	60.40
ISRO0940_15F3AC(BDO-Meral (Pipra Kalan))	24.18	83.71	47.71	56.00
ISRO0945_15F3B1(BDO-Jamua-D.C.Office-)	24.20	86.15	40.88	57.00
ISRO0960_15F3C0(BDO-D.C.Office-Manatu-)	24.17	84.35	29.77	50.80
ISRO0936_15F3A8(BDO-Dhurki)	24.14	83.45	36.13	62.00
ISRO0948_15F3B4(Vinobha Bhave University-Hazaribag	24.02	85.38	28.51	53.29
ISRO0949_15F3B5(BDO-Narayanpur-D.C.Office-)	24.05	86.61	49.51	86.00
ISRO0962_15F3C2(BDO-D.C.Office-Panki-)	24.03	84.47	40.55	52.00
ISRO0975_15F3CF(BDO-Chanho)	23.51	84.98	36.72	58.86
ISRO0968_15F3C8(BDO-D.C.Office-Angara)	23.40	85.51	40.19	60.16
ISRO0971_15F3CB(CTR&TI-CTRTI Ratu-)	23.42	85.21	38.24	65.00
ISRO0976_15F3D0(BDO-Lapung)	23.22	85.05	36.24	52.39
ISRO0973_15F3CD(BDO-Bindu)	23.17	85.58	36.08	66.67
ISRO0982_15F3D6(BDO-Arki)	23.01	85.53	35.82	84.86
ISRO0985_15F3D9(BDO-D.C Office-Khar sawan)	22.78	85.82	45.41	64.98

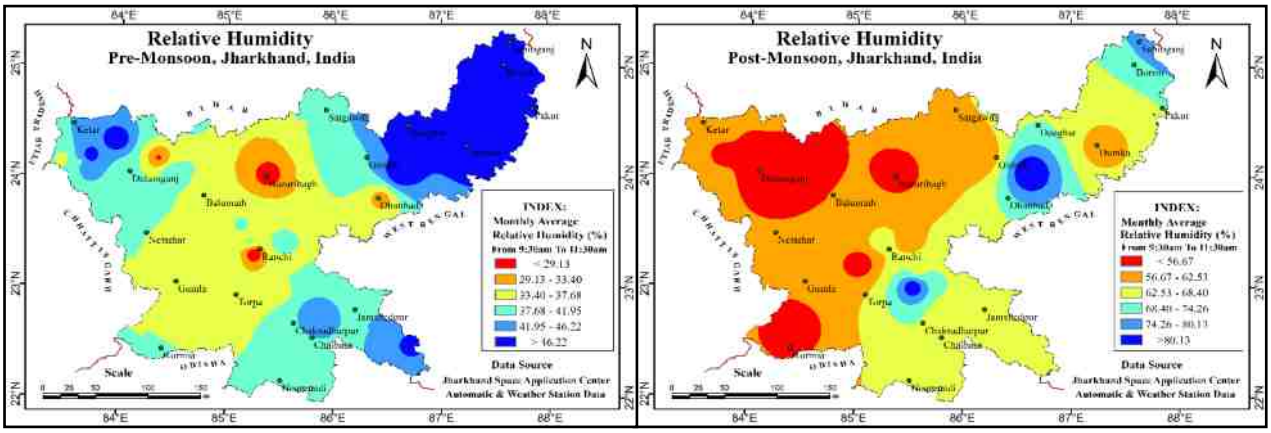

Fig. 3: Seasonal Relative Humidity for the Pre-Monsoon and Post-Monsoon seasons of 2017 over Jharkhand state.

For this study we have collected the ground-based observed Relative Humidity data of Pre-Monsoon andPost-Monsoon seasons of 2017 from the Automatic Weather Station Network (AWS) Jharkhand Space Application Center (JSAC, 2017) over 16 ground monitoring station (Table:1) After that we have extracted only those data are observed between 9:30 A.M. to 11:30

(JSPCB). Those are 1. Ranchi (Albert Ekka Chowk), 2. Sadar Police Station (Hazaribagh), 3. Regional Office (Hazaribagh), 4. Giridih (Tiranga Chowk), 5. Regional Office, Dhanbad, 6. Bastacola (Eco Restoration Rocp), 7. CGMO (Kusumda), 8. Raja Shiv Prasad College (MODA) (Table: 2). All sample sites of the air pollution monitoring station are monitored by the JSPCB. These stations are

are equipped with gravimetric samplers and record PM_{10} regularly using high-volume samplers.

$r_{y,x1}$ = Correlation Coefficient between AOD and RSPM.

$r_{y,x2}$ = Correlation Coefficient between Relative Humidity and RSPM.

Table 2: Seasonal Average Respirable Suspended Particulate Matter (RSPM) or PM10 of 8 different ground monitoring stations by Jharkhand State Pollution Control Board, Government of India for pre-monsoon and post-monsoon seasons in 2017

Sl. No	Regional Offices (JSPCB)	Station Name	Seasonal Average RSPM (µg/m3), 2017	
			Pre-Monsoon	Post-Monsoon
1	Ranchi	Ranchi (Albert Ekka Chowk)	131.88	136.1
2	Hazaribagh	Sadar Police Station (Hazaribagh)	116.83	142.56
3		Regional Office (Hazaribagh)	108.56	109.23
4		Giridih (Tiranga Chowk)	120.75	119.48
5	Dhanbad	Regional Office, Dhanbad	195.48	219.46
6		Bastacola (Eco Restoration Rocp)	282.81	235.59
7		CGMO (Kusumda)	285.51	315.02
8		Raja Shiv Prasad College (MODA)	293.17	372.72

Multiple Linear Regression Model(2)

A correlation coefficient is a numerical measure of the degree to which varies to the value of one variable predicts change to the value of another. In the case of Bi-Variate correlation (r) is determined by equation 2.

$$r = \frac{\sum xy - \frac{(\sum x \sum y)}{n}}{\sqrt{\sum x^2 - \frac{(\sum x)^2}{n}(\sum y^2 - \frac{(\sum y)^2}{n})}} \quad (2)$$

x: Independent variable

y: Dependent variable

n: Number of observations

- **Multiple Regression (R):**

A statistical implement that allows us to inspect how many independent variables are associated with a dependent variable.

- **Computation of R (multiple correlation coefficient)**

For the computation of multiple correlation coefficient (R), we have to calculate the individual correlation coefficient of each pair of variables (Equation: 2). For this study we have to Computed:

1. Correlation between AOD and Relative Humidity (rx1, x2)

2.Correlation between AOD and RSPM (rx1, y) RSPM (rx2, y) 3.Correlation between Relative Humidity and Using this information, we have computed the correlation coefficients of multiple correlation co-efficient "R" using equation 3.

$$R = \sqrt{\frac{\left[(r_{y,x})^2) + (r_{y,x2})^2\right] - (2r_{y,x1}r_{y,x2}r_{x1,x2}}{1 - (r_{x1,x2})^2}} \quad (3)$$

$r_{x1,x2}$ = Correlation Coefficient between AOD and Relative Humidity.

(4)The Formula for Multiple Regression:

$$Y = a + b_1X_1 + b_2X_2 + b_nX_n \quad (4)$$

Y = A predicted value of Y

A = the "Y Intercept"

b_1 = the change in Y for each 1 increment change in X_1

b_2 = the change in Y for each 1 increment change in X_2X = an X score (X is your Independent Variable) for which we are trying to predict a value of Y

- **Computation of (Slopes) b_1 and b_2**

$$b_1 = \left(\frac{r_{y,x1} - r_{y,x2}r_{x1,x2}}{1 - (r_{x1,x2})^2}\right)\left(\frac{SD_y}{SD_{X1}}\right) \quad (5)$$

$$b_2 = \left(\frac{r_{y,x2} - r_{y,x1}r_{x1,x2}}{1 - (r_{x1,x2})^2}\right)\left(\frac{SD_y}{SD_{X2}}\right)$$

$r_{y,x1}$ = Correlation between RSPM and AOD.

$r_{y,x2}$ = Correlation between RSPM and Relative Humidity.

$r_{x1,x2}$ = Correlation between AOD and Relative Humidity.

$(r_{x1,x2})^2$ = The coefficient of determination (r squared) for AOD and Relative Humidity.

SD_y = Standard Deviation for Y (dependent) variable.

SD_{x1} = Standard Deviation for the first X variable

SD_{x2} = Standard Deviation for the second X variable

- **Computation of (Intercept) 'a':**

The Formula for computation of intercept in multiple correlation analysis is bellowed.

$$a = \bar{Y} - b_1\bar{X}_1 - b_2\bar{X}_2 \quad (6)$$

$\bar{Y}$ = The mean of Y (dependent Variable).

$b_1\bar{X}_1$ = The value of b_1 multiplied by the Mean of the first independent variable (In this study AOD).

$b_2\bar{X}$ = The value of b_2 multiplied by the mean of the second independent variable (In this study Relative Humidity).

Air Quality Index from RSPM

The Air Quality Index (AQI) is an index for broadcasting daily air quality. It reveals to us how clean or unhealthy the air is, and what associated health effects might be a concern (Mohan et al., 2007). The AQI emphasises the health effects. The National Air Quality Index (AQI) was introduced in New Delhi on 17 September 2014 under the Swachh Bharat Abhiyan. The Central Pollution Control Board together with State Pollution Control Boards has been functioning the National Air Monitoring Program (NAMP) covering 240 cities in the country and having more than 342 monitoring stations. The earlier measuring index was limited to three indicators, the new index measures eight parameters There are six AQI categories, namely Good, Satisfactory, Moderately polluted, Poor, Very Poor, and Severe (Table:3 & 4). AQI consider eight pollutants (PM10, PM2.5, NO2, SO2, CO, O3, NH3, and Pb) for National Ambient Air Quality Standards are prescribed (CPCB, Government of India., 2022). In this study, only the Particulate Matters (PM10) were considered to analyze the seasonal Air Quality Index (AQI) mapping.

- **Computing the AQI(7)**

The air quality index is a piecewise linear function ıe pollutant concentration. At the boundary between AQI categories, there is a discontinuous jump of one AQI unit. To convert from concentration to AQI this equation 7 is used:

$$AQI = \left\{\frac{(PM_{obs} - PM_{min}) \times (AQI_{max} - AQI_{min})}{(PM_{max} - PM_{min})} + AQI_{min}\right\} \quad (7)$$

PM_{obs} = observed 24-hour average concentration in µg/m3

PM_{max} = maximum concentration of AQI color category that contains PM_{obs}

PM_{min} = minimum concentration of AQI color category that contains PM_{obs}

AQI_{max} = maximum AQI value for color category that corresponds to PM_{obs}

AQI_{min} = minimum AQI value for color category that corresponds to Pm_{obs}

Figure: 4 depicted the detailed flow chart for thisstudy for the air quality index mapping from satellite-measured AOD

Table 3: Air Quality and Health Impacts

AQI	Associated Health Impacts
Good (0–50)	Minimal impact
Satisfactory (51–100)	May cause minor breathing discomfort to sensitive people.
Moderately polluted (101–200)	May cause breathing discomfort to people with lung diseases such as asthma, and discomfort to people with heart disease, children and older adults.
Poor (201–300)	May cause breathing discomfort to people on prolonged exposure, and discomfort to people with heart disease.
Very poor (301–400)	May cause respiratory illness to the people on prolonged exposure. The effect may be more pronounced in people with lung and heart diseases.
Severe (401–500)	May cause respiratory impact even on healthy people, and serious health impacts on people with lung/heart disease. The health impacts may be experienced even during light physical activity.

Table 4: AQI Category, Pollutants and Health Breakpoints

AQI Category	Range	Breakpoints (µg/m3)	PM_{10} (24hr) Average Concentration (µg/m3)	RSPM Breakpoints (µg/m3)
Good	0 - 50	0	0–50	0
Satisfactory	51–100	50.5	51–100	50.5
Moderately polluted	101–200	100.5	101–250	100.5
Poor	201–300	200.5	251–350	250.5
Very poor	301–400	300.5	351–430	350.5
Severe	401–500	400.5	430+	430.5

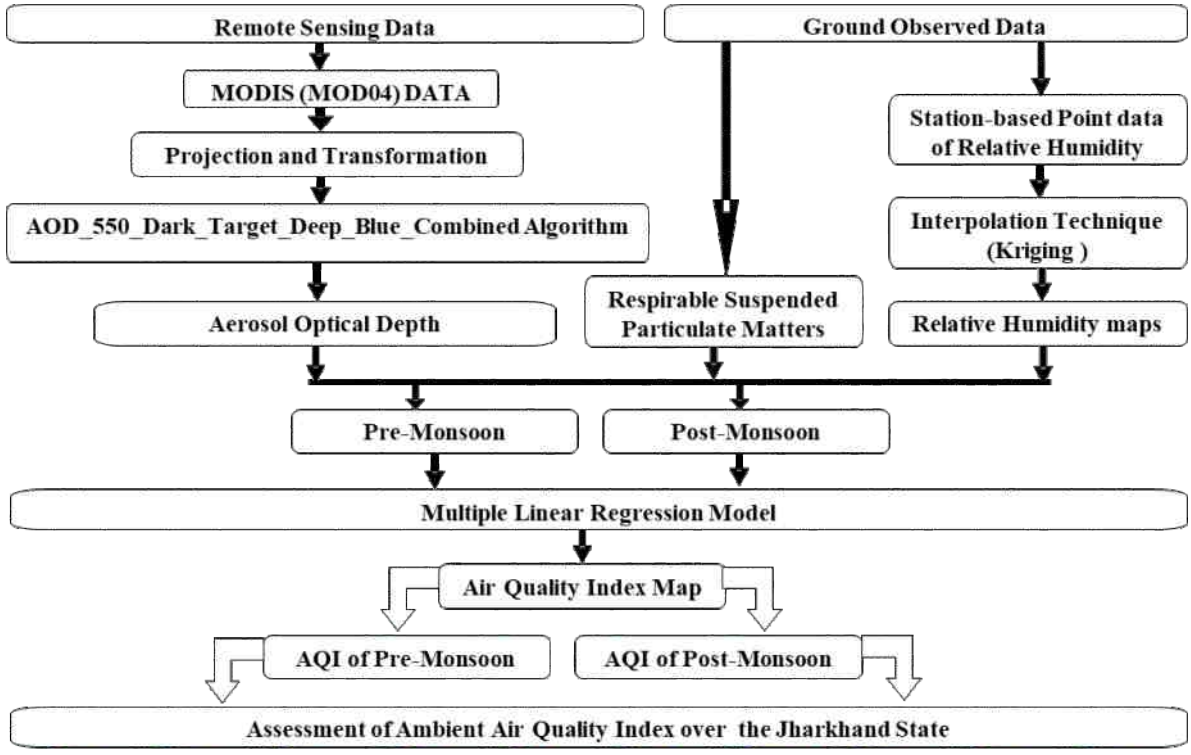

Fig. 4: Flow chart of the methodology for assessing the ambient Air Quality Index from satellite-derived AOD over Jharkhand State, India for the pre-monsoon and post-monsoon seasons in 2017.

Results and Discussion

Analysis of estimated RSMP or PM_{10}:

An attempt has been made to estimate the Respirable Suspended Particulate Matter (RSPM) concentration over the Jharkhand state by using satellite-derived Aerosol Optical Depth (AOD), ground-based measurement of RSPM and relative humidity (RH). To estimate the RSPM over the whole Jharkhand state we have performed the Multiple Linear Regression Model for pre-monsoon and post-monsoon seasons in 2017.

For this model fitting in the pre-monsoon season, the Multiple R2 = 0.87, suggests that the model can explain 76% of the variability in ground-level RSPM concentrations. And in the post-monsoon season, this can explain 64% of the variability in ground-level RSPM concentration over Jharkhand. This Multiple Linear Regression Model achieved better results in pre-monsoon than in the post-monsoon season (Figure:5). The standard error of estimation is 47.77 μg/m3 in pre-monsoon and 68.69 μg/m3 in the post-monsoon season. This indicates that information on spatial variability builds on the meteorological factors of the area. The reason for this phenomenon can be explained as follows: ambient air pollution is largely influenced by emission sources and meteorological factors. In the colder season (post-monsoon), the atmosphere is typically stable over short periods, meaning that RSPM estimations are dependent on pollutant emissions within a certain area of spatial width; during warmer seasons (Pre-monsoon), varying weather patterns significantly affect the formation and dispersion of air pollutants, RSPM estimations are dominated by meteorological factors, which vary considerably over time.

In case of pre-monsoon season, the highest (>351 μg/m3) RSPM occurred in the eastern and north-eastern parts of the state, namely Borrio, Pakur, Jamshedpur and Southern part of Dhanbad, Jamtara, Dumka district. And the lowest (<50 μg/m3) RSPM occurred in the Western and North Western parts of the state, Namely Gumal, Palamu, Chatra, Latehar, Lohardaga districts and the Northern part of Hazaribagh and Giridih district.

Whereas, the spatial pattern of RSPM is fully different in the post-monsoon season. The highest (> 350 μg/m3) RSPM occurred in the North-Western part of the Sahibganj district, which is covered by a mining area and a lot of stone crushers. And the second highest AOD occurred along the Northern and Eastern Boundary of the state, namely, the Northern part of Palamu, Kodarma, Satgawan, Godda, Sahibganj districts and the Eastern and Middle parts of Bokaro, Dhanbad, and North-Eastern parts of West Singhbhum district.

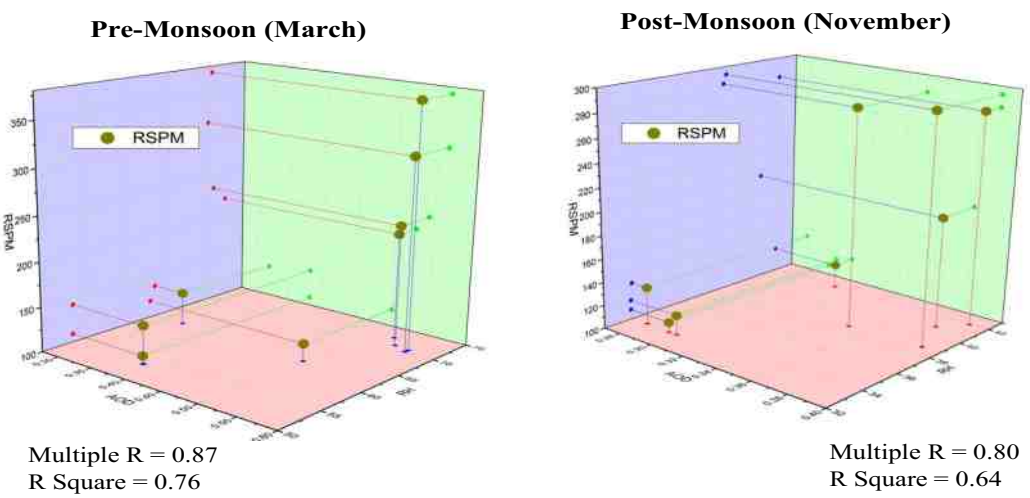

Fig. 5: Scatter plot of Aerosol Optical Depth, Respirable Suspended Particulate Matter and Relative Humidity of Pre-monsoon and Post-Monsoon in 2017 over Jharkhand State, India

Air Quality Index of Pre-Monsoon:

In the pre-monsoon, the seasonal air quality has been generated using satellite-derived AOD and ground observed data products. In the pre-monsoon (March) 2017 air quality over the Jharkhand existed in five categories, those are good (<50 µg/m3), satisfactory (51 to 100 µg/m3), moderately polluted (101 to 250 µg/m3), Poor (250 to 350 µg/m3) and very poor (351 to 430 µg/m3), which are situated in the North-Western part to Eastern part respectively. The highly polluted air category (poor and very poor > 251 µg/m3) occurred mainly in the Eastern part of the state, which is covered by Industrial zones, mining areas, Stone crushers, high population density, Industrial zone, High Road density (>17 km per km square) namely, Dhanbad, Dumka, Jamshedpur, Pakur, Borrio and southern part of Noamundi block. The middle part of the state, namely, Giridih, Deoghar, Ranchi, Topra, Hazaribagh, Chakradharpur covered by the moderately polluted (RSPM >101 to 250 µg/m3). All these areas are covered by moderate vegetation cover (NDVI<0.4) and moderate dense population.

The Western and North-Western parts of the State are covered by the Good and Satisfactory air quality category. This area is covered by Gumla, Lohardaga, Latehar, Palamu, Chatra and Garhwa districts and some parts of Simdega, Hazaribagh, Giridih and the Western part of Ranchi and Simdega districts. Which is covered by dense vegetation (NDVI>0.5) cover, low population density (<177 per square km), and is far from the industrial zones of the eastern part of the state. The spatial pattern of air quality of the state from west to east represents good to poor air quality in the pre-monsoon season (Figure:6a).

Air Quality Index in Post-Monsoon:

The spatial pattern of the distribution of air quality in post-monsoon over Jharkhand is different from the pre-monsoon, though the major patterns are almost the same as the pre-monsoon. In this season (post-monsoon) the overall air quality of the state appeared three primary categories, these are satisfactory, moderately polluted and poor air pollution category. Though in the North-Western part of Sahibganj district occurred a very poor air category, which is covered by a lot of mines and stone crushers over this region.

The poor (RSPM 251 to 350 µg/m3) air category occurred in some parts of the Northern and Eastern parts of the state, namely, the Northern part of Palamu, Kodarma, Giridih, Godda and Sahibganj district and Eastern part of Pakur, West Singhbhum Bokaro and Dhanbad district. All of this area is covered by highly polluting industries, nearest to the mining area, stone crusher and high population density. The moderately polluted (RSPM 101 to 250 µg/m3) air occurred in most of the state, which is covered by Giridih, Deoghar, Hazaribagh, Ranchi, Chatra, Garhwa, Latehar, West Singhbhum, Dumka districts and some part of Pakur, Godda, Simdega and Sarikela-Kharswan district. And the satisfactory (RSPM 51 to 100 µg/m3) air category occurred in the South-Western part of the state, mainly Gumla and the northwestern part of the Simdega district. And also, the western part of Ranchi, Khunti and Lohardaga districts, which are covered by dense vegetation cover (NDVI >0.5) and low population density (<171 persons per square km) and which is situated far from the industrial zones and other anthropogenic activities (Figure: 6b).

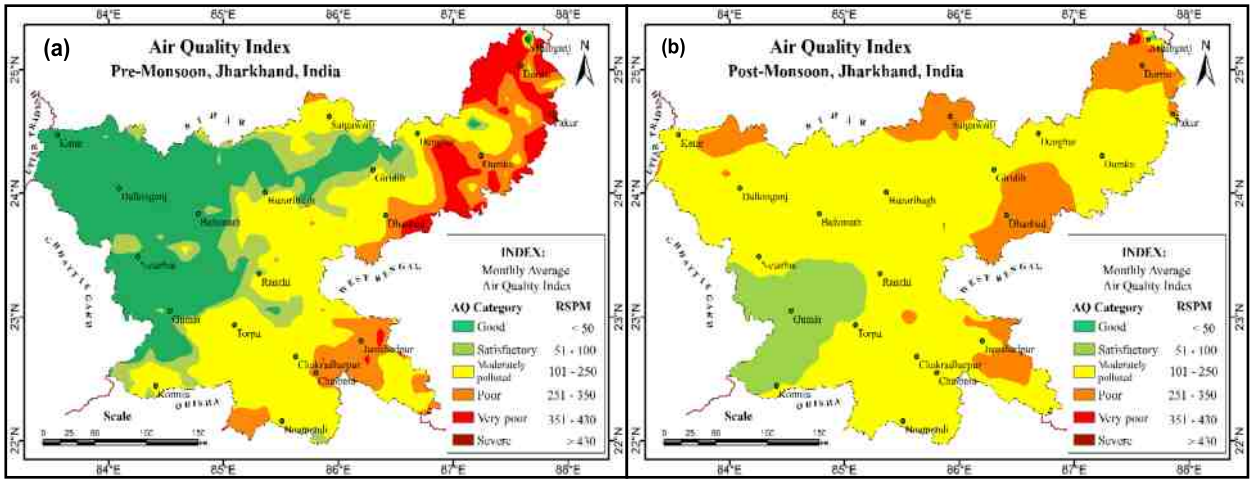

Fig. 6: Ambient Air Quality Index Map of Jharkhand statefor (a) pre-monsoon and (b) post-monsoon season in 2017.

Conclusion

High concentrations of AOD in the North-Eastern part of Jharkhand were attributed to mining, industrial areas, stone crushers etc., in and around Dhanbad and Jamshedpur regions. Air quality index over Jharkhand estimated from multiple linear regression model using (i) satellite data derived AOD, (ii) measured Respirable Suspended Particulate Matter (RSPM) and (iii) Relative Humidity for pre-monsoon and post-monsoon seasons. The correlation coefficients of satellites derived AOD, RSPM and Relative Humidity in the pre-monsoon and post-monsoon respectively for the year 2017, were estimated as 0.87 and 0.80. The highest RSPM (> 350 µg/m3) was found in the Eastern part of the state whereas, the South-Western part of the State witnessed the lowest RSPM (<50 µg/m3). During pre-monsoon air quality of Jharkhand varies gradually from good (RSPM<50 µg/m3) in Western Jharkhand to very poor (RSPM 251 to 350 µg/m3) in East. In the post-monsoon season, the spatial pattern of air quality category has been changed though good or satisfactory (RSPM<101 µg/m3) in the South-western part of Jharkhand, whereas, the poor (RSPM> 251 µg/m3) air quality was estimated in North-eastern boundary of the state. This study thus provides an alternative perspective on revealing ambient air quality index patterns in and around Jharkhand and also facilitates environmental and epidemiological studies by indicating their related causes using remote sensing techniques.

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Coastal Zone Management in India - A Legislative Approach

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Abstract

The Ministry of Environment, Forest and Climate Change (MoEF&CC), Government of India, promulgated the Coastal Regulation Zone (CRZ) Notification, 2019 on the 18th of January, 2019, with a view to ensuring livelihood security to the fisher communities and other local communities living in the coastal areas, to conserve and protect coastal stretches, its unique environment and its marine area and to promote development through sustainable manner, based on scientific principles taking into account the dangers of natural hazards in the coastal areas and sea level rise due to global warming. The Notification declares the coastal stretches of the country and the water area upto its territorial water limit, as the Coastal Regulation Zone (hereinafter referred to as the CRZ) and restricts the setting up and expansion of any industry, operations or processes and manufacture or handling or storage or disposal of hazardous substances. The Notification mandates the coastal States/UTs to prepare the Coastal Zone Management Plans on 1: 25,000 scale by identifying and classifying the CRZ areas in accordance with the guidelines, for the approval of the MoEF&CC, Govt. of India. The legal framework for coastal management in India consists of Acts of Parliament, Rules and Notifications, Administrative orders from the national to the local levels as well as international treaties and agreements. The present paper discusses about the Legal framework and the various legislative provisions applicable for sustainable management of the coastal areas in India as outlined in the Indian constitution as well as the methodology for preparation of the Coastal Zone Management Plans (CZMPs).

Keyword: Coastal zone, Coastal zone management plan, CRZ notification.

Introduction

The coast is a unique environment where land, sea and atmosphere interact continuously influencing a strip of spatial zone defined as coastal zone (MoEF&CC, 2018). The limits of the coastal zone are arbitrarily defined, differing widely among nations, and are often based on jurisdictional limits or demarked by reasons of administrative ease (Chua 1993). Different countries use different distance criteria for defining the coastal zone. Coastal zones are the most fragile, dynamic and contain productive ecosystem. The terrestrial processes such as wind actions and marine process namely tide, wave, currents, erosion / accretion etc continuously modify shoreline and make the coastal zone dynamic and fragile. Coastal environment plays a vital role in nation's economy because of the productive habitats and rich biodiversity and other environmental facilities (Swaminathan Committee report, 2005).

India has a coastline of about 7,500 kms of which the mainland accounts for 5,400 kms, Lakshadweep coasts extend to 132 kms and Andaman & Nicobar Islands have a coastline of about 1,900 kms. Nearly 250 million people live within a distance of 50 kms from the coast (Swaminathan Committee report, 2005).India's mainland coast is divided administratively into nine states and two Union Territories (UT); the island groups also have UT status. Each State/UT is further subdivided into districts. Including those in the island groups, there are 79 coastal districts with a total population of over 20 million as per census of India, 2011. As per the Census data of 2011, there are 486 census towns along the coast of India, accounting for a population of 41.7 million constituting 20.7% of the total coastal population (MOEF&CC, 2018). Fishing is the primary activity, with over an estimated 4.0 million people depending on the marine fisheries resources for their livelihoods (National Policy on Marine Fisheries 2017).

Coastal ecosystems such as coral reefs, mangroves forest and coastal geomorphological features namely beach and dune system serve as critical natural defences against storm surge, flooding and erosion. The coastal ecosystem maintains an ecological balance that accounts for shoreline stability, beach replenishment, nutrient generation and recycling. A coastal ecosystem reduces the impacts of pollution originating from land (example, wetlands absorbing excess nutrients, sediments, human waste). The fertile lowlands of the coastal region, abundant marine resources, water transportation and

aesthetic values made human settlements along the coastal region feasible, facilitating their livelihood. The various anthropogenic activities have put tremendous pressure on the fragile coastal environment. The coastal zones are exposed to varied issues mainly, coastal erosion and loss of coastal habitat, urban pollution, industrial and urban development, disasters like storm surge, tsunami and also the global warming induced sea level rise (Nayak, 2017).

Legislation for Protection of Coastal Environment of India

Constitutional provisions on coastal environment: The history of legislative actions started with the Indian Penal Code, 1860. Section 268 defined what is public nuisance. Abatement of public nuisance is also a subject of Sections 133 to 144 of I.P.C. These are only prohibitive provisions. Sections 269 to 278 of the Indian Penal Code are penal provisions which means that a person guilty of violating any of the provisions is liable to prosecution and punishment. The Constitution of India came into force on the 26th of January, 1950. Originally, the constitution contains no specific provisions for environmental protection, even the word "Environment" did not find a place in the constitution. The provisions relating to the protection of environment were incorporated for the first time by adding a new provision in Article 48-A in the Chapter, Directive Principles of State Policy by the Constitution (Forty Second Amendment) Act, 1976 and in subsequent amendments.

Environmental Protection and Preamble of the Constitution: The preamble of our Constitution provides that our country is based on "Socialistic" pattern of society, where the State pays more attention to the social problems than on any individual problems. Environmental pollution which has emerged as one of the biggest social problems is being regarded as a real problem affecting the society at large and thus the State is under an obligation to fulfil the basic aim of socialism, that is, to provide decent standard of living to all which can be possible from a pollution free environment. The preamble further declares that, the rights and freedoms which the people of India intended to secure all citizens include justice, social, economic and political. Justice also includes environmental justice. The Preamble also declares India to be a "Democratic Republic". In a democratic set up, people have the right to participate in government decisions. They also have the right to know and access to information of government policies is very important for the success of the environment policies.

Division of Legislative Powers in Environmental Matters: Under Indian federal system, governmental power is shared between the Union and the State governments. Part XI of the Constitution governs the administrative and legislative relation between the center and the states. Article 246 divides all subject areas of legislation into three categories – Union, State and Concurrent. When a central law conflicts with a state law in a concurrent subject, the former prevails. The aspects related to coastal and marine environmental protection fall under Union, State and Concurrent lists. The coastal governance in India has varied institutional arrangements for decision-making for development and ensuring safeguards for the environment which occur at three levels of government: national, state, and local. Development activities are coordinated by the respective ministries, depending on whether the subject is within the central or state list.

International Environmental Agreements and India's Obligations: India is a contracting party or signatory to various international treaties and agreements relating to regional or global environmental issues. India is under an obligation to translate the contents and decisions of International Conferences, treaties and agreements into the stream of national law. Article 51(c) provides that "the State shall endeavour to foster respect for international law and treaty obligations in the dealings of organized people with one another". Article 253 of the Constitution specifically empowers the Parliament "to make any law for the whole or any part of the territory of India for implementing any treaty, agreement or convention with any other country or countries or any decision made at any international conference, association or other body".

Duties of the Citizen Towards Environmental Protection: The Constitution (Forty-Second Amendment) Act, 1976 added a new part IV-A dealing with "Fundamental Duties" in the Constitution of India. Article 51-A (g) specially deals with fundamental duty with respect to environment that: "It shall be the duty of every citizen of India to protect and improve the natural environment including forests, lakes, rivers and wild life and to have compassion for living creatures". Article 51-A (g) refers to the fundamental duty of every citizen to protect and improve "natural environment".

Duties of the State Towards Environmental Protection: Article 47 of the Constitution reads: "The State shall regard the raising of the level of nutrition and the standard of living of its people and the improvement of public health as among its primary duties and, in particular, the State shall endeavour to bring about prohibition of the consumption except for medical purposes of intoxicating drinks and drugs which are injurious to health". Article 47 calls upon the State to perform the basic duty to look after the health of the citizen and also take necessary and effective steps to improve their standard of living and also raise the level of nutrition. Article 48-A further provides "to safeguard the forests and wild life". This is an important provision as the environment is greatly influenced by forests and wild life. The cumulative effect of Articles 48-A and 51-A(g) appears to be that the 'State' as much as the 'Citizens' both are now under a constitutional obligation to conserve, preserve, protect and improve the environment.

Environmental Protection and Right to Life: Article 21 of the Constitution reads "No person shall be deprived of his life or personal liberty except according to procedure established by Law". The right to life as guaranteed by Article 21 of the Constitution is basic human right and the concept of right to life and personal liberty have been transformed into positive rights by active judicial interpretation such as "Right to Live in a Healthy Environment" (Jaswal and Jaswal, 2009), "Right to Livelihood and Environment"(State of H.P. v. Umed Ram, AIR 1986 SC 847).

Right to Know and Environment: Article 19(1) (a) of the Constitution of India guarantees to all its citizens the right to freedom of speech and expression. The freedom of speech under Article 19(1) (a) includes the right to express one's views and opinions at any issue through any medium, e.g. by words of mouth, writing, printing, picture, film, movie etc. It thus includes the freedom of communication and the right to propagate or publish opinion. The right to know is also implicit in Article 19(1) (a) and it has a close link with Article 21 of the Constitution particularly in environmental matters where the secret government decision may affect health, life and livelihood of the people. The right to know or access to information is the basic right for which the people of democratic country like India aspire for. The right to know plays a very important role in environmental matters (http://shodhganga.inflibnet.ac.in/bitstream/10603/76685/9/09_chapter%202.pdf.)

Right to Equality and Environment: The Indian Constitution guarantees 'right to equality' to all persons without any discrimination. This indicates that any action of the 'State' relating to environment must not infringe upon the right to equality as mentioned in the Article 14 of the Constitution.

Freedom of Speech and Expression and Environment: Article 19(1) (a) guarantees every citizen a fundamental freedom of speech and expression. In India most of the environmental jurisprudence has developed by judicial activism. Most of the cases came before the Court as a result of public interest litigations (PILs) in which the people exercised their freedom of speech and expression sometimes by writing letters to the court or otherwise by filing petitions before it, highlighting the violation of the rights of the people to live in healthy environment in one way or the other.

Freedom of Trade and Commerce and Environment: Article 19(1) (g) guarantees all citizens the right "to practice any profession or to carry on any occupation, trade or business". This right of the citizens is not absolute. It is subject to Article 19(6) under which "reasonable restrictions" in the "interest of the general public" can be imposed. Thus, environmental interest from the hazards of any trade or business can be protected.

Judiciary to protect coastal environment of India

In order to regulate human activities in the coastal zone and preservation and conservation of coastal unique environment, Ministry of Environment and Forest, has notified Coastal Regulation Zone (CRZ). The Supreme Court of India, the High Courts of India, and the National Green Tribunal have played vital role in protection and conservation of India's coastal environment. Some landmark judgements of Apex court are *Indian Council for Enviro-legal Action v Union of India [(1996) 5 SCC 281 (1996 AIR 1446, 1996 SCC (3) 212); S. Jagannath v Union of India* [(1997) 2 SCC 87: AIR 1997 SC 811]; *In Vaamika Island v Union of India and Ors. [(2013) 8 SCC 760].*

National and International law applicable in the coastal zone of India

National law

Important legislative provisions applicable to the coastal areas are follows:

Table 1. Legislative provisions applicable to the coastal areas in India

Sl. No.	Legislative provisions
1	The Indian Fisheries Act, 1897.
2	Indian Ports Act, 1908
3	The Indian Forest Act, 1927 and
4	Merchant Shipping Act, 1958
5	Major Port Trust Act, 1963
6	Wildlife Protection Act, 1972
7	Water (Prevention and Control of Pollution) Act, 1974
8	Maritime Zones of India (Regulation of Fishing by Foreign Vessels) Act, 1976
9	Marine Fishing Regulation Act, 1978
10	Air (Prevention and Control of Pollution) Act, 1981
11	Environment (Protection) Act, 1986
12	Forest Conservation Act, 1980 (amended in 1988)
13	Hazardous Wastes (Management and Handling) Rules, 1989
14	CRZ notification, 1991
15	National Environment Tribunal Act, 1995
16	The National Environmental Appellate Authority Act, 1995
17	The Biological Diversity Act 2002
18	The Coastal Aquaculture Authority Act, 2005
19	Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006:
20	EIA, Notification 2006:
21	CRZ notification, 2011, IPZ notification, 2011
22	The Wetlands (Conservation and Management) Rules, 2017
23	CRZ notification, 2019, ICRZ notification, 2019

International law applicable in the coastal zone: India is signatory to various international conventions and treaties related to environmental protection and has also taken numerous initiatives towards implementation. Table 2.1 depicts the key international conventions and treaties on the subject signed by India.

Coastal Zone Notification- Legal Provision Towards Protection of Coastal Resources of India

History of Indian coastal zone management: The Prime Minister (PM) Smt. Indira Gandhi in 1981, after taking a note of unplanned development in the coastal areas wrote letters to all the coastal States to take adequate measures for protecting the coastal environment. As the follow-up of the PM's directive, the then Department of Environment & Forests initiated preparation of a guideline for protecting the beaches of the country. These guidelines were prepared by experts and were provided to the coastal State Governments/Union Territory Administrations for implementation. However, none of the State/UT Governments took the guidelines seriously since, it had no statutory backing (Swaminathan Committee report 2005). Taking into note the failure of such guidelines without statutory backing, the Ministry of Environment & Forests carried out an in-house consultation and issued a draft Coastal Regulation Zone (CRZ) Notification, 1989 under Environment (Protection) Act, 1986 inviting suggestions and objections from public. Based on the comments received from the public, the Ministry finalized the CRZ Notification on 19.2.1991.

Coastal Zone Management Plan (CZMPs) of India – as per CRZ notification, 2011

The Ministry of Environment, Forest and Climate Change (MoEF&CC), Government of India, New Delhi issued Notification No. S.O. 19(E) dated 6th January 2011 which is referred to as the Coastal Regulation Zone (CRZ) Notification, 2011 in supersession of CRZ Notification 1991, with a view to ensuring livelihood security to the fisher communities and other local communities living in the coastal areas, to conserve and protect coastal stretches, its unique environment and its marine areas and to promote development through sustainable manner, based on scientific principles taking into account the dangers of natural hazards in the coastal areas and sea level rise due to global warming. The CRZ Notification 2011 declared that the coastal stretches of the country and the water area upto its territorial water limit, excluding the islands of Andaman and Nicobar and Lakshadweep and the marine areas surrounding these islands upto its territorial limit, as Coastal Regulation Zone (hereinafter referred to as the CRZ) and restricted the setting up and expansion of any industry, operations or processes and manufacture or handling or storage or disposal of hazardous substances. The respective State Governments and Union Territories were directed to prepare Coastal Zone Management Plans on 1: 25,000 scale by identifying and classifying the CRZ areas within the respective territories in accordance with the guidelines given in Annexure-I of the CRZ Notification 2011, for the approval of Ministry of Environment, Forest & Climate Change (MoEF&CC), Govt. of India.

The Coastal Zone Management Plans are prepared in 1:25,000 scale with Survey of India toposheets as base maps. Demarcation of High Tide Line (HTL) & Low Tide Line (LTL) is the major step to prepare CZMPs. The HTL is defined as “the line on the land up to which the highest

waterline reaches during the spring tide" which is different from the well-known and widely accepted definition of High Tide Level. The above definition of HTL takes into consideration not only the level of inundation due to maximum tide (spring tide) but also the wave set up (having a seasonal periodicity). The sea level thus formed due to the combined effect of spring tide and wave set up gives the line of maximum reach of water on the land. Unlike the HTL, the Low Tide Line (LTL) has not been defined for CRZ.

The HTL required specific definition since the 100, 200 and 500m setback lines are defined with respect to the HTL. The conventional definition of lowest low water level and the resultant low water line during spring tide is taken as the LTL. This has been done by using aerial photographs/satellite data. Manual on "Demarcation of High Tide Line and Low Tide line" prepared by NCSCM is referred during the delineation of HTL and LTL. Another important task is to map areas that are ecologically sensitive (ESAs) and the geomorphological features i.e. CRZ IA. NCSCM was assigned the task of mapping ESAs by MoEF&CC. The task was undertaken in partnership with various expert agencies such as Archaeological Survey of India, for Archaeological Sites data, Indian Institute of Science, Bengaluru for Turtle Nesting Grounds data, Zoological Survey of India, Kolkata for Horseshoe Crab data. 500 m CRZ line on the seacoast and the line marking 100 m or width of the water body for the tidally influenced water bodies, 100 m for bay and 100 m for fishing villages were drawn landward of HTL. The boundary lines of CRZ I (ESAs, archaeological and heritage sites), CRZ II (Developed area/ municipal areas), CRZ III (undeveloped /rural areas) and CRZ IV (water body) have been incorporated. In case of CRZ III (sea front), a 200m No Development Zone (NDZ) line was drawn on the CZMP maps. In case of mangrove areas of greater than 1000 sq.m, a buffer line of 50m has been provided. Other buffer lines were drawn wherever necessary, as specified in the CRZ Notification 2011. With this information, the final maps in 1: 25,000 scale were generated as per CRZ Notification, 2011. Details of steps involved in the preparation of CZMP maps are shown in Figure 1. The CZMPs map were presented before the Technical Scrutiny Committee (TSC) constituted by NCSCM to scrutiny the CZMPs. Based on the comments/suggestion of TSC, the maps were modified. Then, the modified maps were presented before the National Coastal Zone Management Authority (NCZMA) and based on the recommendation of NCZMA, MOEF&CC has given approval. The status MOEF&CC approved CZMP as per CRZ notification, 2011 and CRZ notification, 2019 were provided in Table 4.

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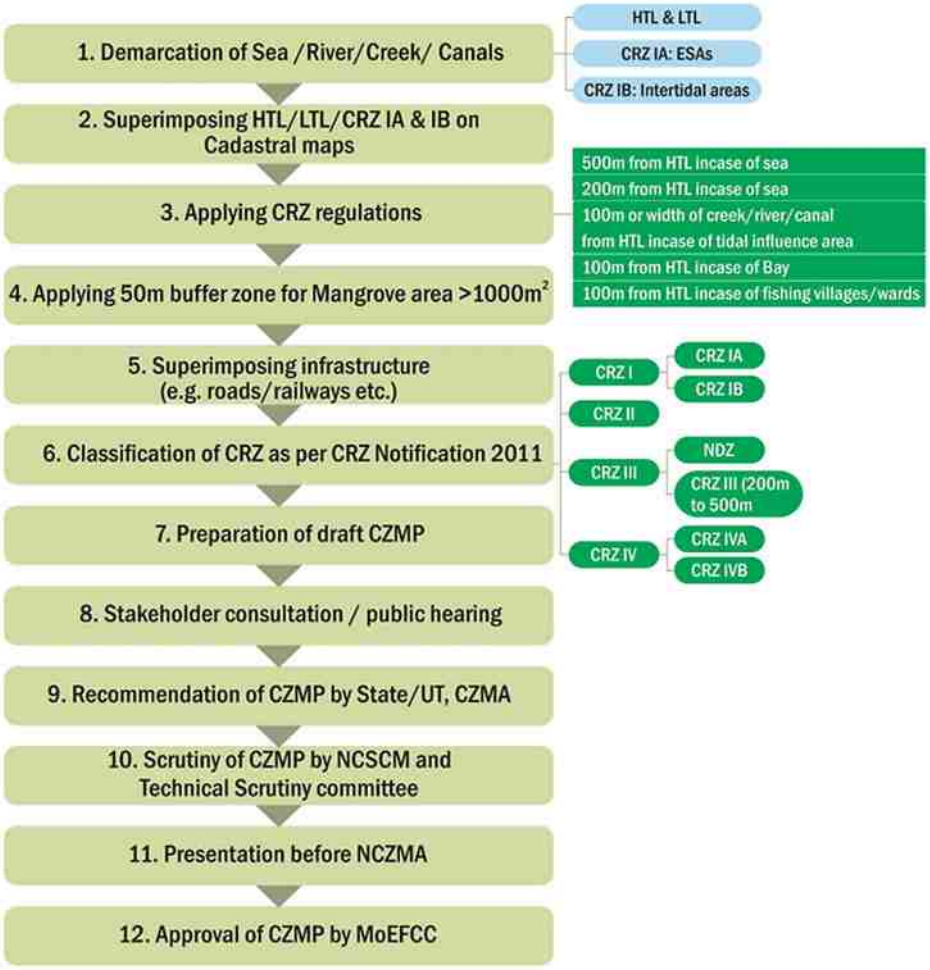

Figure 1. Various steps involved in the preparation of CZMPs

Table 2. Major International conventions and treaties on environment signed by India

Sl. No.	Convention
1	Convention Relative to the Preservation of Fauna and Flora in their Natural State (London Convention of 1933)
2	International Plant Protection Convention (1951)
3	International Convention for the Prevention of Pollution of the Sea by Oil (1954)
4	The Antarctic Treaty (Washington, 1959)
5	Ramsar Convention on Wetlands of International Importance (Ramsar, 1971)
6	Convention Concerning the Protection of the World Cultural and Natural Heritage (Paris, 1972)
7	Convention on International Trade in Endangered Species of Wild Fauna and Flora (Washington, 1973)
8	Convention on the Conservation of Migratory Species of Wild Animals (Bonn, 1979)
9	Convention on the Conservation of Antarctic Marine Living Resources (Canberra, 1980)
10	United Nations Convention on the Law of the Sea (Montego Bay, 1982)
11	Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (Basel, 1989)
12	Protocol on Environmental Protection to the Antarctica Treaty (Madrid, 1991)
13	United Nations Framework Convention on Climate Change (Rio de Janeiro,1992)
14	Convention on Biological Diversity (Rio de Janeiro, 1992)
15	Agreement relating to the Implementation of Part XI of the UNCLOS 1982 (1994)
16	Protocol to the United Nations Convention on Climate Change (Kyoto,1997)

Table 3. Brief history with time line of Indian coastal zone management initiatives

Sl.No.	Year	Events
1	1981	PM writes to CMs to conserve beaches
2	1983	A national committee to study the problems of beaches
3	1987	Beach guidelines issued for the protection of the beaches
4	1989-90	Draft Coastal Regulation Zone Notification issued in 1989 and reissued on 1990
5	1991	First CRZ Notification 1991
6	1992	Shri B.B. Vohra Committee – on issues relating to tourism (constitute committee)
7	1994	Supreme Court's directive to implement CRZ 1991
9	1996	Prof. N. Balakrishnan Nair Committee - on issues relating to Kerala on Coastal Regulation Zone
10	1996	Fr. Saldanha Committee (I) - to advice on withdrawal of groundwater and extraction of sand in Andaman & Nicobar Islands
11	1996	Supreme court direction to approve CZMP as per CRZ notification, 1991
12	1997	Fr. Saldanha Committee (II) - to examine specific issues relating to CRZ
13	2000	Shri D.M. Sukthankar Committee (I) – to examine the issues relating to Mumbai and Navi Mumbai
14	2000	Shri D.M. Sukthankar Committee (II) - to prepare a National Coastal Zone Policy of India (NCZP)
15	2004	CRZ & National Policy reviewed by Dr.M.S.Swaminathan Committee(2005 report submitted)
16	2008	Draft Coastal Management Zone (CMZ) Notification (due to Wide protest against CMZ Notification Honourable Parliamentary Committee of Science and Technology & Environment and Forests also considered CMZ 2008 Notification
17	2009	- Committee constituted under Prof. M. S. Swaminathan to examine CMZ issues in June 2009
18	2009	Review of Coastal Management Zone (CMZ) Notification subtitled report: final frontier on July 2009 (Set aside CMZ Notification and steps taken to strengthen CRZ 1991)
19	2010	Draft CRZ 2010 issued by MOEF
20	2010	Draft IPZ Notification issued by MOEF
21	2011	Final CRZ 2011 issued on 6th January 2011
22	2011	Final Island Protection Zone Issued on 6th January 2011
23	2011	NCSCM established by MOEF&CC
24	2014	Sailesh Nayak committee to review CRZ 2011 notification.
25	2017	Draft MCRZ notification (set aside)
26	2018	Draft CRZ notification 2018
27	2018	Draft ICRZ notification 2018
28	2019	Final CRZ notification 2019
29	2019	Final ICRZ notification 2019

Table 4. Status of MoEF&CC Approved CZMPs as per CRZ Notification. 2011 and 2019

Sl. No.	State	Agency Prepared	CRZ Notification, 2011	CRZ Notification, 2019	Available of CZMP
		CRZ notification, 2011/CRZ notification, 2019	Date of Approval	Date of Approval	
1	Gujarat	NCSCM / NCSCM	10.01.2019 28.02.2019 07.02.2019 02.12.2019 07.02.2020	-	http://www.gczma.org https://gpcb.gujarat.gov.in/webcontroller/viewpage/final-map-of-draft-coastal-zone-management-plan-of-various-districts-which-is-approved-by-bisag
2	Daman and Diu	NCSCM / NCSCM	24.10.2018		https://www.daman.nic.in/websites/Coastal_Zone_Mgnt_Authority/documents/2019/14-25-01-2019.pdf
3	Maharashtra	IRS/NCESS / NCSCM	16.08.2018 28.02.2019	29.09.2021 (Mumai City & Sub-Urban)	https://mczma.gov.in/czmp
4	Goa	NCSCM/	22.08.2022		
5	Karnataka	NCSCM / NCSCM	07.08.2018	02.09.2022	https://ksczma.karnataka.gov.in/info-4/Approved+CZMP+2018+&+Karnataka+Coastal+Zone+Management+Plan+Maps/en
6	Kerala	NCESS / NCESS	28.02.2019		http://keralaczma.gov.in/#maps
7	Tamil Nadu	NCSCM / NCSCM	24.10.2018		https://www.environment.tn.gov.in/czmpmaps
8	Puducherry	IRS / NCSCM	24.10.2018		https://dste.py.gov.in/pczma/Map.html
9	Andhra Pradesh	NCSCM / NCSCM	28.02.2019		http://apczma.ap.gov.in/UI/CZMP.aspx
10	Odisha	OSAC/SAC	07.08.2018	01.06.2021	https://www.sczmaodisha.org/approved_czmp.html
11	West Bengal	IESWM / IESWM	24.10.2018		http://www.environmentwb.gov.in/index.php

Source: Latest Approved CZMP Maps are Available on :https://parivesh.nic.in/Notifications.aspx?id=CRZ; and https://czmp.ncscm.res.in/

The Spatial Non-Stationary Effect of Land Use and Land Cover on Waterlogging in Mumbai

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Abstract

Mumbai is one of the most populous cities in India. The population is 93.56 lakh. 1.4% more than 2021. It's 369 km2. The growing population is worsening the region's waterlogging problem, which ruins property and puts lives at risk. Mumbai sits near the mouth of the Ulhas River on India's Konkan coast. The Arabian Sea borders Mumbai's west side. Several portions of the city are barely 10 to 15 metres above sea level; Salsette in the Powai-Kanheri highlands is 450 metres above sea level. Mumbai gets 1800 mm of monsoon rain between June and September. West winds dominate Mumbai's monsoon. The concretization of roads and pavements was motivated by an annual surge in runoff, which was primarily owing to its previous drainage system's failure to drain off precipitation adequately. This work combines LULC change, NDBI, NDWI, and other Geoinformatics tools on the GIS platform to evaluate land use and land cover changes in Mumbai flood zones during the past 20 years.

Keywords: Water logging, Concretization, Runoff, Metropolitan, NDBI, Change Detection.

Introduction

Massive human-induced activities have been going on for thousands of years with the intention of improving living conditions; yet, these activities are today wreaking havoc on the ecosystem and the living creatures in it. Both the way land is used and how it is covered are undergoing rapid transformations, which are having an impact not only locally but also regionally and worldwide. It is absolutely necessary for future ecological planning and management of the environment. Differences between terrestrial and subsurface research can be attributed to land cover, which is the biophysical condition of the earth's surface (Turner et al. 1995). It gives a description of the land's physical characteristics, such as its agriculture, mountains, and forests (Meyer, 1995 Moser, 1996). According to Meyer and Turner (1994), land cover consists of plant life, water, and soil. Also included are man-made structures (buildings) and materials used for housing (Praveen, 2017). To begin, the interaction of land cover with the atmosphere controls the hydrologic cycle and the energy budget, both of which are necessary for accurate weather and climate forecasting (DeFries et al., 2002).

Land cover refers to natural vegetation, water bodies, rock/soil, artificial cover, and other types of cover, whereas land use refers to the activities that humans engage in and the many ways that land is used (NRSA, 1989). Monitoring a property or phenomenon at regular periods in order to identify shifts or modifications constitutes change detection. It is utilised for the development of new agricultural practises, the transformation of landscapes, the deterioration of land, and the onset of desertification. Cities and coasts have an effect on the preprocessing of photographs, as well as the patterns of urban landscapes, the amount of tree cutting, and the amount of quarrying. The natural environment is being supplanted and messed with as a result of urban expansion. This is leading to significant shifts in land use and land cover, which in turn causes waterlogging in metropolitan areas.

In many parts of the world, urban waterlogging is caused by excessive rainfall, as well as worries about the environment.Precipitation accumulation promotes urban waterlogging by increasing surface runoff and turning roads into streams. Consequences include temporary evacuation of residents, worsening water quality, the possibility of epidemics, and disruption of municipal infrastructure with a negative impact on the living landscape, which causes severe economic losses and threatens sustainable city growth policies (Tang et al., 2018). Causes of waterlogging (Wang et al., 2017; Ning et al., 2017; Yu et al., 2018), stormwater (Subrina and Chowdhury, 2018; Joksimovic and Alam, 2014), simulation of waterlogging areas (Xue et al., 2016), and spatial evaluation of waterlogging threats (Tang et al., 2018) and vulnerability (Shi, 2013) are all topics of the current study on urban The entire globe faces problems. Examples: Paris built an urban drainage system in 1852 to combat urban floods. Paris' sewage system is 2400 kilometres long, significantly longer than its metro. Other nations are updating their urban drainage systems as technology progresses and waterlogging prevention gets popularity. Many communities continue to battle with urban water logging due to harsh weather. As urbanisation

has developed in China's central Henan region, urban sprawl and impermeable areas have risen substantially. Dhaka's monsoons cause waterlogging. Massive concrete pipelines and natural canals transfer rainwater to flood plains and rivers, but because most canals are taken by encroachers or obstructed with rubbish, even a little rain floods city streets. The city's storm-water drainage system can barely handle 20mm of rainfall before the streets flood at 40mm. Mumbai needs a complete drainage system to collect, convey, and store precipitation that connects rivers, flood plains, water retention basins, and canals. India's administration has to restore potholes, clean drainage lines often, establish a resilient rainwater drainage network, and deal with excessive rains.

To solve this problem, recarpet roadways every five years and construct a new drainage system. The study's main contribution is to analyse the area using a GIS-integrated platform for dynamic visualisation and analytics, resulting in the NDWI, a satellite-derived index from the NIR and SWIR channels with interrelationship to NDBI, The Normalized Difference Built-up Index (NDBI), which emphasises artificially constructed built-up areas using the NIR and SWIR bands to maximise the impact of the research.

Study Area

Mumbai is India's most populous metropolis and the capital of Maharashtra, with 20 million inhabitants. India's Deccan area, on the Arabian Sea's western shore. Island City is seven islands. Mumbai has three rivers on its outskirts that originate in a national park and many bays along its shore. This island metropolis has city and alluvial soil suburbs. The research zone is 468 square kilometres and has an average height of 10 to 15 metres. Its coordinates are 19° 4' 33.9240" N and 72° 52' 38.7336" E. The metro area is 4355 km2 (refer MMRDA basic statistics). The 2011 Indian census put Mumbai's Urban Agglomeration at 20,748,395, with the city at 12,478,447. Tropical, rainy and dry environment makes Mumbai hot and humid. Average temperature is 32°C and rainfall is 242.2cm. Summer highs average 32 °C (90 °F) while winter lows average 18 °C (64 °F). Mumbai has 3 seasons: 1. Winter (October to February) temperatures range from 15 to 20°C; 2. Peak winter months (December to mid-February) average 12 to 19°C; Summer (March to May) average 30 to 27°C; Peak summer months (Mid-March to 1 June week). In July, 710 millimetres (28 inches) of rain may fall in Mumbai during the monsoon season, which lasts from June to early October. In July and August, the sky is often overcast and the humidity is excessive, although the sea breeze helps. Mumbai's yearly rainfall is 2,200 mm (86 in). Mumbai is facing tropical cyclones. Cyclones occur between April and December, with two peaks before and after the monsoon (from late April to early June and in October-November). Before 2020, cyclones evaded Mumbai by travelling north or south; nevertheless, Cyclone Nisarga hit in early June 2020 and Cyclone Tauktae in mid-May 2021. Cyclones may bring

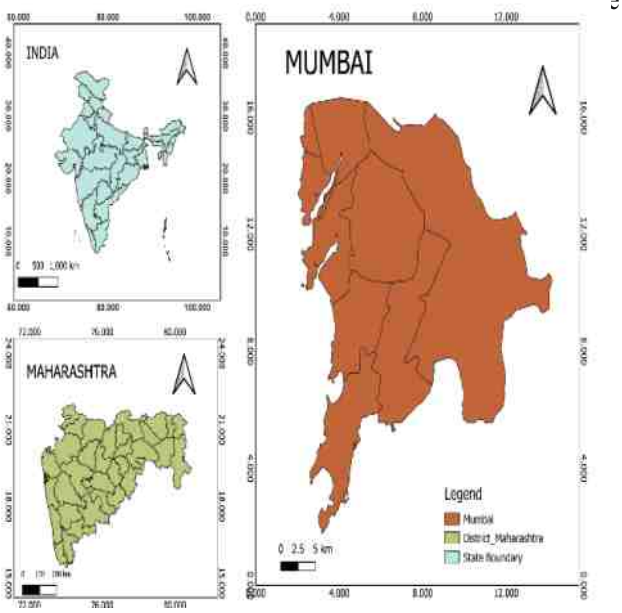


Fig. 1: Study Area

Materials & Methods

Data

To track LULC change with NDWI and NDBI indices in Mumbai, compare data from at least two time periods. Problem nature. Comparing satellite photos from two or more time periods is frequent when using remote sensing to analyse land use and land cover changes. This study used equivalent spatial resolution images (15 m). Images from the Landsat data archive, which are consistent with older data, allow long-term assessments of LULC changes locally and worldwide (Irons et al. 2012). This study analyses cloud-free Landsat (7) Thematic Mapper Plus (ETM+) sensor scenes to determine LULC variation in Maharashtra. Due to pre-processing, the photos were radiometrically corrected and improved for better interpretation. Since June 2003, the sensor's Scan Line Corrector (SLC) has caused data gaps. Each picture was SLC-corrected. Data cloudiness is less than 5%. By interpolating raster and land-use/land-cover information

using GIS tools to create tables and better interpretation. Since June 2003, the sensor's Scan Line Corrector (SLC) has caused data gaps. Each picture was SLC-corrected. Data cloudiness is less than 5%. By interpolating raster and land-use/land-cover information using GIS tools to create tables and figures, the waterlogging effect on Mumbai was assessed. This caused waterlogging

Table 1. Details of LANDSAT 7 used with present study

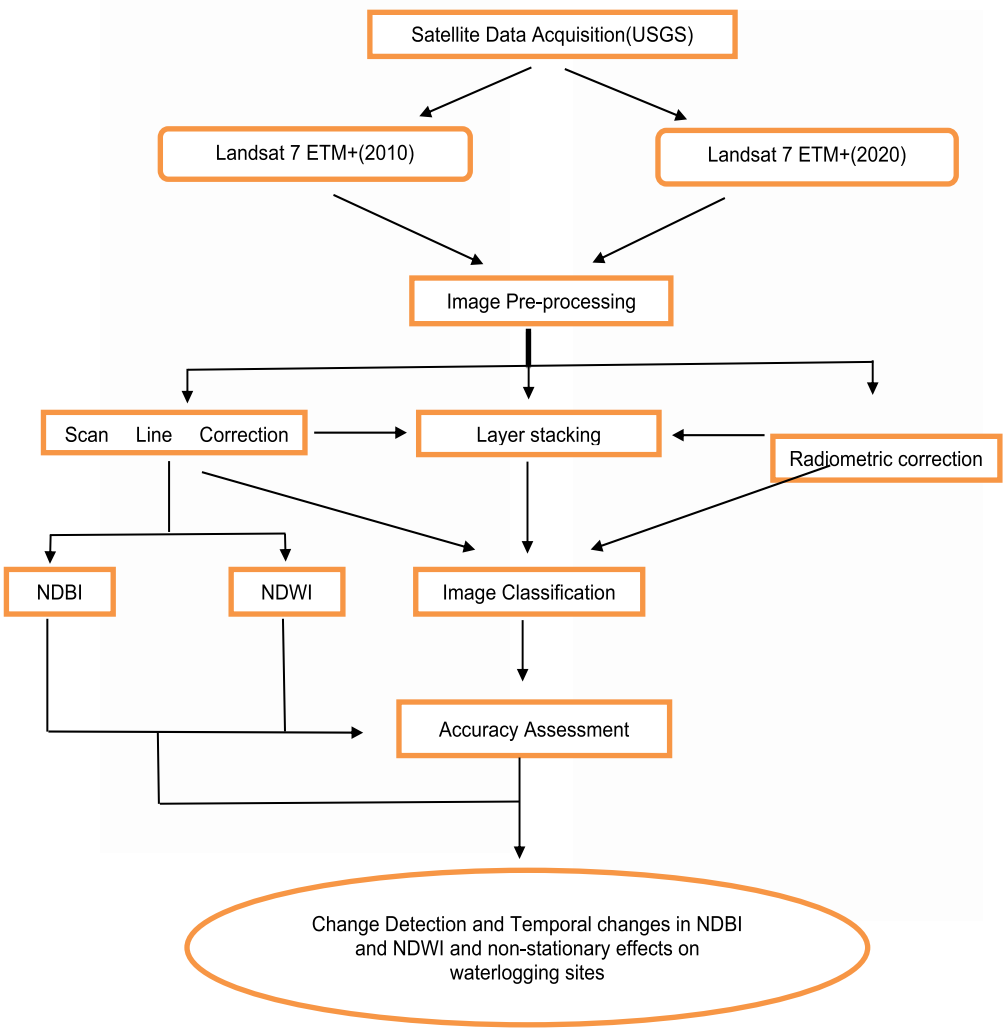
Type Of Data	Date of Acquisition	Row/Path Number	Source
Landsat 7 ETM	11-05-2010	147/47	USGS Earth Explorer
Landsat 7 ETM	06-05-2020	148/47	USGS Earth Explorer

Methodology

LULC Classification

Land usage and land cover have different meanings, but are occasionally used interchangeably. Land cover comprises plant, infrastructure, water, barren soil, etc. Land cover identification supports thematic mapping and change detection. Land usage includes leisure, wildlife habitat, and agriculture. When used with Land Use/Land Cover (LULC), the word refers to the classification of human activities and natural features on the landscape across time using scientific and statistical methods of analysis of acceptable source materials. Land cover is earth's surface substance. Socioeconomic land use describes how people use land.

In this study, user picked pixels in an image that are distinctive of various classes and instructed image processing software to utilise these training sites as references for categorising all other pixels in the picture. User knowledge determines training venues (also known as testing sets or input classes). The user selects the similarity threshold for grouping pixels. These bounds are commonly established by the training area's spectral qualities plus or minus an increment (often based on "brightness" or strength of reflection in specific spectral bands). The user also sets the image's classes.



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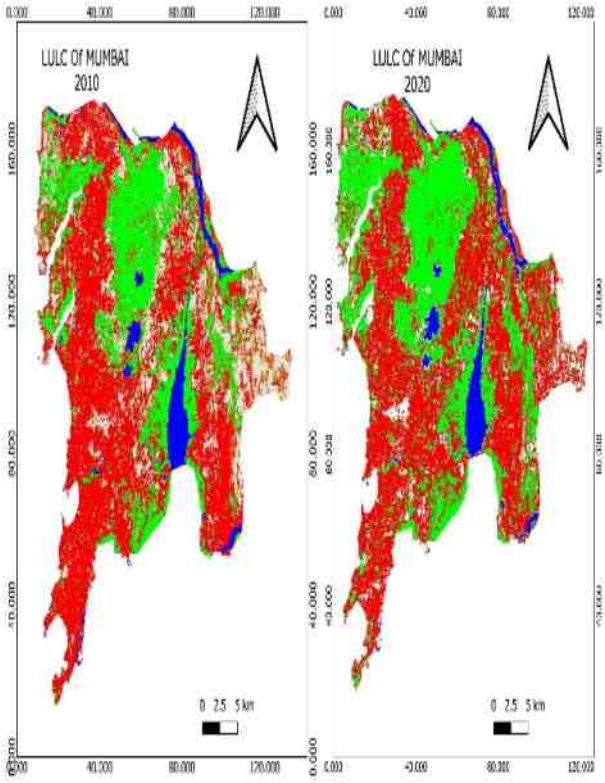


Fig 2: LULC Map of Mumbai

Normalized Difference Water Index (NDWI)

Examining water bodies with NDWI. The index uses green and near-infrared remote sensing photographs. NDWI can usually improve water information. It can be developed and overestimates water bodies. NDWI and NDVI change products can be used together to analyse apparent change regions. Low-reflective water Only visible light is reflected. In general, liquid water reflects more blue (0.4 - 0.5 m) light than green and red (0.5 - 0.6 m). Blue-reflecting clear water. Bluewater follows. Cloudy water reflects more visible light. NIR and beyond have no reflection. Gao (1996) established NDWI to enhance landscape water quality. It uses NIR and SWIR wavelengths. The formula for NDWI:

NDWI = (4 - 5)/ (4 + 5) for Landsat 7 data.

The formula's outcomes are bad. Water doesn't reflect NIR or SWIR. Xu modified NDWI calculations (2005). Green and SWIR are used.

MNDWI = (Green SWIR) / (Green + SWIR) for Landsat 7 data.

NDWI runs from -1 to 1. In general, NDWI is over 0.5. Vegetation has lower values than water, making it easy to detect. Positive build-up values are 0 to 0.2.

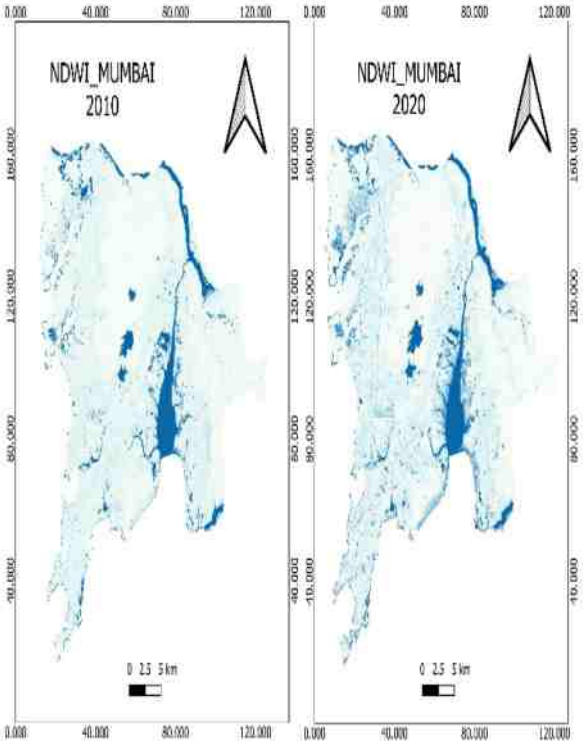


Fig 3: NDWI Map of Mumbai

Normalized Difference Built-up Index (NDBI)

Many indexes measure built-up area. The most common built-up indexes are the Built-up Index (NDBI), Built-up Index (BU), Urban Index (UI), Index-based Built-up Index (IBI), and Enhanced Built-up and Bareness Index (EBBI). Each index has its own formula and calculation method. Urban and barren land reflect more SWIR than NIR. The water doesn't reflect IR. NIR reflection is higher than SWIR reflection for green surfaces. Improve performance with Built-up Index (BU). The Build-up Index is used for urban pattern analysis with NDBI and NDVI. Built-up index is a binary graphic where only greater positive values reflect built-up and undeveloped regions, allowing BU to map the built-up area automatically.

= NDBI - NDVI

The process of picture categorization (supervised and unsupervised) is long and difficult. It takes compositive band and several procedures to reach the goal. An image analyst's approach and skill affect the accuracy of picture categorization. However, NDBI computation is easy to derive. The NDVI formula is presented.

NDBI = (SWIR-NIR)/(SWIR-NIR)

Landsat 7 NDBI = (Band 5 - Band 4) / (Band 5 + Band 4)

Normalise The Build-up Index is -1 to 1. Negative NDBI values indicate aquatic bodies, whereas positive values signify urban areas. Low NDBI value for vegetation.

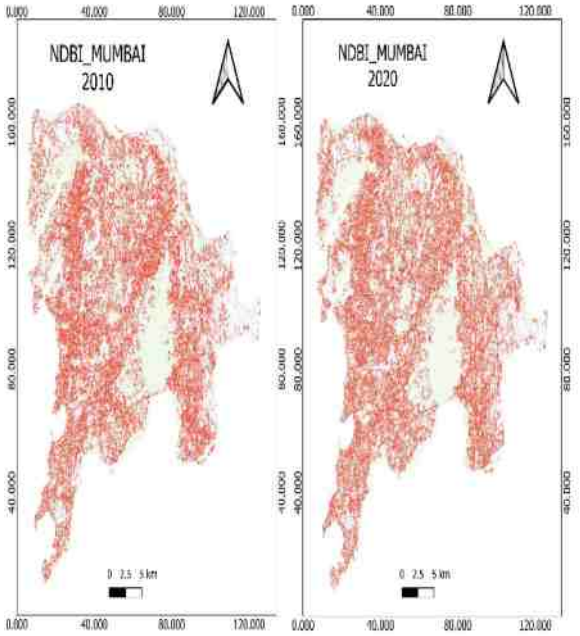


Fig 4: NDBI Map of Mumbai

Results and Discussion

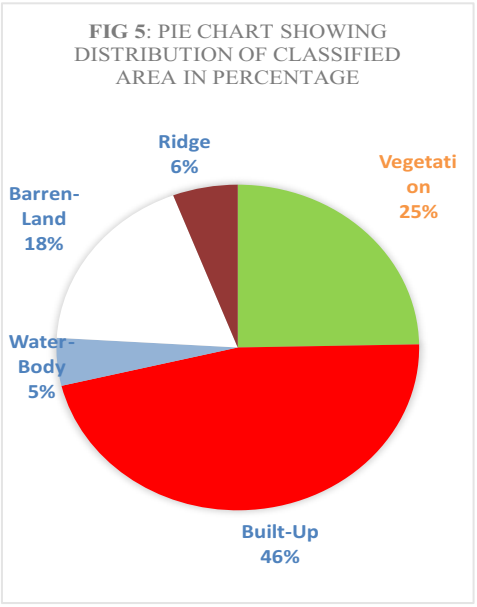
The accuracy evaluation estimate comes in as the final step in the picture categorization process (Foody 2002). Determine how successfully different land cover classes were sampled using pixels and quantify the degree of success. The error matrix, also known as the confusion matrix, is the most efficient accuracy evaluation model available for the classification of remotely sensed data (Congalton 1991; Congalton and Mead 1983; Sanjoy Roy et al., 2015). The standard kappa coefficient, the overall accuracy, the producer's accuracy, and the user's accuracy were all approaches that were used to evaluate accuracy. The overall accuracy estimator works by counting the pixels in the image that are right. The photograph was divided into a number of categories, including built up, waterbody, flora, barren plain, and ridges. The accuracy of the user is determined by how frequently the map's class is present. The number of pixels that have been accurately categorised is one way to assess the accuracy of the producer. The ground truth data for both 2010 and 2020 were collected with the use of Landsat ETM+ photos. A maximum likelihood classifier was used to create the classes that were used to categorise the picture. Table compares confusion matrix-classified data (Pontius and Millones 2011). The maximum likelihood classification method begins with the presumption that the statistics for each class within each band are normally distributed. It then calculates the probability that a given pixel belongs to a certain class based on this assumption. All of the pixels will be categorised unless a probability threshold is specified beforehand. Each pixel is distributed according to the class that has the highest possibility of receiving it (that is, the maximum likelihood). The pixel will not be assigned a classification if the highest likelihood is lower than the threshold that has been set.

Table 2. Accuracy Assessment by kappa Coefficient

Signature Class	Percentage	PA	UA
Vegetation	24.6	0.637	0.843
Built-Up	46.5	0.73	0.738
Water - Body	4.7	0.918	0.84
Barren - Land	18.2	0.424	0.245
Ridge	5.7	0.41	0.383

Overall Accuracy % = 82.5644
Kappa Classification= 74.21

According to the examination of accuracy, the maximum likelihood supervised classification produced an image with an overall accuracy of 82.5%. This was established by looking at the image. However, the accuracy of the producer ranged from 41% to 91.8%, whereas the accuracy of the consumer ranged from 24.5% to 84.3% (Table 2). (Table 2). The large amount of variance in accuracy suggests that barren land and other types of land cover groupings are frequently confused with one another. In addition, the measure of the accuracy of the producer, which is referred to as Sensitivity, shows the accuracy of the prediction for the category. The reliability of the categorization as perceived by the user can be inferred from the accuracy of the user. The correctness of the user is the single most important factor in determining the usefulness of the categorization in the real field. It was discovered that waterbody provided the most reliable results, with a user accuracy of 91.8%. (Table 2).



With reference to the land use land cover classification, NDWI and NDBI are also classified with the help of LANDSAT 7 images of years 2010 and 2020 and found that all the three components are interrelated to each other. In the current study, NDWI and NDBI were computed in order to determine the locations of the various water bodies and built-up regions within the area under investigation. During the course of the investigation, there are some slight shifts in both the NDWI and NDBI values.

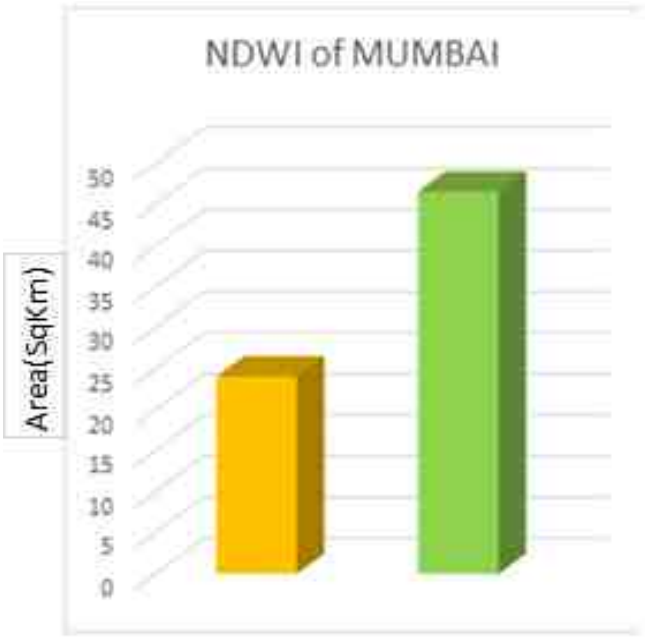


Fig 6: Bar Graph Showing NDWI

The resultant maximum and minimum values of NDBI and NDWI ranged near +1 (NDWI), which indicates either a high water content or a water surface that is leading towards waterlogging conditions in Mumbai, and NDBI ranged near positive value, which shows that the water and built up both are increased, and therefore the indices are showing that the drainage can be less maintained or not constructed maybe with the current day scenario, which is why the waterlogging issue arises.

Conclusion

The population of Mumbai is expected to grow at alarming rates between the years 2010 and 2020, resulting in a rise in the city's density of settlement, which in turn contributes to a variety of issues facing the metropolitan region, such as waterlogging. Because of its proximity to the coast, the city's climate is prone to experiencing frequent shifts, with mild temperatures across the region and a monsoon that is responsible for creating a chaotic environment within the city. This study examines three distinct aspects, each of which is tied to the others: the LULC classification, the NDWI indices, and the NDBI indices. According to the findings of the study, the water level in the region grew with the expansion of the built-up area, which caused the waterlogging issue to become increasingly severe in the region.

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Multiple Indices based Drought Risk Prediction in Chengalpattu District of Tamil Nadu, South India – A Geo-spatial approach

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Abstract

Drought is a natural hazard broadly defined as "Sever Water Shortage" which is slow on-set that has dreadful impacts on economy, social life and environment of a country or region. The slow on-set of drought is too difficult to analyze when it is started and when ended. Due to the insufficient climatic data and other relevant data sets, the drought predictions and modeling are not proper in the earlier days. In recent years, Remote Sensing (RS) data have played a key role in studying different types of droughts and drought risk assessment. The present study has made an attempt to derive spatio-temporal drought risk areas facing agriculture as well as meteorological drought by using various indices of temporal Landsat satellite images with rainfall data of the study area. There is high degree of land and water resources of Chengalpattu district has been utilized by the urbanization process of Chennai Metropolitan City.

Keywords: SPI, Drought Index, LST, Water Stress & VCTI.

Introduction

This analysis presents an insight into sustainable sub-urban resource management using GIS techniques and highlights the significant constraints that the city is facing. The techniques will be helpful for the planners to remove and clear the encroachments and obstructions in the waterways which may further leads to floods and other natural disaster due to climate extremes. Sustainable water resources management is a concept that emphasizes the need to consider the long-term future as well as the present. Water resource systems that are managed to satisfy the changing demands placed on them, now and on into the future, without system degradation, can be called sustainable. Because sustainability is a function of various economic, environmental, ecological, social, and physical goals and objectives, water resources management must inevitably involve multi-objective tradeoffs in a multi disciplinary and multi-participatory decision-making process. There is no single discipline, and certainly no single profession or interest group, has the wisdom to make these tradeoffs themselves. They can only be determined through a political process involving all interested and impacted stakeholders. The participants in this process must at least attempt to take into account the likely preferences of those not able to be present in this decision making process, namely those who will be living in the future and who will be impacted by current resource management decisions. The main aim of this study is to develop and conserve the natural resource are the major steps for sustainable development to the resources further proceedings of developing the resources are occurred with the basic proper management to the resources in the region.

Study Area

Chengalpattu district is situated on the north east coast of Tamilnadu with a total geographical area of 2945 Sq.Km. The district is bounded on the north by the Chennai district, West by the Kancheepuram district and on the south by the Vilupuram district. With a coastal length of 57 Km, the district is bounded in the east by the Bay of Bengal. Chengalpattu features a tropical wet and dry climate.

The river Palar is one of the major rivers in the state of Tamil Nadu traversing through Chengalpattu district for a length of 54 Km. The river Palar enters the district at Palur village and confluxes with Bay of Bengal between Vayalur and Kadalur village.

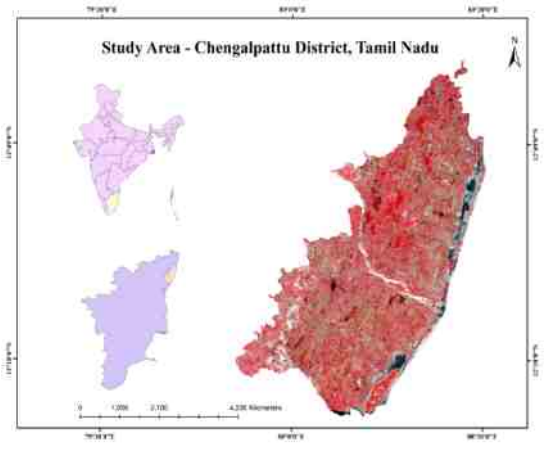

Fig. 1. Study Area

Materials & Methods

Satellite Data Used: LANDSAT imageries of Chengalpattu district and 25 years precipitation data were considered for the present study.

Methodology: The downloaded raw dataset are set to preprocess using geo-techniques and layer stacking the bands. The administrative boundary of Chengalpattu district is subset for further analysis. The Land use land cover classification, Indices maps were derived using the satellite imageries. The SPI calculation is done through the 25 years rainfall data for analyzing the probability of precipitation in the region.

Results and Discussion

The SPI is used to analyze the rainfall probability to understand the process of atmospheric behavior for different time period. The SPI values are ranges from Extremely Wet to Extremely Drought. Standardized Precipitation Index, 2010 to 2020 the normal condition is getting changed the drought is dry to severe drought. The SPI value of 2020 is ranging from -1 to +1 it indicates the region is occurring extremely drought to severely wet. It shows the land potential and suitability for land practice in the region.

The Chengalpattu district is having average to higher variability for the 20 years. Most of the places are receiving normal to higher amount of rainfall in the district. Due to mismanagement and not conserving the rainfall causes flood and scarcity in the region. The rainfall is the only source to the most of the places in the southern region. As it including only non-perennial rivers and also most of the people's occupation is agriculture and agro based industries. Adequate rainfall is most prominent factor to the enhancement of resources and sustainable development.

Normalized Difference Vegetation Index, is commonly used to quantify the vegetation density and greenness in the region. Thus the Chengalpattu district is obtain high dense vegetation value of 1 for the 2000 and 2010 as well. Due to climatic changes and soil loss the denser vegetation is getting lavished and converted into temporary or permanent dry lands. The highest value of 2020 is 0.6 in the Chengalpattu region.

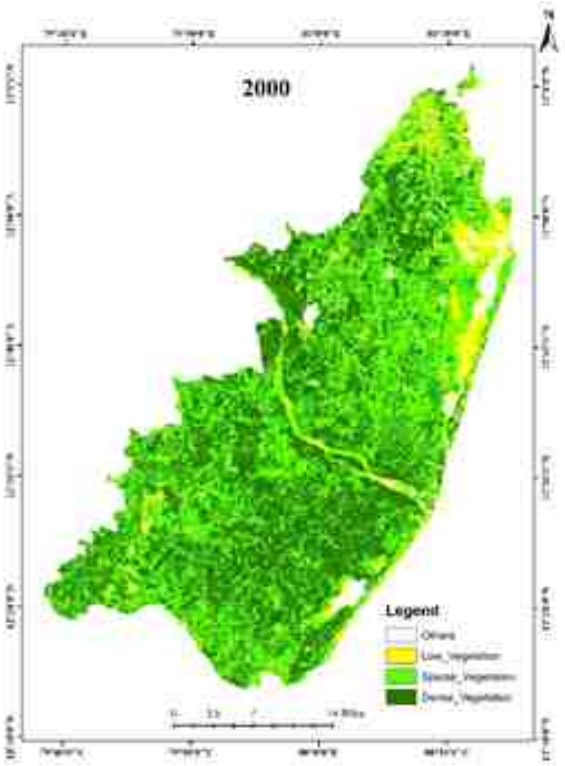

Fig. 2. NDVI - 2000

2000	
Classes	**area in sq.km**
Dense Vegetation	1728.77
Medium Vegetation	599.85
Sparse Vegetation	238.39
Others	92.38
Total	2659.39

Table 1. NDVI - 2000

There is a drastic changes between the dense vegetation of 2000 and 2010 classification. It may causes climatic changes and environmental impacts in various aspects. Slowly the vegetation density is getting reduced due to various causes and many of the dense bushes, open scrubs are converted into built-up land. Vegetation plays a major role in balancing the ecosystem and climatic factors. The Continuous deforestation may cause direct impact to the water resources and soil potential.

Normalized Difference Water Index, is commonly used to quantify the water resources. The surface water bodies are reduced due to increasing demand of domestic, agriculture and industrial purpose. In 2000 the water resources ranges are higher when comparing 2010 and 2020. The water resources are depleting continuously it should be properly monitor and maintain valuing future.

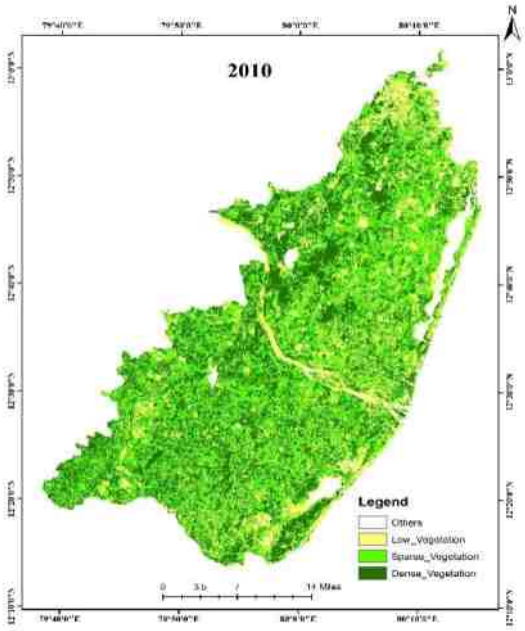

Fig. 3. NDVI -2010

2010	
Classes	**area in sq.km**
Dense Vegetation	477.447
Medium Vegetation	911.546
Sparse Vegetation	1087.618
Others	187.72
Total	2664.33

Table 2 . NDVI -2010

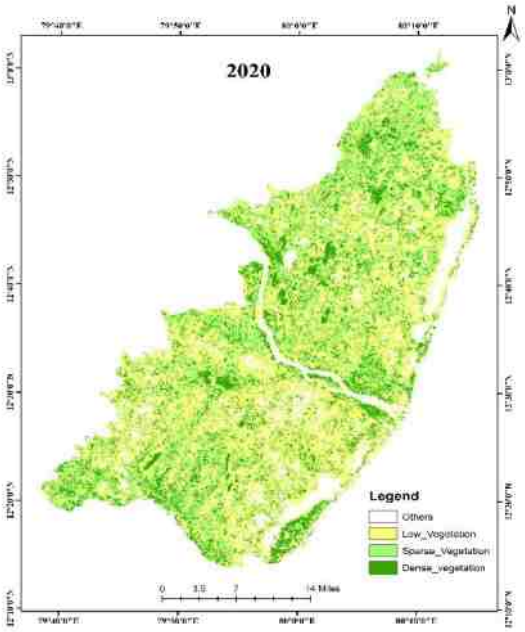

Fig. 4. NDVI -2020

Table 3 . NDVI -2020

2020	
Classes	**area in sq.km**
Dense Vegetation	180.2
Medium Vegetation	1085.49
Sparse Vegetation	962.03
Others	432.38
Total	2660.1

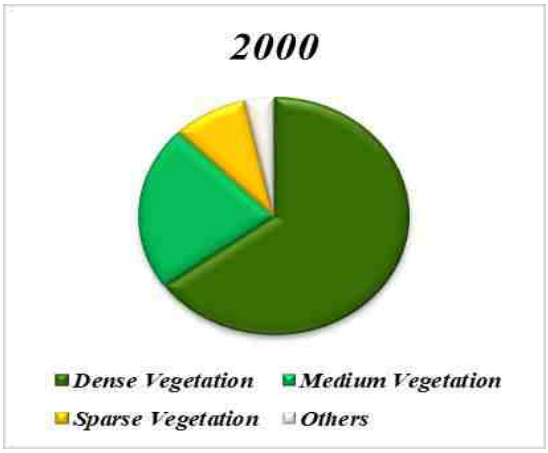

Fig. 5. NDVI Pie Chart -2000

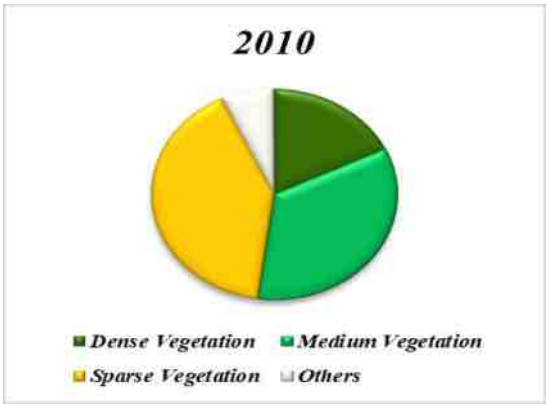

Fig. 6. NDVI Pie Chart-2010

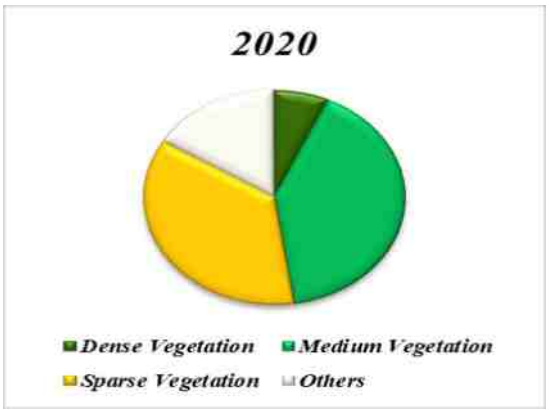

Fig. 7 NDVI Pie Chart-2020

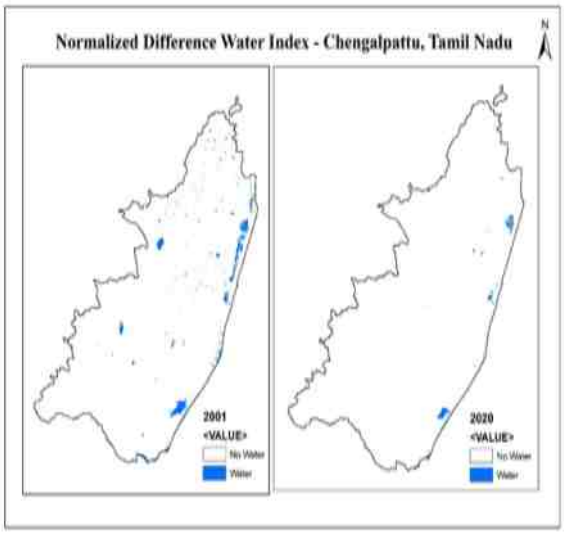

Fig. 8. NDWI

Normalized Difference Moisture Index, is help to analyze the water stress and water logging in the region. The moisture content in Chengalpattu area is decreasing periodically due to land cover practices are changing. Retaining the moisture content is very important to control water stress and scarcity. In Chengalpattu district the moisture content is somehow maintained due to its healthy vegetation in the region. The land use practices are impacting the ecology which causes moisture depletion in the region.

Land Surface Temperature is essential tool to derive the temperature analysis of the surface in the region. The LST values are calculated using remote sensing data set which indicates the spatio temporal variations of temperature in the land surface. The land surface temperature influence the plant growth. The remote sensing indices are interlinked and deriving the results for agricultural drought. The land practice of the agriculture is supporting and maintaining the socio-economic balance to the local community.

The Land use land cover analysis with the timely remote sensing data is used. The NRSC classified level-I classification is used for deriving the land use land cover of Chengalpattu region. The derived land use practice map indicating that Built-up is continuously increasing and broadening its area periodically than comparing other features.

The Chengalpattu district is majorly depending on agriculture sector it increased from 2000 to 2010 and there is a depletion between 2010 and 2020 due to conversion of wastelands. There is a continuous reduction in the forest area due to rapid increase of urbanization and conversion of waste lands.

The land use land cover classification shows the timely changes which occurred over the vegetation and water resources. The dense vegetation and forest lands are converted into built-up and farm lands slowly, it converts into permanent fallow it causes inefficient utilization of land potential due to lack in management planning and land policy. Thus, it causes land degradation and soil erosion it leads to drought.

LEVEL I - Land Use Land Cover Classification						
	2000		2010		2020	
Class	In Hectares	In %	In Hectares	In %	In Hectares	In %
Built-Up	20957.13	7.866256	23972.32	8.998008	39247.65	14.7316
Agriculture	62022.78	23.28024	123007.6	46.17089	90212.32	33.86118
Forest	110699.82	41.55116	72647.21	27.26812	71861.24	26.97311
Wasteland	48136.59	18.06806	25058.12	9.405563	46634.82	17.50437
Waterbody	24601.77	9.234272	21732.84	8.157419	18462.06	6.929732
Total	266418.09	100	266418.09	100	266418.09	100

Table 4. Land Use Land Cover

The scrub land, fallow land and empty lands are considered as waste land and it is significantly maintain its values in the region. It indicating that the unprocessed and not efficiently practiced land potential in the region. This should be considered and proper maintenance and structured planning help for future sustainable development in the region. The surface water resources are decreasing periodically due to urban expansion and agriculture purpose. The land potential and agricultural crop suitability should be analyzed properly and the type of cultivation for the region should be fixed and monitor in regular basis.

The sustainable development of water resource planning is helpful and most important analysis for many research works and disaster management. The rapid growth of settlement and its encroachment over the classes such as Barren, agriculture, vegetation, waterbody, waste land is analyzed. The red colour identifies the settlement and there is no changes over the built-up lands in the region and the other classes which mentioned in the legend are occupied by settlement in 2020 of the classes which existed in the 2000.

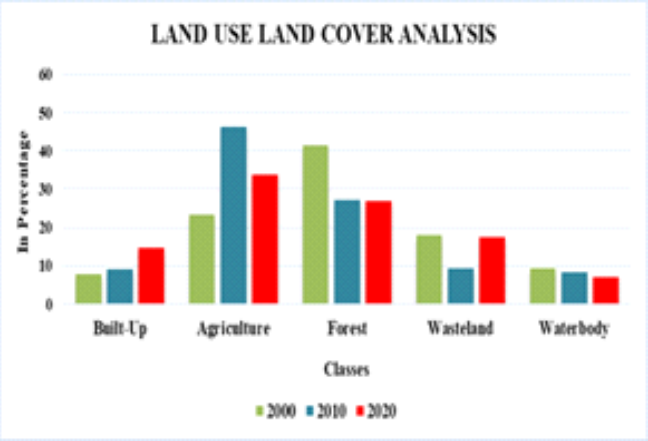

Fig. 9. Land Use Land Cover

The water bodies which cannot be replaced as like its earlier status in the location which are very sensitive regions and the encroachments of waterbodies are extremely disastrous to the region it directly affecting the other classes such as vegetation and agriculture in the region. The water supply to the domestic and agricultural uses are affected and water markets and trading are raising in this status to feed the region for various demands.

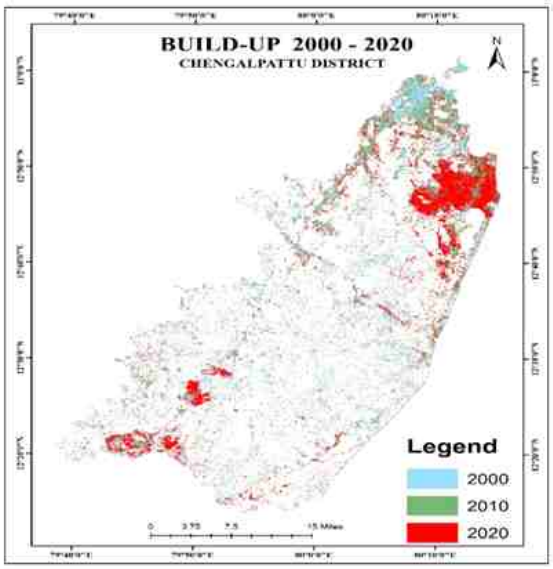

Fig. 10. Built-up

Air temperature is dependent on surface temperature and if there is a strong correlation between LST and air temperature during cloudy conditions, then observed air temperature estimates the LST when direct satellite observation sare unavailable.mChengalpattu district is mainly reliant on the southwest and the northeast monsoon rains, and so when there is a failure, it leads to distress. The Palar river running through the district remains dry most of the years.

The climatic and geographical features are affected and environmental imbalance occurred due to this improper resource management in the region. The table shows that the changes over from the period of 2000 to 2020 in the region using with the reference of change detection analysis and the area which encroached by the settlements in the Chengalpattu region.

The built-up lands in Chengalpattu district and its changes over a different time period is showed in this figure. In 2000, very few disperse settlements are located and most of the lands remains forest and vegetation cover. Due to anthropogenic development over a decade the scattered settlements are converted into cluster. Near the water resources and agricultural land the cluster settlements are raising and processing the land for their different purposes. Thus, in 2020 the northern part of the district the sub-urban area is showed dense population and it is expanding timely.

Conclusions

Drought preparedness and management are effective strategies to reduce risks and therefore the impacts associated with droughts. Preparedness for drought necessitates greater institutional capacity at all levels of government and more efficient coordination between different levels of government. Preparedness also implies increasing the coping capacity of individuals and communities to deal with drought events.

Most commonly, there are three components in a drought plan: monitoring and early warning; risk assessment; and mitigation and response. Given the improved tools and technologies available today, it is possible to provide drought information that enables action to maximise the probability of successful crop production and/or minimise the potential damage to established crops and other assets.

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Ship Detection for Multi Band, Multi Polarization and Multi Resolution SAR Sensors based on the Wavelet Transform

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Abstract

Ship detection and monitoring plays an important role in maritime surveillance in sea. It is an important application of global monitoring of sea environment and security. Maritime Surveillance with satellite Synthetic Aperture Radar (SAR) is used because of its capability to provide ship information at medium to high resolution over wide swaths images in day/night and all weather imaging conditions. SAR specially suited for those regions where frequent cloud and fog cover makes it difficult to acquire images through visible and infrared satellite sensors.

In this paper a new method of fast and accurate ship detection is presented which work on the basis of coherent image generated by the discrete wavelet transform of the SAR images. This method exploits multiresolution property of wavelet transform which enhance the ship pixels and suppresses sea clutter. Invariant statistical distribution of background clutter in wavelet domain gives the advantage which makes the detection of ship like object with respect to the surrounding sea more convenient and reliable. The detection performance of this method are presented on both medium resolution Sentinel-1A/B, C-band, VV-VH, dual polarization SAR and High resolution, Terrasar-X , X- band, VV & HH single polarization SAR. Results are highly appreciated with recall and precision better than 90%, which confirms the robustness of the method. This method works well on multi- band, multi polarization and multi resolution SAR images.

Keywords: Ship detection, wavelet, coherent, maritime, polarization, SAR

Introduction

Ship detection is important application for many national and state departments such as naval defence, situation assessment, traffic surveillance, maritime rescue, and fishery management. Today many countries are doing maritime surveillance on sea surface using satellite based SAR images, which are less influenced by time and weather. To detect ships quickly, accurately and automatically from remote sensing images against vulnerable ocean environment it is very important for the rational exploitation of marine resources and thereby to control and monitor maritime traffic. Currently, SAR has demonstrated considerable potential in maritime surveillance tasks because of the sensors wide-swath coverage, high resolution, day and night capabilities, and weather-independent functioning [1], [2].

Thus, wavelet based method for detection of ships is proposed to meet the maritime applications by SAR. As the wavelet transform (WT) provides a multiscale analysis of the images, according to their spatial and frequency characteristics, multiresolution processing with wavelets is a suitable tool for modelling the operation of the human vision. Furthermore, wavelet theory permits characterizing the statistical behaviour of a function locally.

This paper is organized as follows : Section II briefly explains Wavelet concepts which are used in our ship detection method. Section III explains our methodology for SAR Image Ship detection. In Section IV discusses results, validation and performance of the method. Section V concludes the paper.

Wavelet Theory

In this section, some of the aspects of the wavelet transform will be briefly discussed. For more detailed mathematical concept on wavelet please refer [3]. Wavelet means small wave. Wavelet transform provides the time and frequency information simultaneously, hence giving a time-frequency representation of the signal.

It is well known that the wavelet transform (WT) of a function at a particular point depends on the values of the function smoothed by the wavelet in a neighbourhood, whose dimensions are proportional to the scale. Thus, for fine scales, the WT shall provide localized information about the variation of the function around a certain point or, namely, about its local regularity. Therefore, irregularities will be sharpened in the transformed domain or, more specifically, the existence of discontinuities in the original

signal will result in local maxima in the wavelet transform. The WT proposes the study of a complex phenomenon, dividing it into different simpler pieces. Mathematically, this implies projecting it in a function space, in which it is located by measuring its degree of similarity with each basic function or atom, i.e., is a

$$F(\tau, s) = \frac{1}{\sqrt{s}} \int_{-\infty}^{\infty} f(t)\, [\psi^*(\frac{t-\tau}{s})]\, dt \text{ ---(1)}$$

where $f(t)$ is the discrete signal, $\psi^*(\frac{t-\tau}{s})$ discrete wavelet basis function, s is the dilation and translate time across the signal. In a wavelet transform, the basic functions come from dilations(scaling) and translations of a "mother wavelet" localized in both time and frequency [4].

Each term of the basis, therefore, allows the representation of the signal at a particular frequency scale and time/space position. If s (dilation) and (translation) chosen on the basis of power of 2, it is called Dyadic scale filter banks .This will give compactness level of compression or stretch to the signal. By using this particular characteristics of wavelet, we can design any number of high and low pass filter banks i.e., multiresolution and multi frequency analysis filters.

Wavelet orthonormal basis function 'Haar filter' which is shift invariant having one vanishing moment and 2 wavelet coefficients, best for discontinuities, anomalies and closely spaced feature detection. Hence in our method we used 'Haar filter' wavelet transform [4]. Graphical representation of Haar filter properties are shown in figure. 1.

SAR Images Ship-Detection Workflow

Typical block diagram of methodology for ship detection is shown in figure. 2.

Radiometric and Geometrically Corrected Level-2 Product: Input SAR datasets must be radiometrically, geometrically corrected and calibrated. After acquisition and processing of SAR data at level -1, detected product must be radiometrically corrected i.e. level -1 (L1b) antenna pattern corrected and may be de- speckled by applying some of the speckle filters like lee, kaun etc. SAR Image must be calibrated. After that SAR L1b product are geolocated to get level-2 (L2) product. In this paper we have used Terrasar- X(TSX) and Sentinel1A (S1A), Level-1b (L1b) products. These products are calibrated by using the annotation files provided inside the respective products. TSX and S1A L1b products are geolocated by using the geolocation grid, and the mapping grid of the products. The expected pixel location accuracy is around 2m for TSX [8] and 10m for S1A [9] products.

Land Water separation: This step is important to prevent applying of ship detection in land areas and thereby reducing of false alarms. Accurate land masking is generally difficult due to inaccuracy of referenced coastline, tidal variations, and coastal constructions. GSHHS (Global Self-Consistent Hierarchical High-resolution Shorelines) vector files are used to derive land-mask. For this step we require SAR Image L2 products. In this process we use a shoreline buffer zone variable which is used to limit the applying of ship detection to sea area. Land-water masked binary file was generated during this step. Only water portion was used for ship detection.

Wavelet based Coherent Image generation: This is the step where we are actually doing the ship like object detection using wavelet based algorithm. Here we are using special properties of wavelet transform as mentioned in section 2. Wavelet theory i.e. The two dimensional wavelet transform of an image creates a set of 4 sub-band coefficients viz. horizontal (CsH), vertical (CsV) and diagonal(CsD) and approximation sub-band(As) at scale 's'. At each level, the wavelet transform is applied to the approximation sub-band, breaking down into further approximation and detail sub-bands.

By correlation of the four sub-band components, a coherent Image is generated [5]. As shown in Figure 3, input SAR Image is decomposed by 2D Haar wavelet filter. Generated coherent image results in suppression of sea clutter and enhancement of coherent ship object values [6]. Background noise is gets reduced, whereas the structured object like ship, is greatly enhanced. Contrast of the object gets increased by many folds when compared with input image. Accordingly, a global threshold (*T*) is computed for generated coherent image by using equation (2).

$$T = \mu + n\sigma \text{ ------(2)}$$

where μ stands for the mean of the image, whereas σ is its standard deviation and n is a parameter which is empirically adjusted once for specific to SAR imaging band and polarization datasets [7]. An optimal threshold could be identified that is suitable for all the tested images. It provides correct ship detection with very low false alarms.

False Alarm Removal: The thresholding stage might cause some false alarms, along with the true ship objects. Commonly false alarms are minimized by the size filtering to discard very small objects. Moreover, for each detected ship physical dimensions are also verified to further reduce these false alarms. Like ship length less than 30m and greater then 700m are rejected.

These false alarms are generally divided into two categories, one which are near the coastal lines and other in the deep sea. Near the coastlines false alarm are reduce up to some extent at the time of 'land water separation step' by adjusting the shoreline buffer zone. Deep sea region false alarms generally happened when sea is very rough due to wind and weather conditions which are more prominent in VV polarized SAR images. Hence, wavelet based method works well in this situation as mentioned above in 'Wavelet based Coherent Image generation '. To further reduce these false alarms wind vectors information is required. in our method we haven't attempted to use this information.

Automatic vector/shape file generation: Final output of ship detection were generated as vector file, which contains each ship geolocation, length, width, date-time, satellite, sensor and algorithm used for ship detection.

Results and Validation

In this section we are presenting the adaptability and effectiveness of our method. We have tested our method on many X- band, Terrasar –X (TSX) and C-band, Sentinel-1A/B (S1A/S1B) datasets [10] [11], but due to the constrain of size of the paper, we are only showing the results on two datasets of TSX and one dataset which is dual polarized of S1A. To show the adaptability, results are presented on two different SAR sensor datasets of different band, different polarization and different resolution. Test datasets details are shown in Table -1.

To show the quantitative performance of the method recall and precision are estimated. Generally, any logical classifier algorithm performance is evaluated by recall and precision. Recall is also known as sensitivity. It is the detection capability of a classifier whereas precision tells the how correctly or accurately detection had happened. Hence precision is also known as accuracy of the algorithm. General formula used to estimate recall and precision are shown in equation (3) and (4). In equation (3) '*Actual Ships Present*' means the actual total ships that are present in the SAR image. The total number of *Actual Ships Present* in the scene are identified manually. To minimise the human error, three human operators are assigned the same job independently and maximum likelihood number used for the calculations. By using equation (6) we can calculate the number of ships missed by our method. *Total Detection* means the total number of ships that are detected by our method. This includes both *Actual Ships detected* and *False alarms* detection as in equation (5). Estimated recall and precision values for all the datasets are presented in Table-2. Figure 4 shows recall verses precision plot.

Figure 5 shows land-water separated masked image which defines the search area for our method. Ship detection happened only in water portion of the masked image. Figure 6 and 7 shows TSX ship detection results on HH polarised, Singapore strait region and VV polarised, Gulf of Maxico region. Figure 8 and 9 shows S1A ship detection results on dual polarized (VV & VH), Dalian, Yellow sea, China region.

$$Recall = \frac{Actual\ Ships\ \ Detected}{Actual\ Ships\ Present} \quad \text{---(3)}$$

$$Precision = \frac{Actual\ Ships\ Detected}{Total\ Detections} \quad \text{--(4)}$$

$$Total\ Detection = Actual\ Ships\ Detected + False\ Alarms \quad \text{----(5)}$$

$$Actual\ Ships\ Present = Actual\ Ships\ Detected + Missing\ Ships \quad \text{----(6)}$$

Conclusion

This paper presented a new method for ship detection based on the wavelet theory. This approach extends a robust detection, taking advantage of the difference of statistical behaviour of the ships and sea. More specifically the specified methodology is capable to producing better results for multi band, multi-polarization and multi-resolution datasets. By comparative analysis of the results we can conclude that by using this method better recall and precision values are achieved.

The ship detection still shows some limitations in coastal areas due to inaccurate land masking, geophysical phenomena such as tidal change, strong weather conditions etc. For smaller ships (length < 30 m) specially in Sentinel-1A medium resolution SAR images, the assessment of quality is still more challenging which cause false alarms. This paper also presented comparative analysis of ship detection for sentinel-1A dual polarization dataset. For ship detection application dual polarized HH & HV (or VH), medium resolution, wide coverage data will give more accurate result. This approach makes ship detection output more accurate and reliable.

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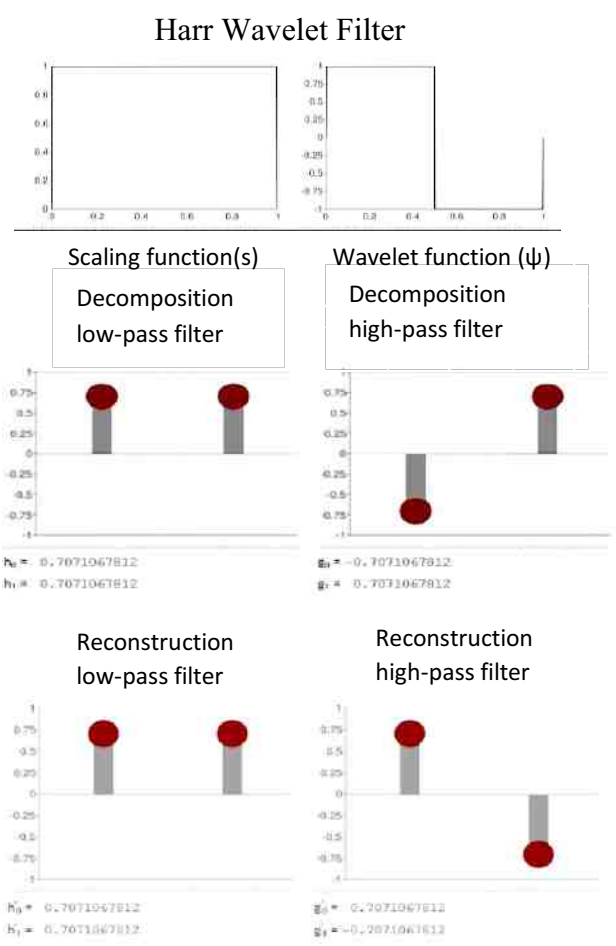


Fig. 1 Haar filter properties

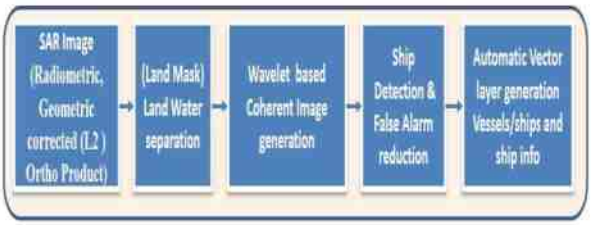


Fig. 2 Workflow of Ship Detection on SAR

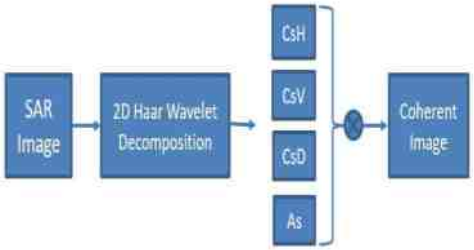


Fig. 3 Wavelet based coherent Image generation

Table: 1 SAR Test Datasets Details		
Sensor	***X-band(Terrasar-X)***	***C-band(sentinel-1A)***
Carrier Frequency	***9.649GHz***	***5.45GHz***
Polarization	***HH/ VV***	***VV VH***
Imaging mode	***Stripmap(SM)***	***Interferometric Wide Swath(IW)***
Product type	***MGD***	***GRD***
Resolution	***3m***	***14m***
Coverage	***30KMX65KM***	***250KMX170KM***

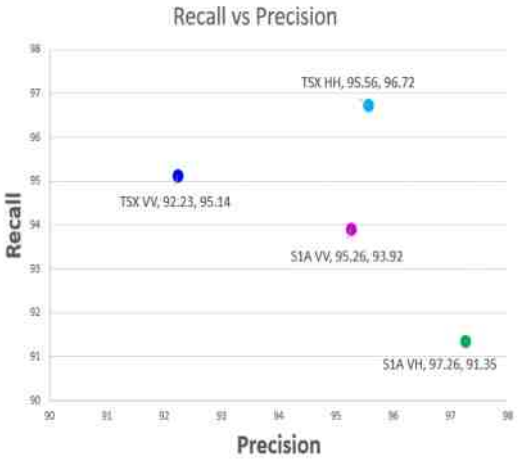


Fig. 4: Recall vs Precision plot for all the ship detection results

Fig. 5 (a) Terrasar-X Stripmap image (Singapore strait) and (b)Sentinel-1A IW, (Dalian, Yellow sea, China) land- water separation maps

Table: 2 Ship Detection Results				
Datasets	***Terrasar-X***	***Terrasar-X***	***Sentinel-1A***	
Polarization	***HH***	***VV***	***VV***	***VH***
DOI	**17-05-2010**	***10-07-2010***	***20-05-2020***	***20-05-2020***
Total Detection	***414***	***98***	***422***	***402***
Actual Ship Present(Visual Inspection)	***428***	***103***	***428***	***428***
Actual Ship Detected	***409***	***95***	***402***	***391***
False Alarm	***5***	***3***	***20***	***11***
Missing Ships	***19***	***8***	***22***	***37***
Recall	***96.72***	***95.14***	***93.92***	***91.35***
Precision	***95.56***	***92.23***	***95.26***	***97.26***
Region of Image	***Singapore strait***	***Gulf of Maxico***	***Dalian, Yellow sea, China***	

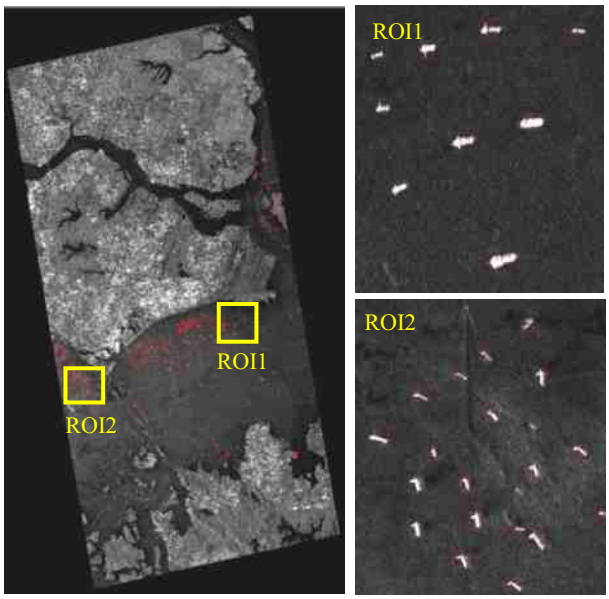
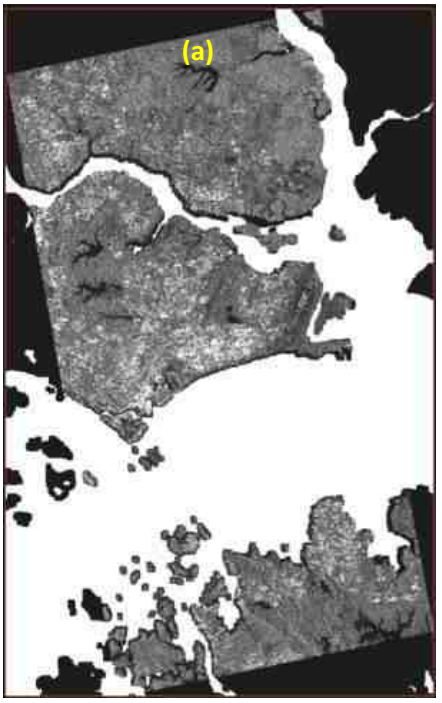


Fig. 6: Terrasar-X Stripmap image (*Singapore strait*) ship detection results



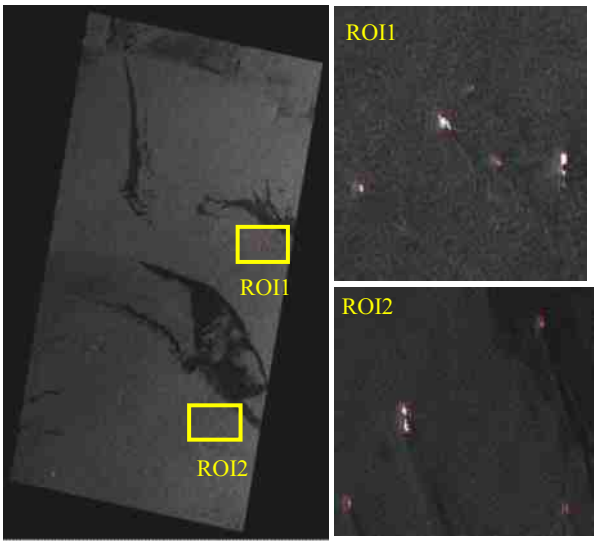


Fig.7: Terrasar -X Stripmap image (*Gulf of Maxico)* ship detection results

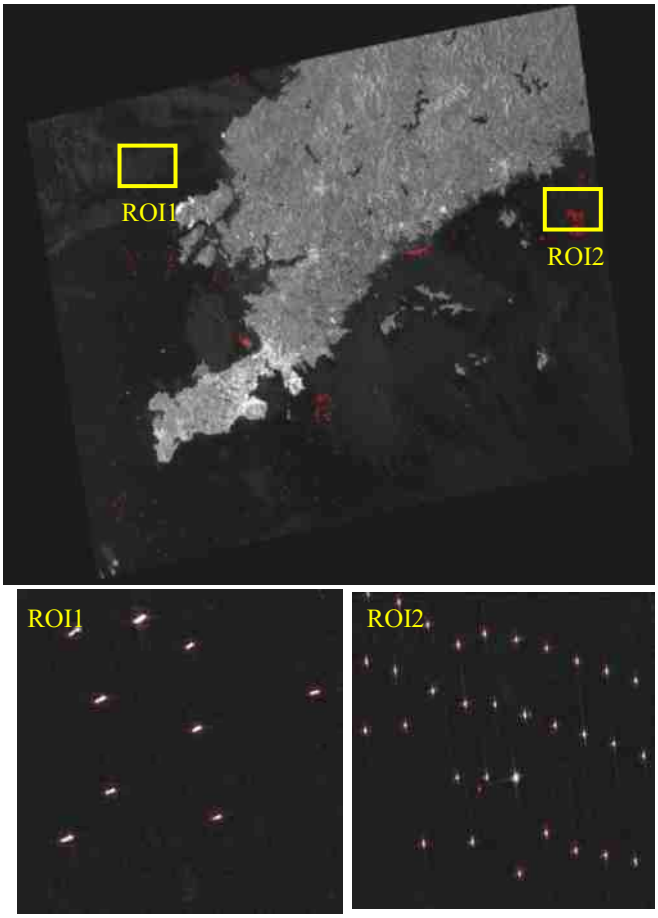


Fig. 8: Sentinel-1A IW, VV (*Dalian, Yellowsea, China*) ship detection result

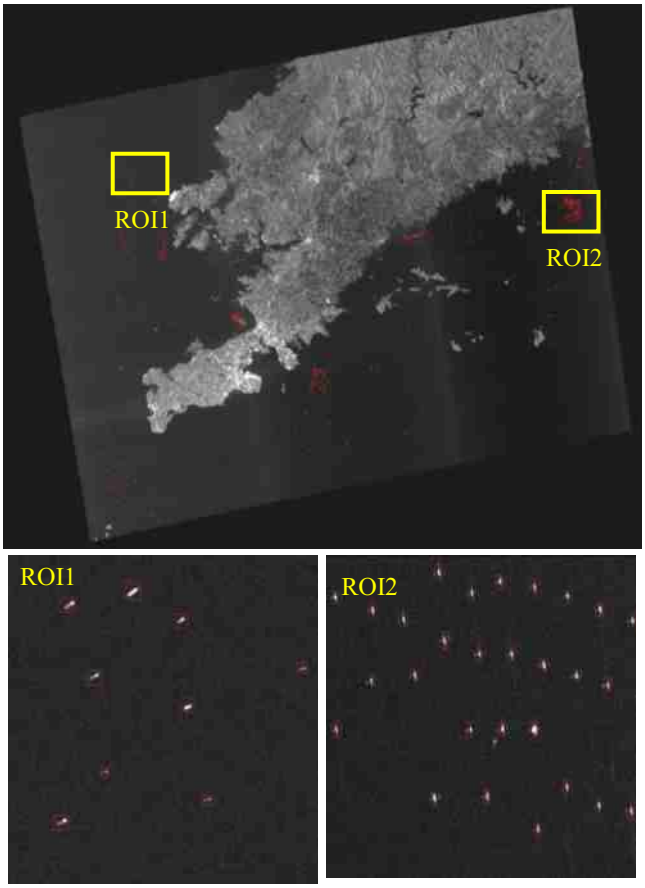


Fig.9: Sentinel-1A IW, VH (Dalian,Yellowsea, China) ship detection result

Cloud Detection and Percentage Estimation in compressed JPEG for Indian Remote Sensing Satellite Data

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Abstract

Indian Remote Sensing Satellites, such as Carto-2 series of satellites acquire high resolution data in panchromatic and multispectral bands regularly. The data acquired is processed for both radiometric and geometric corrections. Geometric correction for the acquired data is performed using on-board system information and reference points from known sources in an automated procedure. However, a percentage of products are unable to use reference points due to failure in automatic matching procedures. Automatic matching procedures do not perform well if the scene is cloudy, having large water bodies or difficulty in fetching appropriate reference. Since the output products are large in number and the volume of the data is enormous, automated processes are needed for estimating cloud cover. Hence, the algorithms were developed for JPEG compressed format. The method adopted for cloud detection and cloud percentage estimation using compressed JPEG format of high resolution Cartosat-2S data for both PAN and MX with nominal coarse resolution of 12m for PAN and 20m for MX. After a detailed study algorithm as hybrid grid based Adaptive Threshold and OTSU Threshold are used for cloud percentage estimation. The results generated by algorithm method are visually validated and presented in this paper

.

Keywords: Cloud Detection, Compressed JPEG, Adaptive Threshold, OTSU Threshold, System Level Product.

Introduction

Over the past decade, number of satellites for optical earth-observing remote sensing has increased substantially, dramatically increasing the capability to monitor the earth. Increase in the volume of data from remote sensing satellite is primarily driven by improved technology, miniaturization of components, reduced manufacturing and launch cost.

Automated Data Quality Evaluation (DQE) processes assess the geometric accuracy of processed products. These reports are analyzed and feedback is given for appropriate corrections, if any. During Data Quality Evaluation (DQE) analysis, it is observed that a good number of products are generated without using reference points. It is customary to analyze and find reasons for failure of automated matching procedures. However, correction has still taken place using onboard system information. The products which are corrected using onboard system information are termed as system level products. While analyzing system level products, it is found that many of the images are inevitably covered by clouds. Clouds are often a significant problem when conducting remote sensing of the earth's surface as they can locally obscure surface features and alter reflectance. The presence of clouds and their brightening effect complicates the use of data in the optical domain from earth observation satellites. Their detection for system level products analysis, is an important step for DQE evaluation. In order to do the same, the system level products are segregated into two broad categories i.e. products with cloud and without cloud. Cloud estimation is required for categorizing the products. Products without clouds are further categorized into water bodies, desert, hilly terrain and homogenous terrain.

Automating the cloud detection is especially important in the case presented here as hundreds or thousands of images require analysis [8]. Before estimating the cloud percentage, it is important to understand the types of\clouds. There are the different forms of clouds like thick cloud also known as altocumulus clouds, thin clouds also known as cirrocumulus clouds, scattered clouds known as stratus clouds, clouds on the top of snow, cloud patches, hazy clouds [1] etc. Generally, the thick opaque clouds are relatively easier to identify because of their high reflectance in the visible bands but the identification of thin semitransparent clouds is difficult as their signal includes both clouds and the surface underneath [9]. Threshold-based methods cannot be made unique for all

the images as the gray level/pixel intensity varies with various images. Hence, a hybrid method, grid based adaptive threshold mechanism provides us a better approach for cloud estimation.

Cloud estimation on high resolution remote sensing data can be very time consuming due to the large data volumes; hence here the method adopted for cloud estimation is done for compressed JPEG format of high resolution Cartosat-2S data for both PAN and MX with nominal coarse resolution of *12m for PAN and 20m for MX*. The cloud percentage is used for further analysis for validation of system level product generation in case of cloud free image. The feedback is provided to the Data Processing team for further correction, if required. This paper presents the method to estimate clouds in an image and representation of the results in tabulated form. The results from this method are presented in Results section.

Overview

This section 3.1 describes about System Level Products. Section 3.2 describes about the challenges in data preparation and nature of datasets created for the evaluation of the robustness and accuracy of the method. Section 3.3 describes about Classical Algorithms and its limitations. Section 4 describes the Proposed Methodology, its input and sub-process in details. Section 5 describes about the actual implementation of the methodology using Python. Section 5.1 explains about the step by step illustration of the implemented algorithm. Section 6. describes about the Evaluation methods, Test Criteria and Results. Finally, Section 7. about the future refinement work for algorithm optimization for accuracy Improvement. Section 8 concludes the paper with summarizing the results and the future scope of the work. Section 9 presents the references used in this paper.

System Level Data Products and Challenges in Data Preparation

System Level Products

For understanding System Level Products, first it is required to define geometric corrections. Geometric correction is an integral step for remote sensing image processing and application. In Geometric corrections geometric distortions because of variations in the earth curvature, are corrected. This distortion occurs because of the sensor height and speed of the camera. The Nonlinearities in the while capturing of a sensor's field of view and due to the curvature of earth's atmospheric refraction relief displacement is the major cause of the distortions. Corrections are carried out by establishing the relationship between the image coordinates system and the geometric coordinate system using calibration data of the sensor, measured data of position and altitude and ground control points and appropriate mathematical models. The imagery is converted to real world geographic coordinates by the use of distributed Ground Control Points. The geo-referencing is done by the referencing the image coordinates to the ground coordinates [12]. Due to factors like cloud or water bodies few of the satellite image products are generated without using reference points as automated matching fails. However, correction has still taken place using onboard system information. The products which are corrected using onboard system information are termed as system level products. It is customary to analyze and find reasons for failure of automated matching procedures.

Data Preparation

Data preparation is a process of gathering, combining, structuring and organizing data for testing the method. For cloud estimation, benchmark datasets are prepared of different sizes, terrains, content and sensor. The proposed algorithm works equally good for both panchromatic images and multispectral images. Thus, datasets are collected for both PAN and MX. Here the data set preparation comprises collecting the products of various parameters as:

a) Products with and without cloud.

b) Product without clouds are further categorized into water bodies, desert, hilly terrain and urban.

c) Products with various forms of clouds like thin clouds (cirrocumulus), thick cloud (altocumulus,) scattered clouds with snow (stratus), cloud patches etc. Fig 1 depicts the different types of clouds acquired with different satellite.

Input Benchmark Datasets

Figure 1 shows the view of the various input datasets used for testing, analysis and refinement of the proposed methodology.

Top row shows PAN sensor datasets with thick clouds, second row has PAN sensor datasets with thin/scattered clouds. Third row comprises of the thick clouds from PAN sensor.

Fourth row shows the datasets acquired from MX sensor

with thick clouds. Fifth row shows the datasets acquired from MX sensor with snow and scattered clouds.

Input Data Type: JPEG

JPEG is a commonly used method of lossy compression for Digital images. In the present case JPEG compression ratio varies from 10:1 to 30:1 with perceptible loss in image quality according to the input data size.

Classical Algorithms and its Limitations

Classical cloud detection algorithms have their known limitations for cloud detection. The output, varies from image to image based on the input as well as the algorithms used for detection. Based on the result analysis, it is implicit that cloud detection approach cannot be done by single approach or single algorithm method hence there is a need to adopt a hybrid method.

Proposed Methodology and Approach

The proposed method uses hybrid approach to overcome the limitation of the threshold based cloud detection method. It is amalgamation of grid based computation, adaptive threshold based classical algorithm and image statistics based segmentation. It divides the image into multiple logical square grids. Dividing the image in logical square image grids, helped in true representation of the subjective area. For each image grid, further histogram and cumulative histogram statistics are generated, to segment the darker non cloudy regions and brighter cloudy regions of the image.

Cloud detection from the optical band of a satellite remote sensing image considers the differences between the cloud and ground gray levels. The proposed method detects multiple cloud regions and estimate its overall cloud percentage/coverage. It distinguishes clouds in satellite images using histogram statistics and parameters for ground objects by segmenting the images and applying more than one threshold algorithm based on the images. The parameters which are used in the hybrid approach proposed in this paper are as follows:

a) Grid Size N X N
b) Adaptive Threshold Grid Size
c) Lower Threshold (LT)
d) Upper Threshold (UT)
e) Sigma Threshold (σ_T)
f) Biases

Image based Grid Generation

The input image is divided into N X N logical image grids or segments. The multigrid formation of the image helps for the optimization of histogram statistics. The size N X N of the grid is fine tuned for the given spatial resolution of the image.

De-noising an image

It is necessary to de-noise the image before thresholding, which can be done with one of the methods from the Blurring Images. Here Gaussian Blur is used to de-noise the images before performing thresholding.

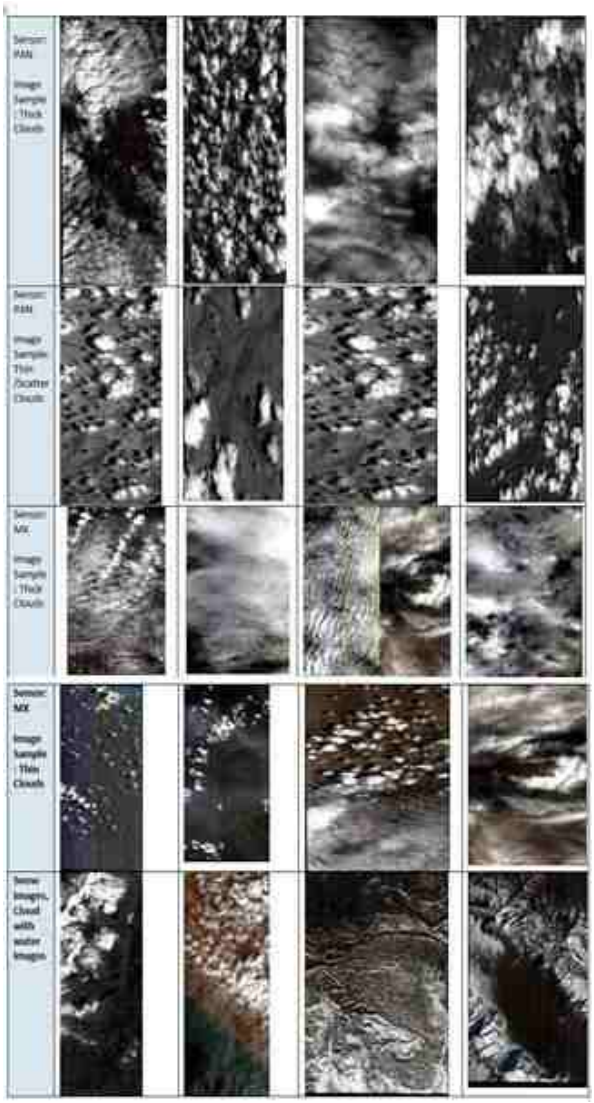

Fig. 1: Different types of cloudy images

Threshold

Thresholding [14][15] is a type of image segmentation, where we change the pixels of an image to make the image easier to analyze. In thresholding, we convert an image from color or grayscale into a binary image, i.e., one that is simply black and white. There are three types of threshold considered for the analysis:

- Simple or global thresholding, the threshold value is

global, i.e., it is same for all the pixels in the image.

- Adaptive thresholding is the method where the threshold value is calculated for smaller regions and therefore, there will be different threshold values for different regions.
- OTSU threshold which is based on the variances of the two classes after thresholding.

Simple threshold

Simple or global thresholding is primitive method for cloud detection. Cloud grey values are identified by image histogram. Further the image is binarized based on the threshold identified using histogram. Hence, finding an appropriate threshold between cloud and non-cloud fulfils the task of cloud detection. Currently, thresholding based methods are not popular in remote sensing areas especially in urban remote sensing applications with high resolution imagery. This is because of high degree of variation of histogram from image to image[16].

Adaptive threshold

In practical scenario, simple thresholding method has limitation of its dependency on the image intensity, which often involves trial and error. To overcome the same, grid based adaptive thresholding [14] [15] method is adopted. It uses a quantitative, mathematical definition for a good threshold that allows us to determine the value of the threshold automatically. The grid size of the adaptive threshold function should be smaller than the image grid chosen. It is worth noting that the principle for simple and automatic thresholding can also be used for images with any pixel ranges as [0.0, 1.0], [0,255]. For example, we perform thresholding on pixel intensity values in the range [0,255] as it is in the test data sets presented here [7].

OTSU threshold

The OTSU's method [13], an optimum thresholding technique is used to find the optimal threshold for the given grid. In optimal thresholding, a criterion function is devised that yields some measure of separation between regions. A criterion function is calculated for each intensity and that which maximizes this function is chosen as the threshold. OTSU's thresholding chooses the threshold to minimize the intra class variance of the thresholded black and white pixels. It is formulated as discriminant analysis; a particular criterion function is used as a measure of statistical separation. It is this threshold that minimizes the weighted within-class variance. This turns out to be the same as maximizing the between-class variance [7]. It operates directly on the gray level histogram [256 numbers, P(i)]. It's fast once the histogram is computed. OTSU assumptions are:

- Histogram (and the image) are bimodal.
- No use of spatial coherence, nor any other notion of object structure.
- Assumes stationary statistics, but can be modified to be locally adaptive.
- Assumes uniform illumination (implicitly), so the bimodal brightness behavior arises from object appearance differences only.

The *weighted within-class variance* is:

$$\sigma_w^2(t) = q_1(t)\sigma_1^2(t) + q_2(t)\sigma_2^2(t)$$

Where the class probabilities are estimated as:

$$q_1(t) = \sum_{i=1}^{t} P(i) \qquad q_2(t) = \sum_{i=t+1}^{I} P(i)$$

And the class means are given by:

$$\mu_1(t) = \sum_{i=1}^{t} \frac{iP(i)}{q_1(t)} \qquad \mu_2(t) = \sum_{i=t+1}^{I} \frac{iP(i)}{q_2(t)}$$

Finally, the individual class variances are:

$$\sigma_1^2(t) = \sum_{i=1}^{t} [i - \mu_1(t)]^2 \frac{P(i)}{q_1(t)}$$

$$\sigma_2^2(t) = \sum_{i=t+1}^{I} [i - \mu_2(t)]^2 \frac{P(i)}{q_2(t)}$$

Now, it is run through the full range of t values [1,256] and the value that minimizes the inter class variances is chosen as optimum OTSU threshold [7].

Image Statistics Based Segmentation

To improve the overall accuracy of cloud detection algorithm, image segmentation based on the a priori image radiometric characteristics knowledge is implemented.

Lower Range

While analysing cumulative histogram, it is found that if 3σ population of the Image grids falls below LT DN value, then it is cloud free image grid.

Higher Range with sigma controlled operator

Image Grids with thick clouds, have higher histogram mean (μ) and less sigma (σ). Using these statistics, the spread of the histogram is used to ascertain the possibility of the clouds or bright feature. If sigma is very narrow, (here it is σ_T count), those are thick clouds, but at the same time if histogram mean is high with high sigma (wide

spread), then it is image with bright feature.

Biases Adjustment

Based on the multiple datasets analysis, there was some of the bias error found between visual cloud estimation and proposed method based estimation. Bias adjustment is carried out to reduce these false alarms which in turn improves the overall accuracy of the algorithm.

Implementation of the Method

Any algorithm or library requires a platform to implement it. This method has been implemented using python as it is fastest-growing programming languages in the tech industry due to Flexibility and Reliability to provide developers with ample time to try new experiments and widely used programming languages for image processing. Its imaging libraries and tools help in achieving the task of image processing very efficiently. Here the algorithm has been implemented using pythonopenCV. Open CV stands for Open Source

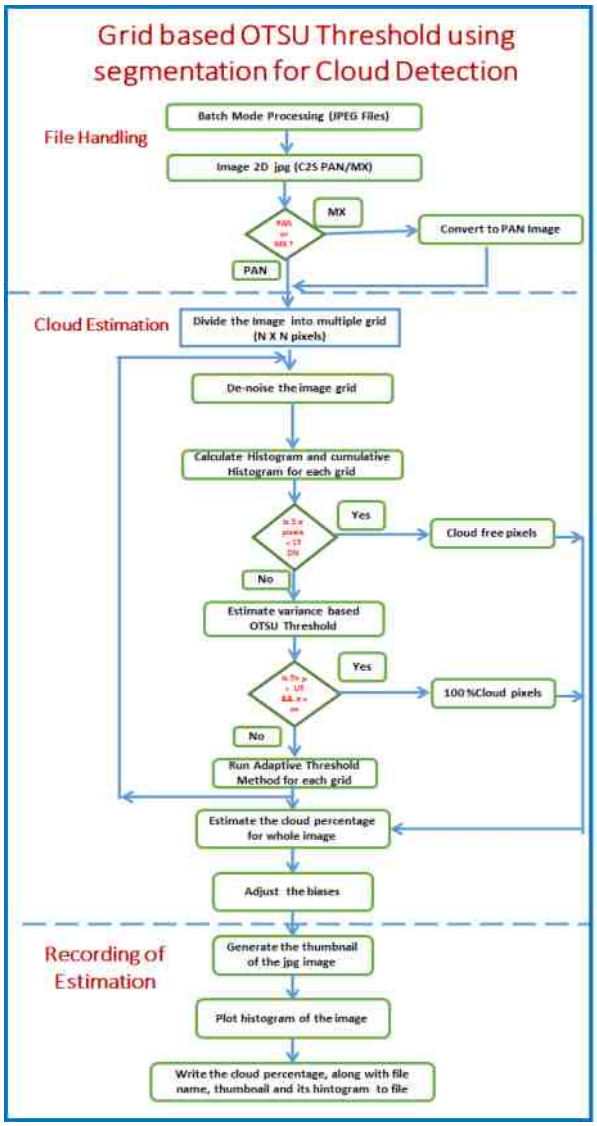

Fig 2: Flow Chart of Cloud Detection Method

Computer Vision Library. This library consists of around 2000+ optimized algorithms that are useful for computer vision and machine learning. There are several ways you can use open CV in image processing, a few are listed below:

a) Converting images from one color space to another i.e. like between BGR and HSV, BGR and gray etc.

b) Performing thresholding on images, like, simple thresholding, adaptive thresholding etc.

c) Smoothing of images, like, applying custom filters to images and blurring of images.

d) Performing morphological operations on images.

e) Building image pyramids.

f) Extracting foreground from images.

g) Image segmentation

Flow chart

Figure 2 demonstrates the flowchart of the implemented algorithm.

Step 1. Input is the folder path/location with the jpegs for which cloud estimation has to be carried. No limitation in the number of images. Batch mode processing has been executed for more 22000 number of images.

Step 2. Each Image file is read sequentially.

Step 3. Module checks PAN or MX image.

Step 4. In case of MX, then it converts MX to PAN image using averaging the MX bands.

Step 5. For each PAN image, program virtually generates the grid images (moving window with no overlap) of grid size of N X N pixels.

Step 6. Each image grid is blurred with Gaussian function.

Step 7. After blur function, histogram and cumulative histogram is computed for the grid image.

Step 8. If 3σ population of the pixels falls below LT gray count, then that image is segregated as clouds free or 0% clouds.

Step 9. If the above condition is false, then OTSU threshold is estimated for the grid image.

Step 10. If the threshold is higher than UT gray count and sigma of the histogram is less than σ_T pixels, then the grid is classified as 100% cloudy pixels.

Step 11. Other than these conditions image goes for Adaptive threshold based segmentation. Adaptive threshold further runs on block based local means.

Step 12. Based on the threshold cloud pixels are segmented for each grid

Step 13. Once cloud estimation for all grids is completed,

cumulative sum of all cloud pixels is computed.

Step 14. Cloud percent is estimated for the full image

Step 15. Input Image thumbnail jpg is generated

Step 16. Input Image histogram is plotted

Step 17. Input file name, its thumbnail jpg, its histogram and estimated cloud percent are tabulated for further analysis

Batch mode processing

The program accepts the complete folder as input and generates the cloud results for each image present in the folder. The necessary validations and checks for the proper file formats are incorporated in the implementation. Algorithm is initially tested for one image at a time and then batch mode processing is introduced to enable cloud estimation of multiple images without user intervention.

Libraries used: os

Image Grid based processing

Each Image is divided into Moving Window grid of N X N pixels to ensure no pixel is left from accounting. Cloud pixels are determined for each grid and later cloud percentage is estimated by following formulae:

$$Cloud\ Percent = \frac{Total\ Number\ of\ Cloud\ Pixels}{Total\ Image\ Pixels} X\ 100$$

Libraries used: os, opencv, pillow, statistics

Tabulating the results in file along with its histogram

Finally, Image file name, its thumbnail jpg, its histogram and estimated cloud percent is recorded in a file. It helps in analysing the correctness and accuracy of the proposed method.

Libraries used: matplotlib, pyplot,xlsxwriter

Evaluation, Test Criteria and Results:

To assess the robustness, efficiency and accuracy of the algorithms, the model was on more sets of images. The results generated by module are programmatically recorded along with thumbnail and cloud percentage for the respective image for better visual analysis to test the robustness of the algorithm. These records are visually validated by the team. Initially the results of the algorithm were evaluated on hundred JPEG samples to verify the results and once after gaining the confidence the algorithm were run on eighteen hundred jpeg samples for evaluation and the outputs are visually verified and found satisfactory.

The cloud detection module results shows the precision and consistency when tested across multiple satellite optical

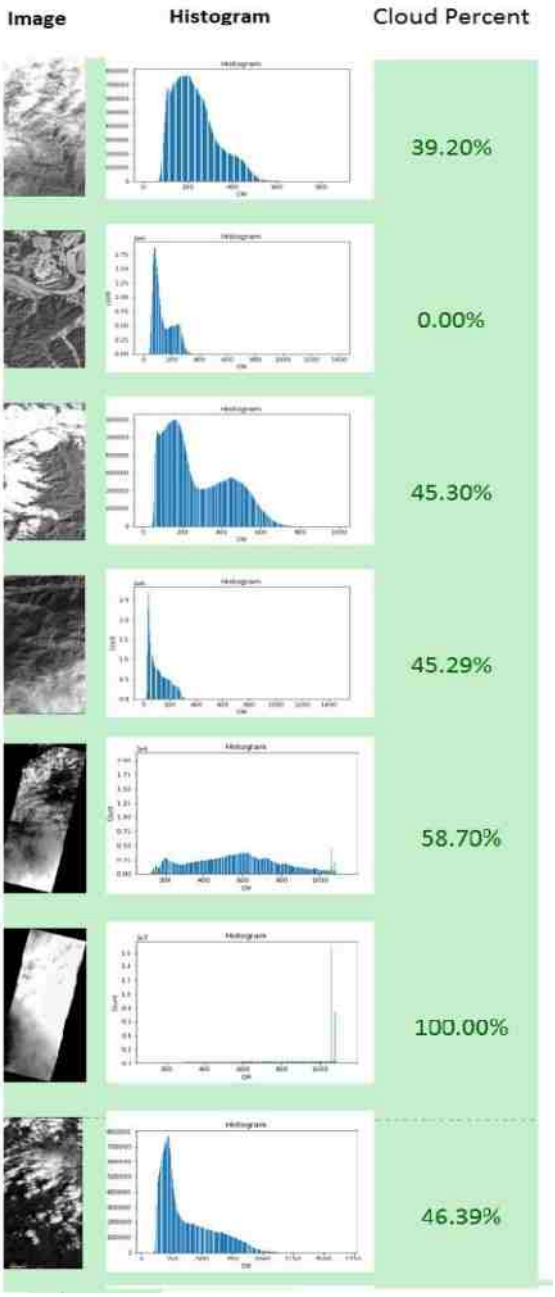

Fig. 3: Output Results of Algorithm with Thumbnail and data sets with an acceptable accuracy of seventy percent.

Tabulated Results Analysis window

Fig 3: Depicts the output results of proposed method along with thumbnail and histogram. To improve the overall accuracy of the algorithm, detailed, accurate and critical analysis is of the utmost important. To facilitate the same, the estimation program itself record/tabulate the outputs in a file with input image file name, image thumbnail jpg, its corresponding histogram and estimated cloud percentage. Later visual interpretation is carried out and false alarm are highlighted. These false alarm are thoroughly analysed which enables for various refinement in the proposed methodology, to increase the overall accuracy.

Output Plots Analysis for PAN Sensor

Table 1 depicts the difference in visual interpretation and

proposed method generated cloud percentage for PAN Images. After analysis of around 300 samples of test data the difference between visually and algorithm computed values falling in the range of 0-20 % i.e. total true cases are 72.45 %.

Table 1 : Accuracy table for PAN Images

Difference in cloud percentage for PAN Images (%)	Percentage of test Images (%)
0	9.17
1-5	34.86
5-10	7.33
10-15	11.00
15-20	10.09
Total True Cases	**72.45 %**
20-25	11.35
25-30	8.20
30-100	8.00
Total False Alarms	**27.55 %**

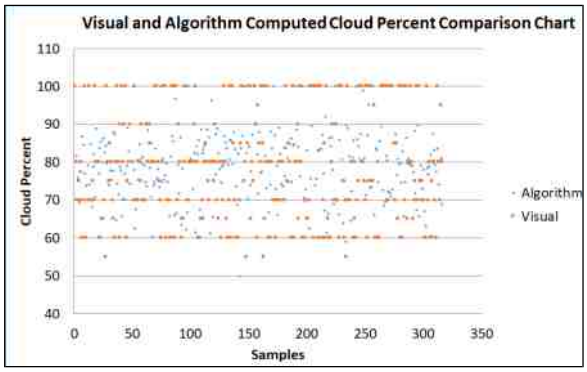

Fig. 4: Comparison Graph of Visual and Algorithm computed cloud percentage for PAN images

The Fig 4 shows the cloud percentage of visual and algorithm computed for 300 sample images. It clearly shows that around 70% of the algorithm computed values are match ing to the visually estimated values.

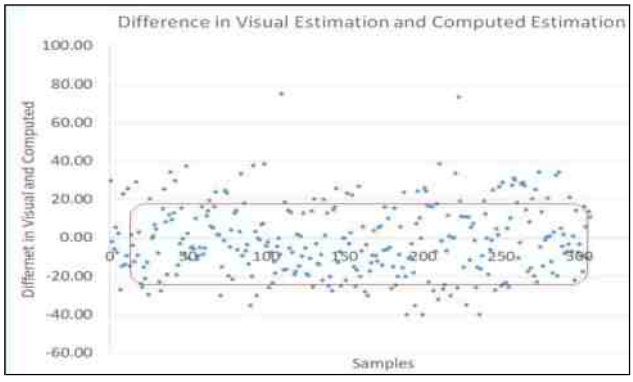

Fig. 5: Difference in values computed by proposed method vs visual interpretation for PAN images

The Fig 5 shows the difference in values in terms of cloud percentage from visual and method perspective. It clearly shows that the maximum values are falling the range of 0 - 20% difference range.

Output Plots Analysis for MX Sensor

Table 2 depicts the difference in visual interpretation and proposed method generated cloud percentage for MX Images. After analysis of around 180 samples of test data the difference between visually and proposed method computed values falling in the range of 0-20 % i.e total true cases is 70.47%.

Table 2 : Accuracy table for MX Images

Difference in cloud percentage for MX Images (%)	Percentage of Test Images (%)
0	3.49
1-5	16.51
5-10	18.41
10-15	17.14
15-20	14.92
Total True Cases	**70.47 %**
20-25	9.84
25-30	12.06
30-100	7.62
Total False Alarms	**29.52 %**

The Fig 6 depicts the cloud percentage of visual and proposed method computed which clearly shows that around 70% of the proposed method computed values are matching to the visually computed values.

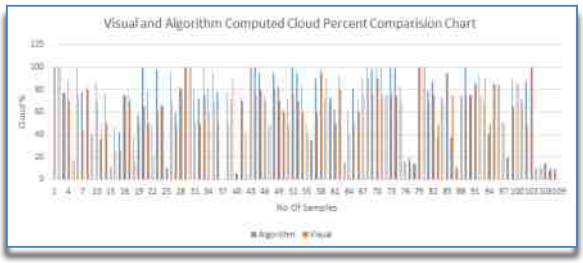

Fig. 6: Comparison Graph of visual interpretation and proposed method computed cloud percentage for MX images

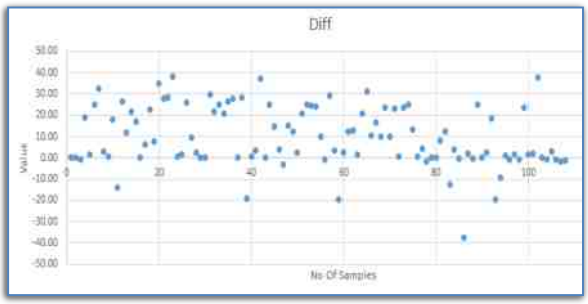

Fig. 7: Difference in values computed by proposed method vs visual for MX images

The Fig 7 shows the difference in values in terms of cloud percentage which has been computed with respect to both

visual and Proposed method computed cloud percentage values. It clearly shows that the maximum values are falling the range of 0 – 20% difference range.

Visual Cloud detection is subjected to the expertise of the user. So there is a possibility of human error induced is also attributed to it. For example, as table2 shows, 3.49% data is exactly matching to visual detection. 1 to 5 % cloud percent detection difference attributes to 16.51% data.

Algorithm optimization for accuracy improvement

The author is also working on the algorithm optimization for accuracy improvement. This can be achieved by improving the following parameters.

- The potential clouds, and water bodies based on their radiometric characteristics will increase the accuracy of cloud detection.
- Refining the image grid window size according to the spatial resolution of the satellite data.
- Refining the sigma controlled operator which controls the thick clouds segments using histogram statistics.
- Fine tuning the adaptive threshold window size.
- Hybrid method which combines spectral, texture and cloud characteristics methods are needed to overcome constraints and drawbacks of existing method.

Conclusion

Classical cloud detection approaches limitations from satellite imagery data is discussed in this paper. No single approach gives the desired accuracy in cloud detection. So, it is suggested to use the hybrid model which is a combination of grid based computation, adaptive threshold based classical algorithm and image statistics based segmentation to reach the desired accuracy. The proposed method has a high overall accuracy rate, but if the non-cloud area is highly reflective, as the cloud area, it is mostly misidentified. Based on the visual analysis, it is recommended that optimization & reduction of false alarm can be done by more refinement of the variable parameters. For the future, it is required to generate the cloud mask so that data can be used for different state of the art applications such as AIML based object detection etc. To improve Turn Around Time of the cloud detection process, multithreading and statistical optimization can be implemented.

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Mapping -Changing Pattern of Sex Ratio and Child Sex Ratio of Ranchi District: Jharkhand

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Abstract

Sex composition of the human population is one of the basic demographic characteristics which is extremely vital for any meaningful demographic analysis. Changes in sex composition determine the socio-economic and cultural patterns of society. Sex-ratio is a social indicator to measure the extent of prevailing equity between males and females at a given point of time. Therefore, the study and analysis of sex-ratio and other population characteristics of a region is very significant. The objectives of the present paper are to determine the sex-ratio of the Ranchi district and its participation as a workforce in the development of the district. Sex composition is expressed with the help of a ratio known as sex-ratio and determined as (the number of females per thousand males in the population) and expressed as- "The number of females/number of males x 1000". On the basis of sex-ratio and child sex-ratio changing pattern of demographic features has been analyzed. The research paper is based on secondary data. Thus, a sex-ratio of 1000 implies complete parity between the two sexes. Sex-ratio and child sex-ratio of the population of Ranchi district is the interplay of sex differentials in mortality, sex-selective migration, the sex-ratio at birth, and at the time of the sex-ratio differential in population enumeration. The analysis shows that the sex-ratio in different blocks of the Ranchi district varies. The changing pattern of sex-ratio at the block level results constantly for several decades but it is also declining in the recent decade's imbalances.

Keywords: Sex composition, Demographic, Decades, Mortality, Enumeration, Negative trend, Nationality, Migration.

Introduction

Sex composition is an important demographic determinant of population. The separate data for males and females are important for various types of planning and for the analysis of other types of demographic characteristics such as nationality, mortality, migration marital status, economic characteristics, etc. (Chandna R.C., 1992, "A geography of population", P.-264-267). In Russia, the sex-ratio is measured as the number of males per thousand females." "Sex-ratio is an important social indicator to measure the extent of prevailing equity between males and females in a society at a given point of time (Mazumdar, 2013)." It has much to do with the interplay of sex differential in mortality. Sex-selective migration, the sex-ratio at birth and at the time the sex differential in abortion and in population enumeration" (Mazumdar 2013). By the sex composition number of females per male population is being determined. It is very important for the balance of the sexes. An imbalance in sex affects the social and economic relations within a community. Sex-ratio in different Communities of society is not found to be similar. It also affects the occupational structure within the community and very importantly the child sex ratio. The future demographic trends and sex-ratio projections are also very much determined by the sex-ratio. The Ranchi district was previously dominated by the tribal community which was very sound with regard to sex-ratio. The sex-ratio data of the previous census years shows more female population than the male population but the sex-ratio in the different blocks of the district is continuously varying. Sex-ratio of the Ranchi district i.e., 949 per thousand of the male population which is similar to the state and country's sex-ratio. Most of the blocks of the Ranchi district are dominantly inhabited by the tribal population. In all the blocks of the Ranchi district sex-ratio in both the adult sex-ratio and child sex-ratio is comparatively higher. The tribal population has their distinct opinion and belief about the female. Female populations play such important role in tribal society. Females have an important participation in agricultural economy and other economic sectors. The tribal females are more open than the other community. There are 18 blocks in the district. In all the different blocks the sex-ratio is comparatively higher. Table.1,depicts that in all the blocks of Ranchi district having different sex-ratio. The important features of sex-ratio are almost increasing order in rural areas but declining and constant in urban areas.

Objectives

The main objective of this research article is:-

1. To bring out the spatial pattern of adult, and child sex-ratio in the different blocks of Ranchi-district.
2. To limelight the differences in the sex-ratio among tribals, and non-tribals.
3 To limelight the causes determines the sex-ratio in the different communities of Ranchi district.

Study Area

The present research paper deals with the Ranchi district which has the total geographical area of 5097 square kilometer and thus characteristics of both rural and urban habitation. The district has two sub-divisions and 18 community-development blocks. The total population of Ranchi district as per the 2011 census is 29,14253. The district is located between 22°52` to23°45` north latitude and 84°45`to 85°50` east longitudeand eliminated by Purulia district of West Bengal in east, Ramgarhand Chatra in the north, Latehar and Lohardaga in the west and the Gumla and the Khunti district in the south (Fig .1)

Database and Methodology

For the analysis of changing pattern of sex-ratio and child sex-ratio in Ranchi district data has been obtained from the census of India and the statistical aspects from Jharkhand state for 2001 and onward census and the collected data has been tabulated and calculated to analyze overviews of sex-ratio. Arch G.I.S, 10.2 software has been used for preparing the thematic maps to show the spatial pattern of sex-ratio in the Ranchi district.

Analysis and discussion

The total population of the Ranchi district in the 2011 Census is 24, 14,253 comparing 14, 94, 937 males and 14, 19 316 females which is i.e. 51.29% and 48.72% respectively. The female and male ratio is 949 females per 1000 males as compare to previous census data (2001). It shows an increase of 20 points but the child sex-ratio has decreased in comparison to the 2001 census. The child sex-ratio in 2011 census was 938, significantly lower than the 960 recorded in the 2001 census. It shows a decrease of 22 points. The population growth in the last census was 23.98% which forms 8.83% of the entire population of the state. Ranchi district has an area of 5097 square kilometers with a population density of 572 people per square Kilometer. The sex-ratio of the Ranchi district has increased. The child sex-ratio is 938 per 1000 males and has decreased as compared to 960 in the 2001 census.

As per Jharkhand enumeration information altogether 68.40 couples in the Ranchi district lived in single families. It is the root cause of decreasing child sex-ratio. The sex-ratio of the Ranchi district in the 2001 census shown in (Fig. 2) The sex-ratio of the Ranchi district in 1901 was 1058, which declined to 1050 in 1911, 1026 in 1921, 1017 in 1931, 974 in 1951, 921 in 1991,929 in 2001 and 949 in 2011. Table. 2 depicts the sex-ratio of Ranchi district has declined for three decades, it is again increased in 2001, and 2011. Like-wise the child sex-ratio had been also decreased but after Census year 1981 it has been increased (Fig.2). Looking at the trend of sex-ratio and child sex-ratio block-wise. It is found that only Lapung block have reported sex-ratio and child sex-ratio more than 1000 in 2011 but most of the blocks show a decreased trend in sex and child sex-ratio. The highest declination is found in Kanke, Ormanjhi Khelari Silli and Bundu blocks. Out of 18 development blocks have below state average sex-ratio as they are Kanke-940, Ormanjhi-947 whereas the remaining blocks have more than the state average (Table .3)

Conclusion

From the above analysis and discussion it is concluded that the sex ratio which is an important demographic factor is not constant in all the census year. All 18 blocks of Ranchi district are found to have disparity in sex-ratio and child sex-ratio as well. Several factors are responsible for fluctuations in the sex-ratio. The following main conclusion has been drawn-

- The sex-ratio varies in the rural and urban areas of the Ranchi district. Sex-ratio in rural areas are comparatively higher in the rural areas than the urban areas.
- Child sex-ratio in rural areas of Ranchi district particularly Bero, Mandar, Rahe,Sonahatu, Ormanjhi and Burmu is highly affected by the seasonal Migration of tribal laborers.
- There is a wide gap in the sex-ratio of the rural and urban populations. Urban areas have remained the center of immigration from the beginning. The adult sex-ratio is higher in urban areas.
- Analysis depicts that the sex ratio in all the census years is below 1000 below except Lapung. Lapung is inhabited by more than 90% of the tribal population. It is also found that all the tribal-dominated blocks of the district had a comparatively higher sex-ratio than the non-tribal block.

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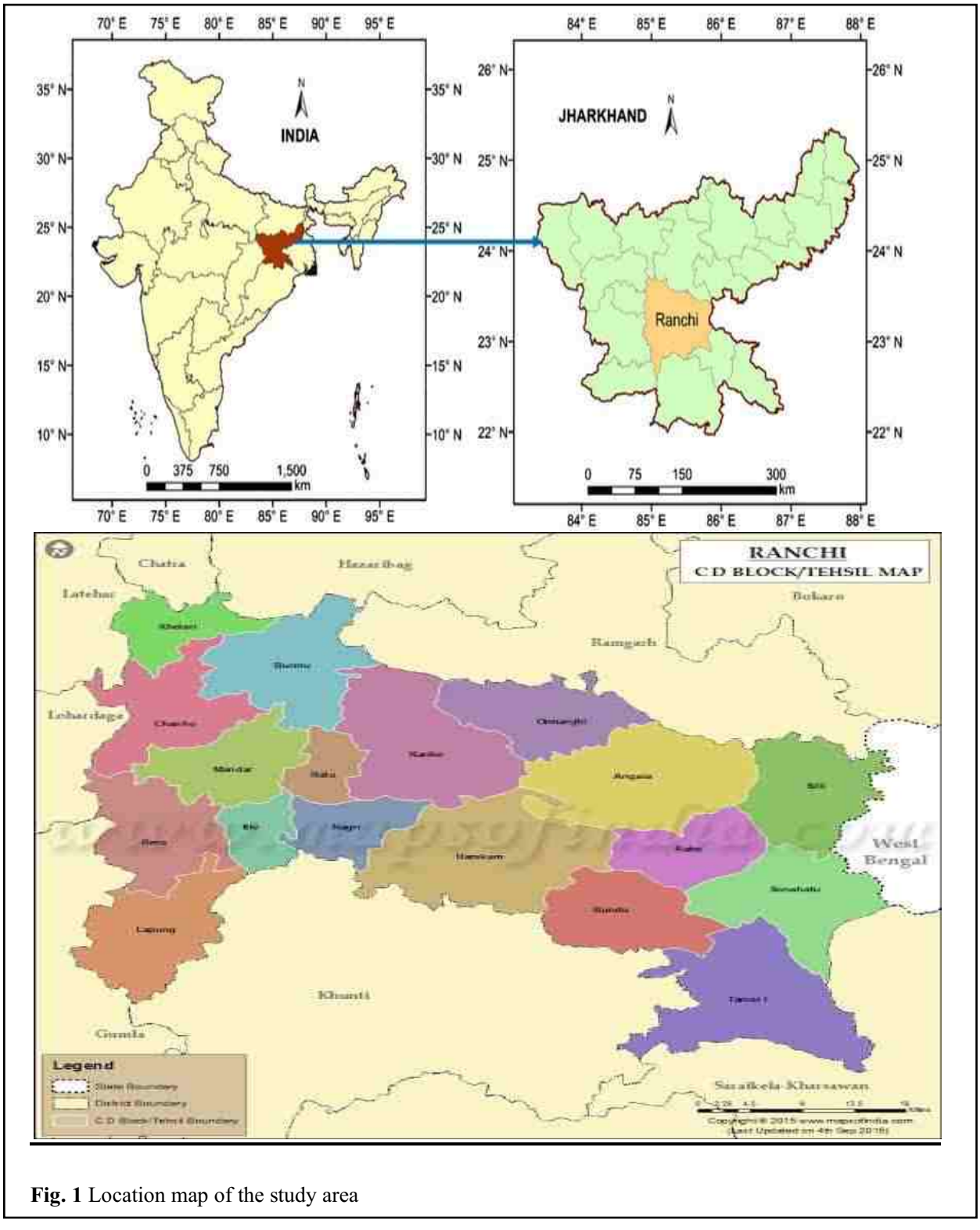

Fig. 1 Location map of the study area

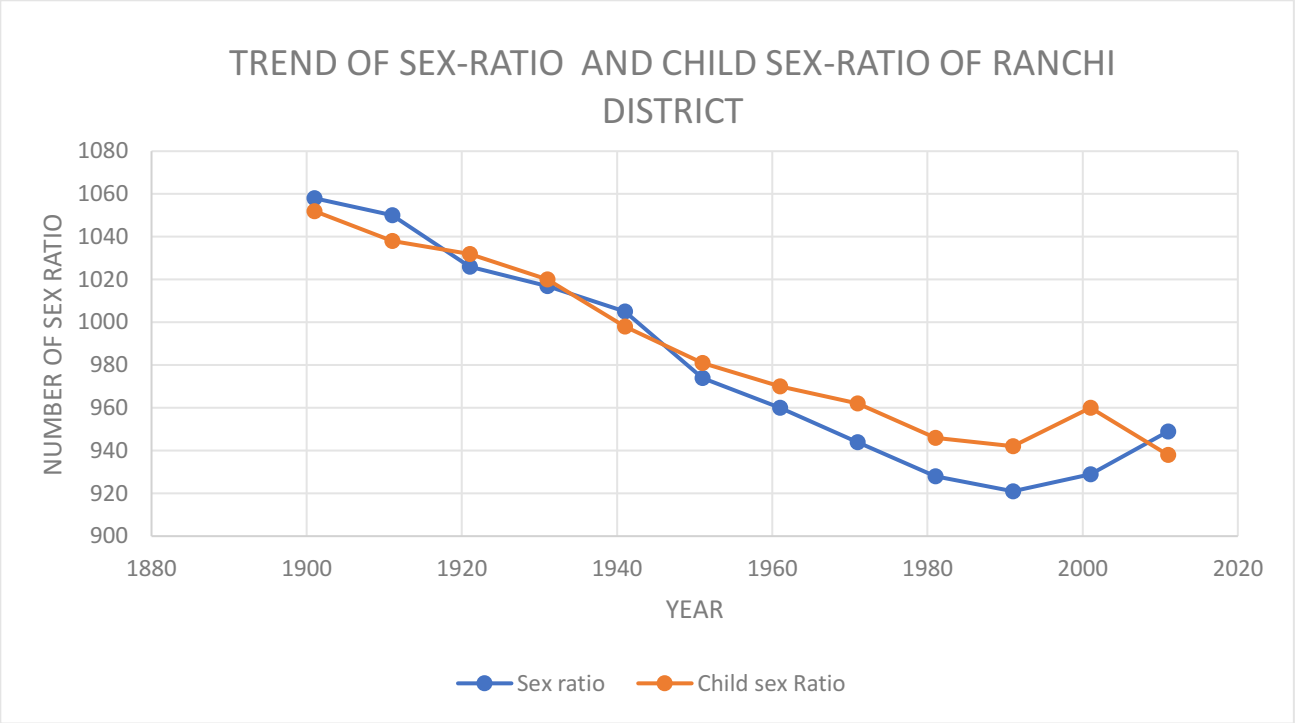

Fig.2: trend of sex ratio and child sex ratio

Table .1 Ranchi district block-wise sex-ratio 2011(*Source: - Census 2011 govt. of India, Jharkhand)*

Sl. No	Name of the Block	Total population	Sex ratio	Child sex ratio
1	Angara	112759	984	975
2	Bero	113090	973	952
3	Bundu	82975	963	927
4	Burmu	89889	969	967
5	Chanho	107503	980	953
6	Itki	50058	984	975
7	Kanke	1317499	924	911
8	Khelari	78219	929	921
9	Lapung	63053	1013	965
10	Mandar	128585	978	965
11	Nagri	76442	983	1350
12	Namkum	145841	967	984
13	Ormanjhi	94137	944	952
14	Rahe	53916	972	947
15	Ratu	76565	974	958
16	Silli	113798	959	1094
17	Sonahatu	77259	974	946
18	Tamar	132672	978	965

Table.2 Ranchi district decadal sex-ratio and child sex-ratio (Source: -Census 2011 govt. of India, Jharkhand)

S.No	Census Year	Total population	Sex ratio	Child sex Ratio
1	1901	477249	1058	1052
2	1911	557488	1050	1038
3	1921	536346	1026	1032
4	1931	629863	1017	1020
5	1941	673376	1005	998
6	1951	748050	974	881
7	1961	894921	960	970
8	1971	1164661	944	962
9	1981	1489303	928	946
10	1991	1827718	921	942
11	2001	2350245	929	960
12	2011	2914253	949	938

Table .3 Block-wise sex and child sex-ratio and their ranking in the district(Source: -Census 2011 govt. of India,Jharkhand)

Sl. no	Name of block	Sex Ratio		Ranking
		2011	2001	
1	Angara	984	978	04
2	Bero	973	979	09
3	Bundu	964	960	12
4	Burmu	969	963	11
5	Chanho	980	978	06
6	Itki	984	975	04
7	Kanke	940	950	16
8	Khelari	951	946	14
9	Lapung	1013	1010	01
10	Mandar	974	970	8
11	Nagri	983	980	05
12	Namkum	989	985	02
13	Ormanjhi	947	949	15
14	Rahe	972	970	10
15	Ratu	987	985	03
16	Silli	962	958	13
17	Sonahatu	974	970	8
18	Tamar	978	975	07

e-Governance for types and distribution of Water Source in Gumla Town, Jharkhand

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Abstract

Water is the basic resource on the earth for all living organisms including mankind and for development and survival of plant community. Environmental process of biosphere are also regulated by water, in this era of technical development and population concentration in urban areas, man has increased the use of water in different forms, which led to quantitative and qualitative deterioration of water resources. As such controlled use and proper distribution in the present context, use and conservation through e-governance has become the need of the hour. Gumla is the headquarter of Gumla district owing to regional urbanization process, Gumla town is continuously sprawling. As there are residential, industrial and commercial areas too along with village areas, the region suffers an acute water supply and distribution problems. Increasing demand of the water supply in the town area, government of Jharkhand has initiated a number of schemes for the distribution system of water in the town. Here the problems regarding water and associated aspects are also thriving for years. e-govern with proper distribution supply of water in the city is the only way to proper drinking water supply in the town. It is also due to massive water requirement and meager ground water potential.

The main objective of the present research paper is first to assess the water potential for drinking water in the Gumla town. Second to assess and analyse the drinking water supply process, third to bring out the problems of e-governance in water supply in the town. To achieve this objective secondary data has been collected from the government offices and analysis have been made through ArcGIS and the satellite maps. The study reveals that Gumla is a small town with a population of 51.264, there are two system of drinking water supply in the town, first drinking water supply system provided by the government of Jharkhand, for this public water distribution has been established that not only monitors the water supply system but also involved in the maintenance control e-governance. Second the town is facing massive water supply mismanagement and faulty distribution of water inequalities in water supply in different parts of the town.

Keywords: Massive water supply, ground water exploitation, mismanagement, inequalities, requirements, population concentration.

Introduction

Water resources are the basic need for the ecology. Its nature spatial distribution, utilization and conservation has become the prime concern in the present era. Water resources consists of all the phenomena of hydrological cycle that passes through all the spheres hydrosphere, atmosphere, lithosphere and biosphere on the earth (dakshinamoorty 1972, Nag and Kath Paliya 1972, K.L. Rao 1968, Laxmi Shukla and D.P. Nag 2019). Erratic water supply and resulted inequality is a big problem now a days in Gumla town. There is considerable water related issue like raw water supply, turbidity and water tax. Water sources in Gumla town is very limited and not maintained properly distribution pattern and also the judicious utilization in Gumla town is presently at a very critical condition. The only source of water supply in the town is south koyal river located at a distance of 20 km north east to the town, this is a seasonal river which becomes bankfull only during the rainy season and most month of the year remains dry. During the dry season none availability of water in the river creates crisis for drinking water supply. All the important ponds and dams becomes dry during the summer season. There are no such water ducts constructed in around Gumla town. Apart from that, ground water potential and its utilization are also serious problem in the town, all those several tube wells have been dug out by the government of Jharkhand and pubic individual cost and effort. There is always a huge gap persisting between recharge and extraction of ground water in Gumla town, the whole area of the town mark by granite and niece rocks characterized by less recharge capacity, rain water harvesting is not up to the mark and most of the open land are either being utilized or any other purpose, recently

government of Jharkhand through municipal corporation forcing public to construct rain water harvesting. The annual rainfall water is more 150 inches yearly but owing to hard nature of rocks with undulating terrains and high degree of slope rain water quickly flow downwards. Apart from this recharge of depleted ground water is also very mearge in many cases, water supply is subjected to manipulation by rich and influential people, this deprives common people in many extents from having fair water supply.

The Study Area

In this paper study area is Gumla town. It is the headquarter of Gumla district with a total gerographical area of 79 square kilometers extending between latitude 22^{0}35" east to 23^{0}33" east and longitude 84^{0}40" north to 85^{0}1" north. The Gumla town is located in the state of Jharkhand constituted by 22 wards. It is municipality, the water distribution system is controlled by PHED. It is a small town situated on the up-land area. Gumla town is spreading over hard granitic and gneissic rocks which characterized by meager potential of ground water resources. The town is spreading over an area of 79 square kilometers. The rate of growth in Gumla is exponential in terms of development and population concentration. Gumla is also a tribal dominated inhabitant, the town is also known as town of ponds, more than three ponds exist in the different location of the town.

Materials and Methods

Drinking water supply in any town and cities is most important for the cities dwellers. PHED is the most trustworthy government agency involved in water supply in the Gumla town, Secondary date source regarding water supply distribution and timing throughout the town area is collected from PHED and municipality, as well for effective water management and water sewerage the municipal corporation and district administration plays the vital role for the planning. Comparative date regarding the water crisis control lodging in different part of the city is provided by PHED. There have been some modification and improvement in recent years due to enhancement and sprawl of city area. The methodology used in the present research included quantitative and cartographic exercises.

Results and Discussion

Drinking water supply particularly in the water deficient area in Gumla town is very important. The water distribution system in the town is directly controlled by the local administration. There are two types of water distribution system in the city first water supply through pipes and second is tube wells. The water supply system in the different wards of the town is given in table number 1.1 which shows areawise availability of water supply system, which is directly e-governed by the local administration.

From the above table, it is evident that there are 22 wards in the Gumla town, all the wards are not fully facilitated by the water distribution system. 18 wards out of 22 are facilitated by the water distribution system directly controlled by PHED and e-governance by the local authority. Four wards of the town have deficiency of water supply system but almost all the wards of the city facilitated by the tube well, the household of the town have the both facility the water system provided by the PHED and agency of government of Jharkhand and tube well provided by the government schemes under the Jal Mission of Government of India and the tube well arranged by the public by their own cost, total number of tube wells in the town are 10215. 200 tube wells out of 10215 have been provided by the Government of Jharkhand under Jal Mission at the public place which are used by the general public, this types of tube wells are found in bus stand, court compound, block offices, different government offices, schools, colleges, churches etc. Most of the tube wells becomes dry during the summer season. Owing to lowering down of water table in hard granite rocks but during monsoon season water table comes up and these tube wells again becomes usable. Wells have been constructed in the decades, there are 20 old wells of which most of them have been dried away. Owing to lowering down of water table. Water distribution in the town through pipes are e-governed, there are four large water tank in the Gumla town through which water is being distributed through out the town.

Gumla town is suffering from scarcity of drinking water during summer season. Somewhere pumps are not working properly. Hard rock surface is another problem in town. Hard rock prevent the easy construction and distribution of water pipes as such there are places which have been left for water supply. Population pockets in the town have to remains under crisis during the summer season.

Ground water plays a crucial role for any urban area regarding water supply. Especially drinking water depth of ground water varies in the town and tube wells failed during the most month of the year.

Conclusion

Water supply and distribution in inequalities is a major problem in the Gumla town. Source of water supply in the town is the south Koyal located 20 km. north east of the town, but that river generally becomes dry during the summer and winter season. In that situation a big reservoir of water required to be constructed on this river to return water table during summer season. It is very essential to protect and conserve the ponds and rivulets sustainable through the tube wells, town sprawl has damaged the water reservoir located in the town area, the outskirt of the city area still facing water crisis, there is essential to have a effective planning for water supply in the Gumla town.

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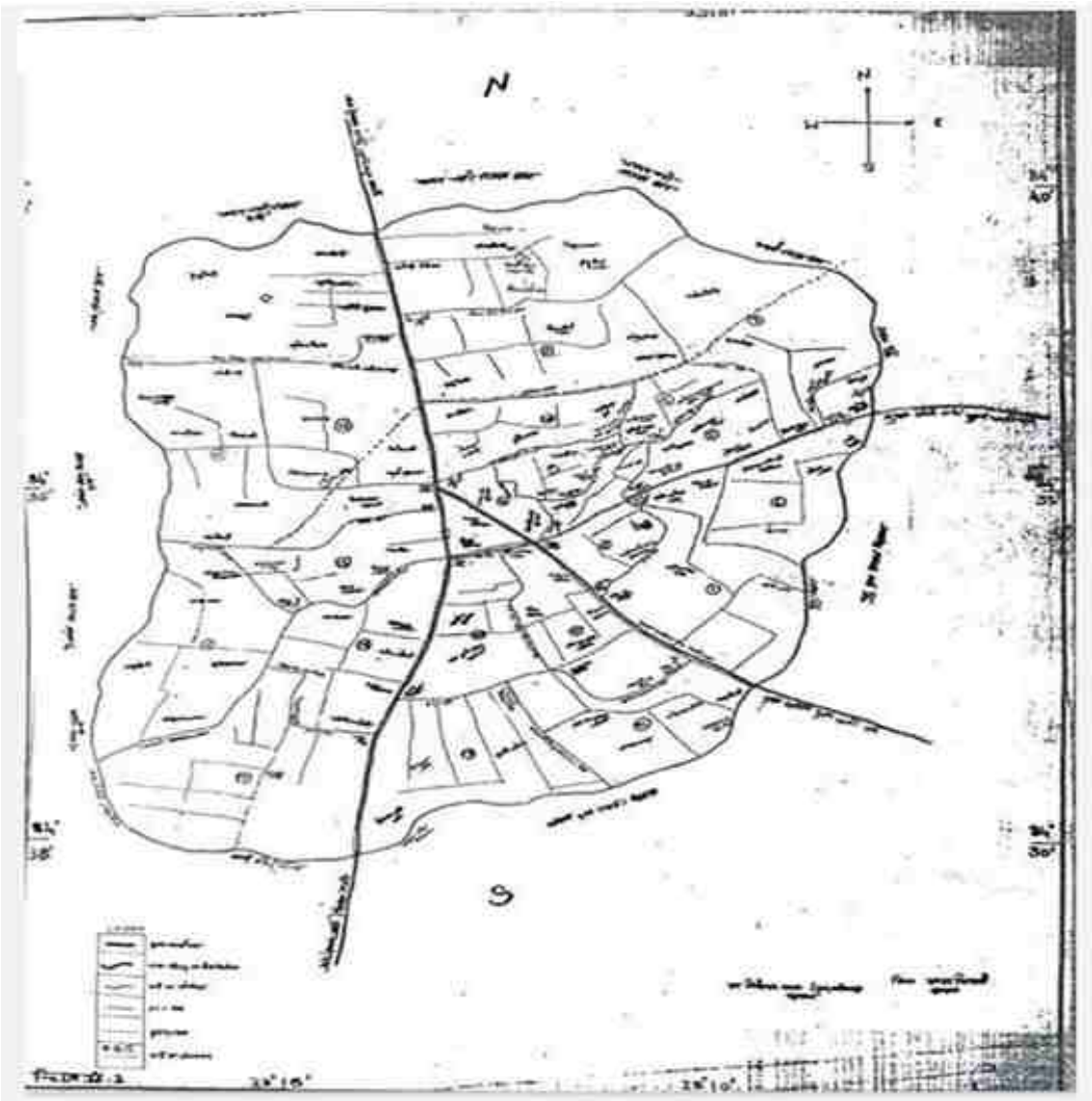

Fig. 1: Location Map of Gumla Town

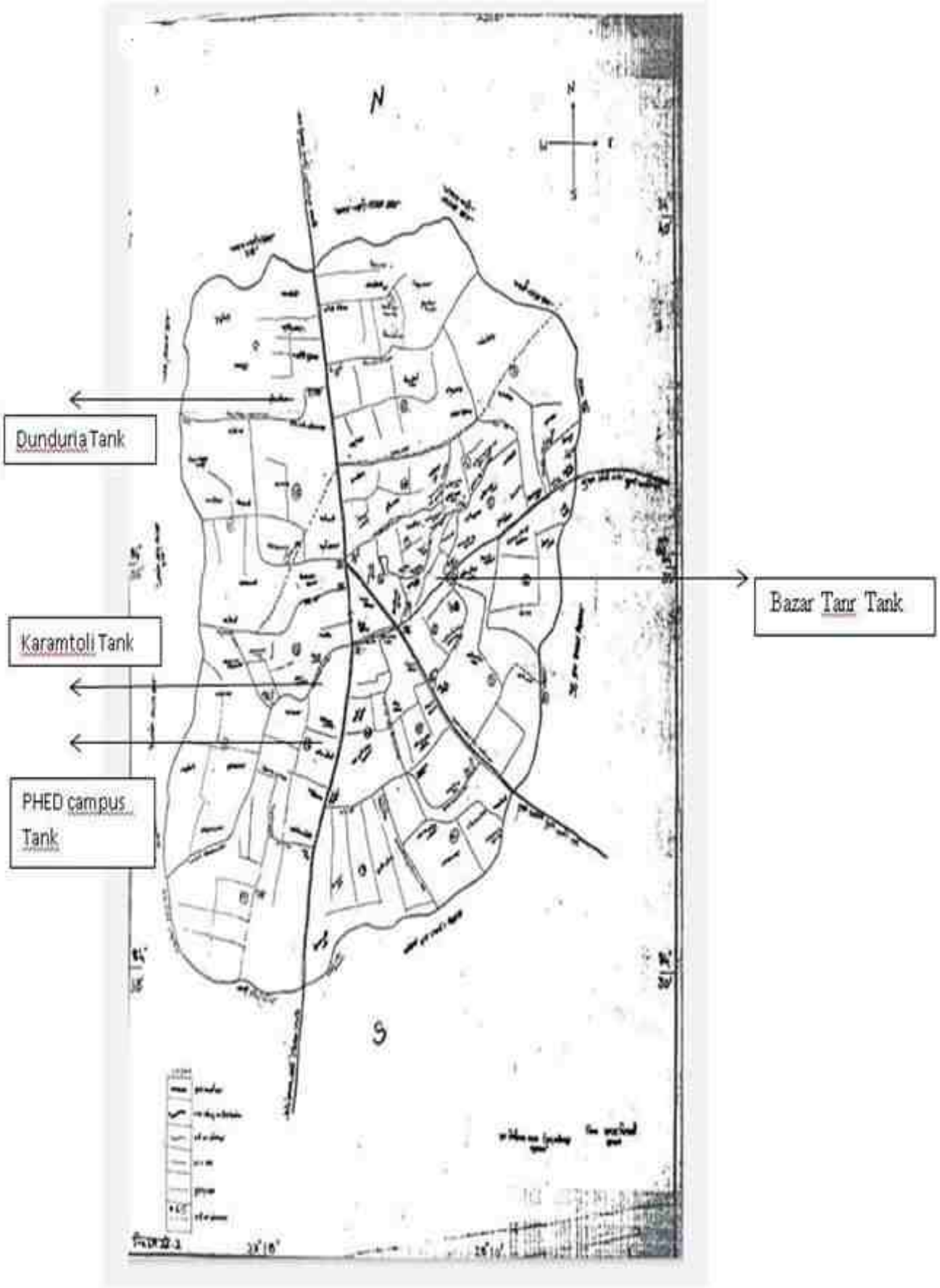

Fig. 2: Water source distribution in Gumla Town

Table 1. Gumla town wardwise water supply system e-governed by local administration (*Source :* PHED Office, Government of Jharkhand)

Sl. No.	Ward No.	Location	Water Supply Running	No. of Tube Wells	No. of Wells
1.	1	Lutharan Mission, Kadam Toli, Tuku Toli, Bus Dipo Muhalla, Anandpur, Kartik Nagar	Lutharan Mission, Tuku Toli, Bus Dipo Muhalla, Anandpur	513	18
2.	2	Dunduria Basti, Bank Colony Ansh, Shiv Nagar, Tangara Toli, Gokul Dham, Santoshi Medical to Old DAV School, More	Whole Ward	424	21
3.	3	Dumartoli, Bagawana, Karanch Toli, Sisai Road, Vinay Petrol Pump to St. Patrik School ke West Boundary Wall ka North Part.	Sisai Road Vinay Petrol Pump to St. Patrik School ke West	612	17
4.	4	Ambedkar Nagar, Kuraishi Muhalla Ansh, Khadia Pada Ansh.	Whole Ward	393	19
5.	5	Khadia Pada Ansh, Bhatti Muhalla, Gaus Nagar, Bazar Tand ka East Side, Sisai Road, Prakash Hotel to Vinay Petrol Pumpka North Side, Gandhi Nagar, Loyala Nagar	Whole Ward	486	21
6.	6	Rashmi Nagar, Nadi Toli, Deep Nagar, Sisai Road, St. Ignasius School to Puggu	Whole Ward	705	13
		Nala ka Southern Part, Jaunpur, Convent School, St. Patrik School, Nadi Toli se Northern Part.			
7.	7	Ghato Bagicha Ansh, Shanti Nagar, Palkot Road, State Bank se Puggu Nala ka Uttari Bhag, Sisai Road, Bhatti Talab ke Samne, Ghato Bagicha ke Gali se St. Ignasius School Boundary ke Southern Part.	Whole Ward	583	25
8.	8	Isalampur Ansh, Mehrab Medical Sisai Road se Tower Chowk ka Southern Part, Sisai Road Pani Tanki Gali se Tower Chowk hote huye Panjabi Gali ka Uttari Bhag, Punjabi Gali se Gunu Chowk tak Purvi Bhag, Palkot Road, Shahnaz Beauty Parlour se.	Whole Ward	482	19
9.	9	Azad Basi, Islampur Ansh, Ambedkar Nagar, Ansh Bhuinya Muhalla, Kuraishi Muhalla, Ansh Ahmad Lane.	Whole Ward	643	18
10.	10	Purana Thana ka Uttari Boundary Wall se Kumhar Nala ka Purbi Bhag, Kumhar Toli, Hussain Nagar, Azad Basti ka Purvi Bhag, Millat Colony.	Whole Ward	539	27
11.	11	Bank Colony Ansh, Dad Muhalla, Khatal Muhalla, Lohardaga Road me Bank Colony More se Kumhar Nala Tak ka Purvi Bhag, Dadu Toli	Whole Ward	408	22
12.	12	Ahir Basti, Sarna Basti, Pandit Muhalla, Dadi Muhalla, Lohardagar Road me Dipak Ekka P.C.C. Road to Last tak ka Purvi Bhag, Lohardaga Road me Sagar Oraon, P.C.C. Road se Thana Chowk, Chetar Road ka Western Side.	Whole Ward	751	16

13.	13	Shanti Nagar, Kanhar Toli, Chetar Anugrah Nagar, Akhada Basti, Pant Tongari, Fun Food Hotel se Ara Mil Nala Tak ka West Side, Rotary Club Muhalla	Shanti Nagar, Fun Food Hotel se Ara Mil Nala tak ka West Side	736	19
14.	14	Punjabi Gali Muhalla, Raja Colony, Purana Thana Muhalla, Babar Gali Muhalla	Whole Ward	534	23
15.	15	Dhobi Muhalla, Ustad Muhalla, Tower Chowk se Patel Chowk Main Road ka Uttari Bhag, Bindesh Hotel se Chetar Nala ka Uttari Bhag, Bus Stand Road, REO Colony, Vikash Colony, Sarhul Nagar ka Ansh.	Whole Ward	581	27
16.	16	Karamtoli, Sarhul Nagar Basti, Police Line, Gandhi Nagar, Masna Road to West Side Bhag.	Whole Ward	305	19
17.	17	Shastri Nagar	Whole Ward	264	21
18.	18	Devnandan Gali se Pashupalan Hospital tak ka P.C.C. Road se Purvi Bhag, Hari Om Colony, Jel Hata, Block Colony, Sadar Hospital, Forest Department, Officer Colony	Whole Ward	389	25
19.	19	Murli Bagicha, Gokul Nagar, Jashpur Road me DSP Road se Kali Mandir Nala ka Purvi Bhag, DSP Road me Jashpur Road se S.S. Mandir School ke Boudary Wall	Whole Ward	258	18
20.	20	Badaik Muhalla, Bada Durga Mandir Muhalla, Main Road me S.S. High School se Patek Chowk ka Dakshin Bhag, Patel	Whole Ward	201	26
		Chowk se Ganesh Handloom tak ka Purvi Bhag & S.S. High School Road ke Paschim Bhag.			
21.	21	Pandit Muhalla, Devi Mandap, Vir Kunwar Singh Colony, Dislari Muhalla, Sukaru Bhagat Chowk se Pakki Path hote huye Water Wadge Gate se Shiv Mandir hote huye PCC Path se Palkot Road tak ka Uttari Bhag.	Whole Ward	205	19
22.	22	Sarana Toli, Jawahar Nagar, Harijan Toli, Water Ways Colony, Palkot Road me Sarna Toli se Pugu Nala tak ka Dakshin Bhag, Shamshan Road Muhalla	Whole Ward	203	15

Geoinformatics-based Assessment of Socio-economic Vulnerability and Risk Analysis due to Cyclone Hazard along the Coastal Odisha, East Coast of India

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Abstract

People of coastal regions around the world are endangered by coastal hazards. Among the various coastal hazards, tropical cyclone is one of the greatest natural hazards and the Bay of Bengal experiences more cyclogenesis than any other marine region. The east coastal states of India experienced severe cyclone hazards. The Odisha coast has seen 260 cyclonic disturbances in total over the past 100 years. The six coastal districts of Odisha have been considered to study the socio-economic vulnerability and risk analysis by identifying the cyclone-vulnerable zones. Geoinformatics has been employed for identifying and mapping the vulnerable zone. The study reveals that all six coastal districts are highly vulnerable to cyclonic activity and high risk prone to cyclonic flood and inundation. The policymaker can use the result of this current study as a tool for formulating disaster management plans and integrated coastal zone management in the area.

Keywords: Tropical cyclone, climate change, vulnerability, risk analysis, Odisha coast, Geoinformatics.

Introduction

Natural disasters along coastlines throughout history have served as stark reminders of coastal communities' fragility. The frequency, strength, and length of cyclones have all increased during the recent decades, in addition to their frequency' (Mazumdar & Paul, 2016; IPCC 2012.).The coastal region enjoys soothing climatic conditions throughout the year and different tourism activities built up along the coastal region. Therefore, these areas are densely populated and their economic importance increased day by day (McGranahan et al., 2007; Murali, 2013). India's east coast is affected by 80% of the cyclones, which were formed over the Bay of Bengal and the Arabian Sea. These coastal areas are already under stress from their extreme populations, who are reacting in diverse ways to catastrophic weather occurrences. It is necessary to investigate the effects of frequent but intense cyclones on the socioeconomic status of the population, and better research must emerge with the development of the concept of vulnerability and incorporate different magnitudes based on people's capability for coping (Cutter et al., 2012; Walsh et al., 2019). Recurring cyclones are responsible for several fatalities, lost possibilities for employment, destruction of both public and private property, and significant infrastructure damage, all of which substantially reverse the recent advances in development. An estimated 32 Cr people, or about one-third of the overall population of the nation, are in danger, according to a broad evaluation of the population at risk. During the last 100 years, 968 cyclones including depressions, cyclonic storms, and severe cyclonic storms hit this east coast. Over the past 100 years, Odisha's coast experienced 21 severe cyclonic storms, 42 cyclonic storms, and 230 depressions. As a result, this area is quite susceptible to cyclonic activity that is why it has been decided to examine the socio-economic vulnerability and risk situation in these six coastal districts of Odisha by defining the cyclone-sensitive zones and employing so many influencing elements. Since geoinformatics is seen to be the most dependable and economical way of mapping vulnerability and risk zones, it has been used to identify and map the susceptible zone. There are six social parameters which are population density, household density, 0-6 years population, SC population, ST population and illiterate population and five economic parameters which are main worker, marginal worker, cultivator, agricultural labour, and non-worker.

Study Area

One of India's east coast states, Odisha, is regarded as one of the world's most susceptible areas to powerful tropical cyclones. It lies between 17º49'N and 22º34'N latitudes

latitudes and 81º27'E and 87º29'E longitudes. The state has a population of 41.94 million people and a population density of 269 people per km^2. It has an area of 156,000 km^2. It has 30 districts, including six coastal districts with a combined 480 km of shoreline. As per OSDMA six coastal districts namely Baleshwar, Bhadrak, Kendrapada, Jagatsinghapur, Puri and Ganjam are identified as the cyclone-prone zone in the state. So, the study was carried out for the entire six cyclone-prone coastal districts (**Fig.1**) to identify the vulnerable zone by applying the SeVI index.

Materials and Methods

The present study was conducted in the coastal district of Odisha. The data representing social and economic vulnerability were obtained from the Census of India, 2011. Village-based data were obtained from the Census of India district statistical handbook. The main method used to identify the theoretical ideas of vulnerability that contributed to this study was a survey of the literature. Six social parameters such as population density, household density, 0-6 years population, SC population, ST population and illiterate population and five economic parameters such as main worker, marginal worker, cultivator, agricultural labour, and non-worker were chosen for this study. The parameters that best indicate socio-economic vulnerability were chosen based on these ideas as per experts' opinion and the available data. There are certain restrictions on data collection, coverage, and presentation, nevertheless. After the collection of secondary data, these were summarised and analysed using Microsoft Excel. The data for each indicator for all six districts were then summarised to determine the socioeconomic vulnerability of the research region. Since the indicators were measured in various units, it may be possible to use a normalisation approach to combine them into a single value that is not based on units, as indicated in the equation.

$$X_i = \frac{x_i - Minx_i}{Maxx_i - Minx_i}$$

where 'i' is the normalised indicator score of villages and its values lie between 0 and 1,represents the value of the i^{th} indicator for villages, and Max and Min stand for the maximum and minimum value of the i^{th} indicator among all the villages. After getting a normalised indicator score for all indicators through the above equation, finally, the village level socio-economic vulnerability index (SeVI) was obtained using the following equation:

SeVI = (Social vulnerability Index + Economic Vulnerability Index)/2

Result & Discussion

Disaster risk is influenced by the severity and frequency of risks, as well as by the area's exposure to and susceptibility to such risks(Peduzzi et al., 2009; Sharma et al., 2009). The IPCC report (2014) states that there are a variety of elements that contribute to hazards, exposure, and susceptibility, such as societal and climatic changes, as well as adaptation and mitigation strategies, which together create total risk or possible consequences'. This study proposes the identification of socioeconomic vulnerability indicators and the creation of a Socioeconomic vulnerability index (SeVI) for cyclone-affected areas in coastal Odisha.

Cyclone Hazard:

The coastal track of India is highly vulnerable to cyclone hazards. Several studies find that the eastern coastal belt is more vulnerable in comparison to the western coastal region .About40% of the population of India is reported to inhabit within 100 kilometres of the coastline –. For this study, 100 years of data, from the years 1921 to 2020 were examined to understand cyclone intensity and frequency. Cyclones generally formed during the pre-monsoon i.e., in the month of May-June, and post-monsoon i.e., in the month of October-November in this coastal region. During the last 100 years, 968 cyclones including depressions, cyclonic storms, and severe cyclonic storms hit the east coast of India. Over the past 100 years, Odisha's coast experienced 21 severe cyclonic storms, 42 cyclonic storms, and 230 depressions (**Fig.2**).These statistical data are enough to show the cyclone-induced vulnerable scenario of the study area and the importance of this study. The intensity of cyclones increased compared to the previous year. Therefore, based on empirical data and the cyclone track, we can state that the villages of the coastal district of Odisha are highly vulnerable to cyclone hazards.

Vulnerability:

In India, the coastal areas have higher population densities than inland areas' . The people and assets in the eastern coastal regions are becoming more vulnerable, according to the studies. The current study's analysis of the east coast's cyclone risk shows that the region is extremely vulnerable. The SeVI is identified using two vulnerability criteria, such as economic vulnerability and social vulnerability.

Social Vulnerability

In this paper, the social vulnerability is calculated based on six parameters such as population density, household density, % population of 0-6 years of age, SC population, ST population and % of illiterate population. One of the primary concerns both globally and in India is the number of people killed and injured because of cyclones and the accompanying storm surges. In areas with a high population density, the storm will have a significant impact and cause significant damage. Therefore, it is very important to work to analyse the population phenomena in the cyclone-affected area. In our study, we can observe that number of very high population density villages belong to the Baleshwar district whereas, the lowest number of very population density villages belongs to the Kendrapara district among the six coastal districts (**Fig.3**). In Bhadrak, 27.01% of villages entitled as moderately dense, 7% as highly dense and 0.90% as very highly dense. A similar picture was observed in Ganjam, Puri and Jagatsinghapurdistricts. In Ganjam24.67% of villages entitled as moderately dense, 6.63% as highly dense and 1.52% as very highly dense. In Puri, 23.63% of villages were entitled as moderately dense, 3.74% as highly dense and 0.92% as very highly dense. In Jagatsinghapur 23.18% of villages entitled as moderately dense, 3.41% as highly dense and 0.47% as very highly dense. Being coastal districts, all of them experience cyclonic activity, in this contest greater rate of population density might incur a higher incidence of loss of life due to cyclones and associated natural hazards.

The population inhabit in their respective household and so, likewise the population, the household faces significant damage during the period of cyclonic. Many people were displaced from their inhabitant and took shelter nearby cyclonic shelter which is arranged by the respective rural local body. Therefore, the household is one of the major social parameters for the analysis of social vulnerability in the coastal area. Mainly the densely populated area shows a high household density. In our study, we can observe that number of very high household density villages belong to the Baleshwar district whereas, the lowest number of very high household density villages belongs to the Kendrapara district among the six coastal districts (**Fig.4**). Being coastal districts, all of them have experienced cyclonic activity, in this context; a greater household density might incur a higher incidence of loss of life due to cyclones and associated natural hazards.

The age group belonging between 0-6 years is most vulnerable to any natural hazard. As they belong to the infant group, they are dependent on the elderly population for any kind of physical as well as financial help. Bhadrak and Kendrapara districts are more vulnerable for this age group people during cyclone time (**Fig.5**).In Bhadrak 20.74% of villages are entitled as moderately vulnerable, 7.61% as highly vulnerable and 0.61% as very highly vulnerable. In Kendrapara, 29.97% of villages were entitled as moderately vulnerable, 12.00% as highly vulnerable and 1.51% as very highly vulnerable.

In India, especially in the rural parts many people belong to a minority groupand they are economically and socially backwards. Among them, Scheduled Caste (SC) holds the first place in terms of population among all other castes. As they are economically and socially backwards, they are more vulnerable to any natural calamities. It is observed that the SC people along these coasts are vulnerable during cyclonic incidents. Jagatsinghapur district occupies the least number of SC people whereas Ganjam district occupies the highest number (**Fig.6**). In Ganjam, 13.55% of villages are entitled as moderately vulnerable, 5.34% as highly vulnerable and 2.07% as very highly vulnerable. In Bhadrak, 15.28% of villages were belongs to moderately vulnerable, 8.76% as highly vulnerable and 2.61% as very highly vulnerable.

Moreover, Scheduled Tribes (ST) is officially designated groups of people and is among the most disadvantaged socio-economic groups in India. Like SC communities, they are also economically and socially backwards and vulnerable to any natural hazards. ST population occupied village number is very less in our study area. More than 90% of villages in Bhadrak, Kendrapara and Jagatsinghapur belong to the very low vulnerable category (**Fig.7**). The villages of Baleshwar and Ganjam districts are slightly vulnerable to the cyclone. In Ganjam, 10.84% of villages are entitled as moderately vulnerable, 1.49% as highly vulnerable and 0.60% as very highly vulnerable. In Balashwar, 11.29% of villages were belongs to moderately vulnerable, 2.78% as highly vulnerable and 4.40% as very highly vulnerable.

The ability to read hazard warnings, raise awareness, and ensure involvement in pre-disaster preparedness requires education. Poor educational levels will make it difficult to comprehend and act on television and radio predictions and early warnings. In our study of coastal districts, the number of illiterate populations is low for maximum coastal villages (**Fig.8**). The highly vulnerable population in terms of illiterate is high in the

Ganjam District. In Ganjam, 17.98% of villages are entitled as moderately vulnerable, 6.66% as highly vulnerable and 1.27% as very highly vulnerable.

Combining the above six social factors, a social vulnerability map (**Fig.9**) for the study area has been derived. At first, we normalized the value of all six parameters and then compute a composite score to prepare the social vulnerability map. Through a single map, we can easily identify the cyclone's vulnerable villages concerning a social parameter. The study revealed that Kendrapara district is more vulnerable and Baleshwar district is less vulnerable in terms of social components. In Kendrapara, 20.08% of villages are entitled as moderately vulnerable, 10.54% as highly vulnerable and 5.78% as very highly vulnerable. In Baleshwar, 9.07% of villages were entitled as moderately vulnerable, 3.52% as highly vulnerable and 1.44% as very highly vulnerable. Being coastal districts, all of them experience cyclonic activity, in this contest higher vulnerability score might incur a higher incidence of loss of life due to cyclones and associated natural hazards.

Economic Vulnerability

In this paper economic vulnerability calculate based on five parameters which are main worker, marginal worker, cultivator, agricultural labour, and non-worker. Due to cyclones, huge economic loss was observed along the coastal region. The main worker is an important economic parameter. Main worker and vulnerability have a reversal relation. Increasing the number of main workers decreases the chances of vulnerability in the vulnerable zone. In **Fig.10** district wise main worker mapping was presented for the study area. In Ganjam, 16.17% of villages were entitled as moderately vulnerable, 7.58% as highly vulnerable and 1.93% as very highly vulnerable. A similar picture was observed in Bhadrak, Puri, and Baleshwar districts. In Bhadrak17.90% of villages are entitled as moderately vulnerable, 5.68% as highly vulnerable and 0.84% as very highly vulnerable. In Puri, 15.15% of villages were entitled as moderately vulnerable, 5.21% as highly vulnerable and 1.00% as very highly vulnerable. In Baleshwar13.78% of villages are entitled as moderately vulnerable, 4.43% as highly vulnerable and 1.23% as very highly vulnerable.

The marginal worker also plays a vital role in vulnerability assessment. The increase in the number of marginal workers increases the chances of vulnerability. In **Fig. 11**village-wise marginal worker mapping was presented for the study area. Except for the Ganjam district, the number of marginal workers is low for the rest of the districts. Therefore, the villages of Ganjam district are highly vulnerable to cyclone hazardsconcerning marginal workers. In Ganjam, 18.48% of villages were entitled as moderately vulnerable, 9.48% as highly vulnerable and 3.96% as very highly vulnerable. The villages of the Jagatsinghapur district are the least vulnerable to cyclonic hazardsin the case of the marginal worker parameter. In Jagarsinghapur, 68.76% as very low vulnerable and 18.02% as low vulnerable and only 0.31% of villages fall under the very highly vulnerable category.

Agriculture is the primary activity in the coastal regions. Therefore, the concentration of cultivators is very high in the study area. As the agriculture activity solely depends on nature, therefore, the cyclonic activity often devastated the agricultural sector in the coastal area. Therefore, if the number of cultivators is high, then there the chance of vulnerability is also become high. In the map (**Fig. 12**), the village-wise cultivators were represented. It shows that, in the Bhadrak district, the number of vulnerable cultivators is comparatively higher than in the other districts. In Bhadrak, 18.28% of villages were entitled as moderately vulnerable, 2.00% as highly vulnerable and 0.23% as very highly vulnerable. The villages of the Jagatsinghapur district are the least vulnerable to cyclonic hazards in case of the marginal worker parameter. In Jagarsinghapur, 52.17% as very low vulnerable and 35.12% as low vulnerable and only 0.08% of villages fall under the very highly vulnerable category.

Agricultural labour is also an important economic parameter to evaluate the cyclonic vulnerability of the study area. In the map (**Fig. 13**) district-wise agricultural labour was represented. It depicts that in the Bhadrak and Baleshwar districts, the number of vulnerable cultivators is comparatively high than in the other districts. In Bhadrak, 8.29% of villages were entitled as moderately vulnerable, 1.23% as highly vulnerable and 0.38% as very highly vulnerable. In Baleshwar, 6.93% of villages were entitled as moderately vulnerable, 1.58% as highly vulnerable and 1.13% as very highly vulnerable.

In the map (**Fig. 14**)the concentration of village-wise non-workers were represented. The number of non-workers is comparatively high in all the districts. Bhadrak district is highly vulnerable in terms of the number of non-workers. In Bhadrak, 28.19% of villages were entitled as moderately vulnerable, 11.75% as highly vulnerable and 0.84% as very highly vulnerable. Baleshwar district

experience a low level of vulnerability. In Baleshwar, 16.88% of villages were entitled as moderately vulnerable, 4.47% as highly vulnerable and 0.42% as very highly vulnerable.

Combining the above five economic factors, an economic vulnerability map (**Fig.15**) for the study area has been derived. At first, we normalized the value of all five parameters and then compute a composite score to prepare the economic vulnerability map. Through a single map, we can easily identify the vulnerable villages due to cyclonic hazards concerning the economic parameters. The study revealed that Kendrapara district is more vulnerable and Baleshwar district is less vulnerable in terms of economic components. In Kendrapara,32.24% of villages werebelongs to moderately vulnerable, 15.11% as highly vulnerable and 7.52% as very highly vulnerable. In Baleshwar, 18.04% of villages were entitled as moderately vulnerable, 3.80% as highly vulnerable and 1.37% as very highly vulnerable. Being coastal districts, all of them experience cyclonic activity, in this contest higher vulnerability score might incur a higher incidence of loss of economic resources due to cyclones and associated natural hazards.

Socio-economic Vulnerability Index (SeVI)

For the six coastal districts in Odisha, the socio-economic vulnerability index (SeVI) has been developed in this study. The relevant Information regarding social and economic condition was collected from the district census handbook of Baleshwar, Bhadrak, Ganjam, Jagatsinghapur, Kendrapara and Puri. Socio-economic vulnerability along the coast is the ability and capacity to withstand catastrophic events, like cyclones and the surges that go along with them. In the current study, SeVI as a combination of social vulnerability and economic vulnerability was examined. The result shows that 32.50% of the total study area is moderately vulnerable. 11.74% and 4.93% of the total study area fall under the highly vulnerable and very highly vulnerable categories respectively (**Fig.16**). Apart from the entire study area, the individual district's socio-economic vulnerability index was also calculated. From individual district studies, Puri falls under the highly vulnerable zone and the Baleshwar district is less vulnerable to cyclone hazards. The veryhighly vulnerable area is suffering from imbalanced social and economic conditions. Therefore, the region falling under the high and very highly vulnerable categories need attention in terms of development.

Conclusion

Around the world's densely populated coasts, cyclones are one of the most dangerous natural disasters. About 40% people of the planet currently reside within 100 kilometres or less from the shore.To assist in the creation of successful cyclone mitigation strategies and the execution of measures, regular risk assessment is crucial.According to the present study, cyclones negatively impact people's social lives and the environment. By combining the socialand economic parameters, a composite socio-economic vulnerability index of the six coastaldistricts with the cyclone data is prepared with the help of statistics and the GIS platform. Therefore, we will advocate employing geoinformatics in such kind of analysis for significant outcomes in the coastal research.The result shows that 3012 villages fall under the moderate vulnerable zone, 1044 villages come under the highly vulnerable zone and 436 villages appear under the very highly vulnerable zone. The results of this study will help to formulate strong adaptation and mitigation plans, which include a wide range of resilient strategies, like establishment of new educational institutions, building coastal embankments, cyclone shelters, construct road networks, improve electrification, construction of the pucca house and improving the cyclone warning system.The created vulnerability and risk maps will provide decision-makers with baseline data to generate superioraction plans, with the end goal of providing direction to policymakers and governmental and non-governmental authorities to establish long-term action plans, disaster preparedness, and mitigation methods

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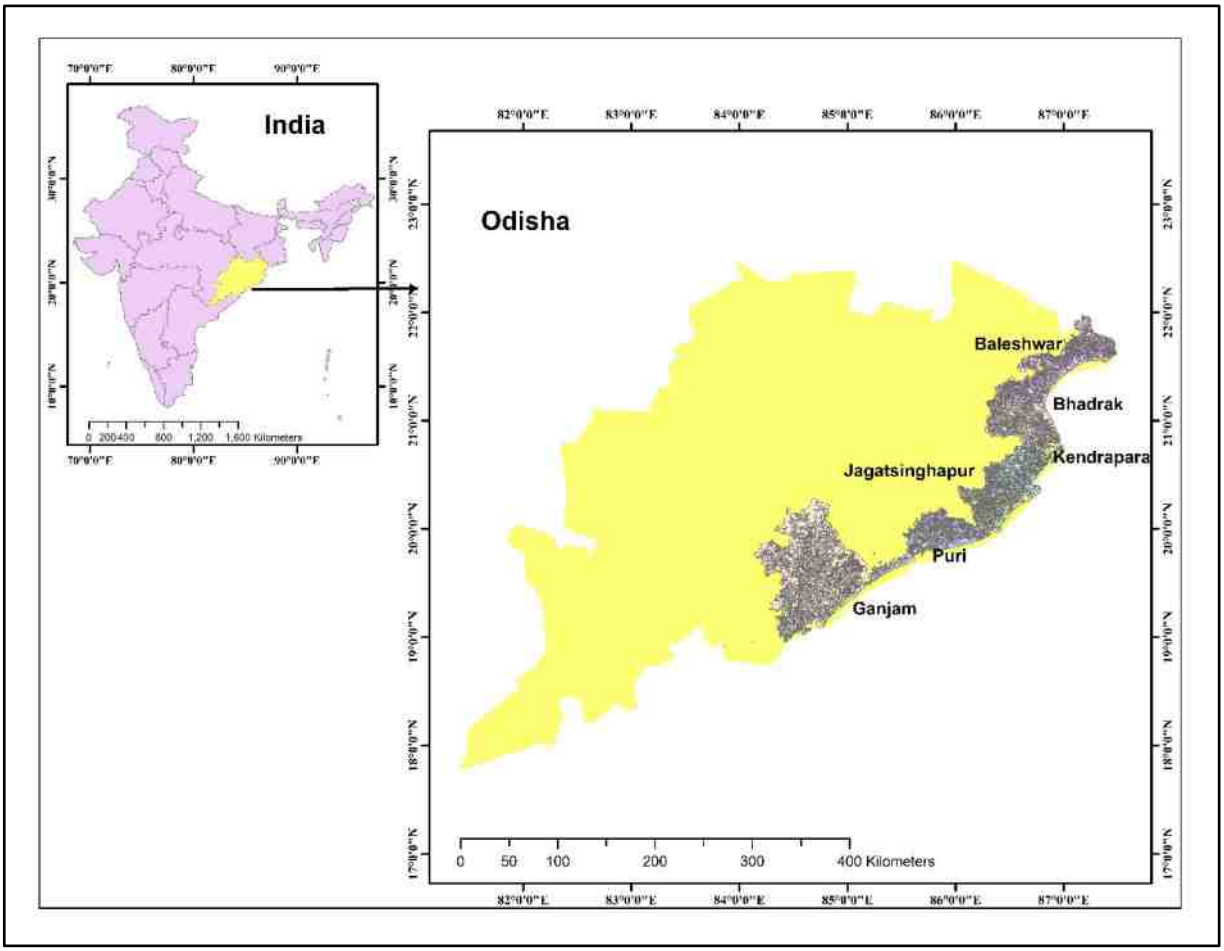
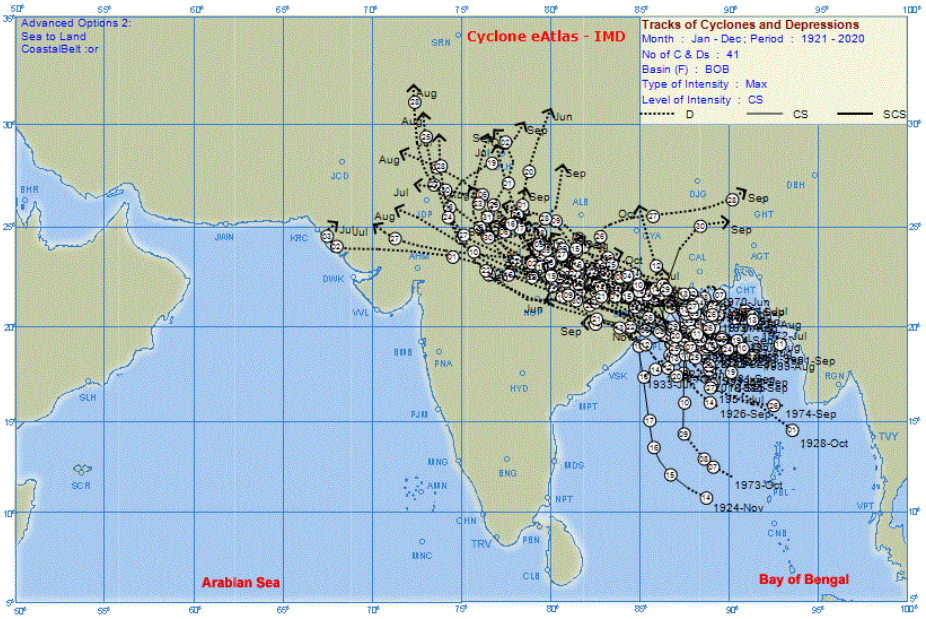
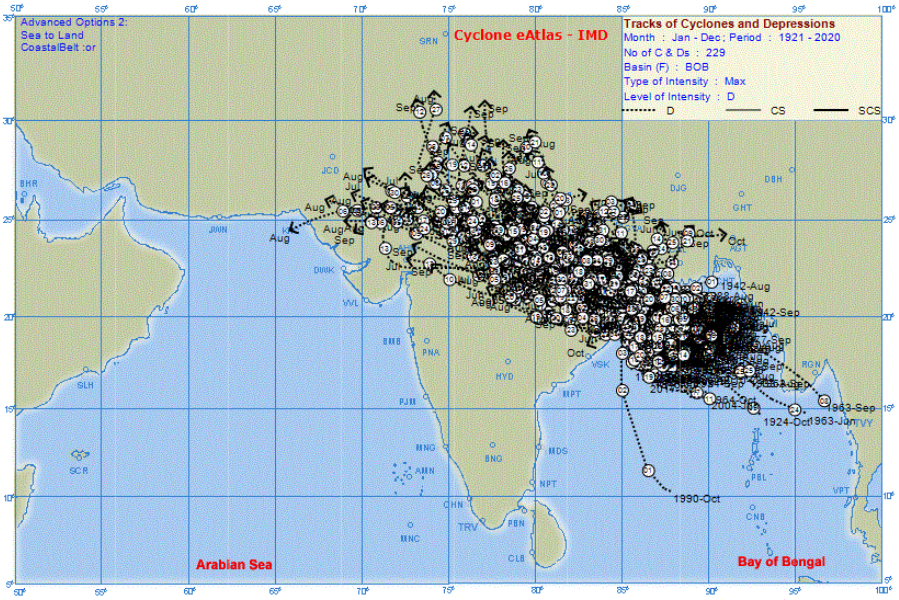


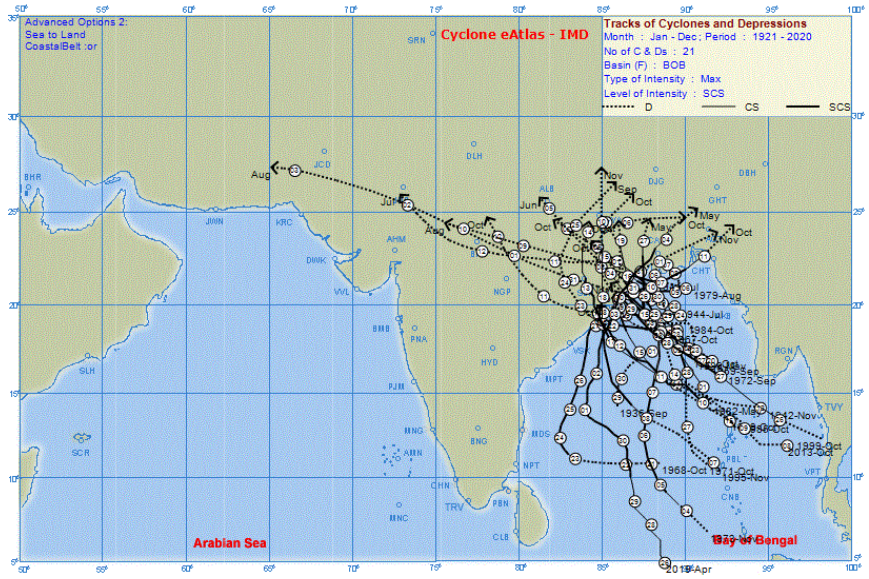
Fig.1 Location of the study area



Cyclonic storm map from 1921-2020



Depression map from 1921-2020



Severe Cyclonic Storm map from 1921-2020

Fig. 2 Cyclonic map of Odisha

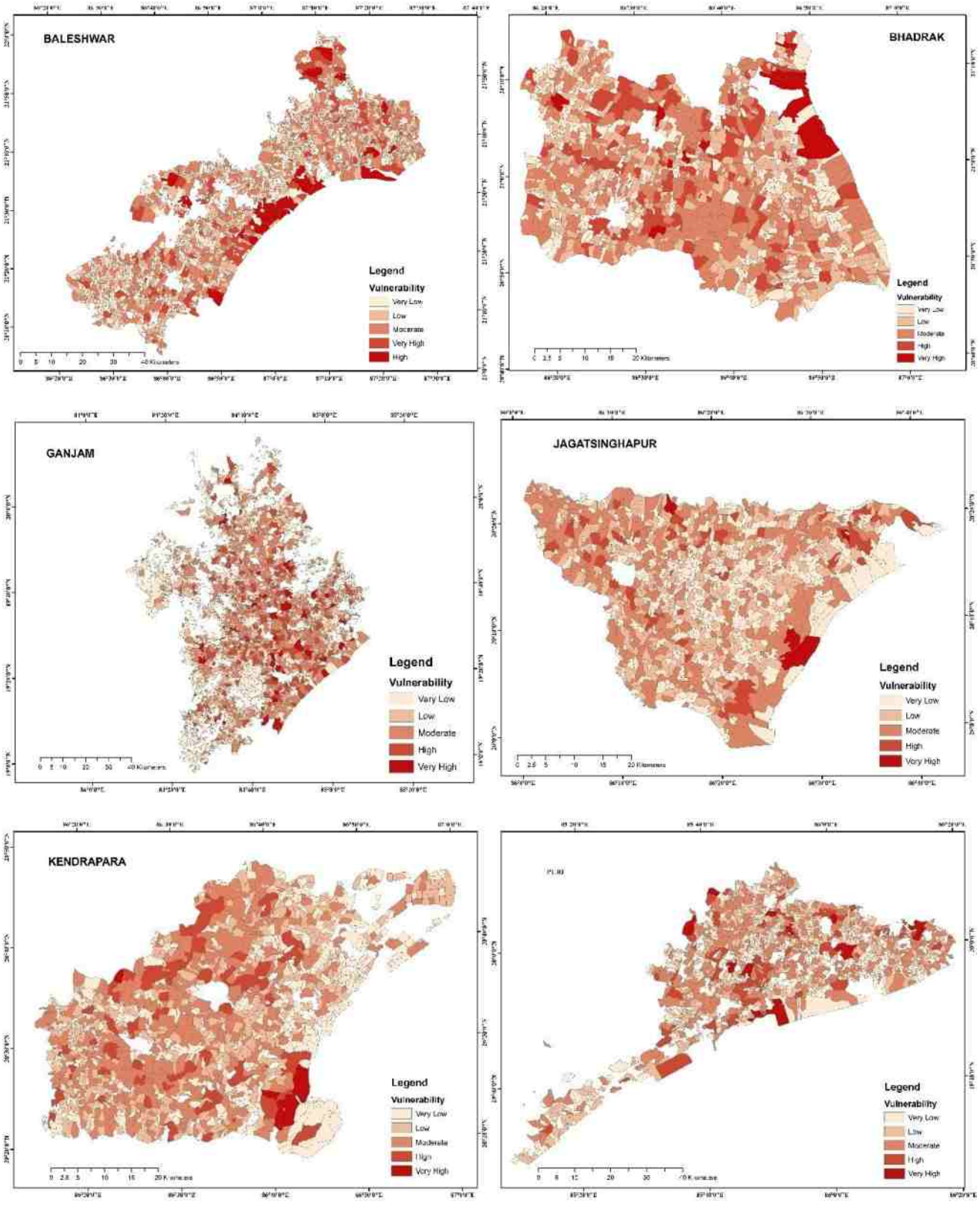


Fig.3 District wise Population Density Vulnerability Map

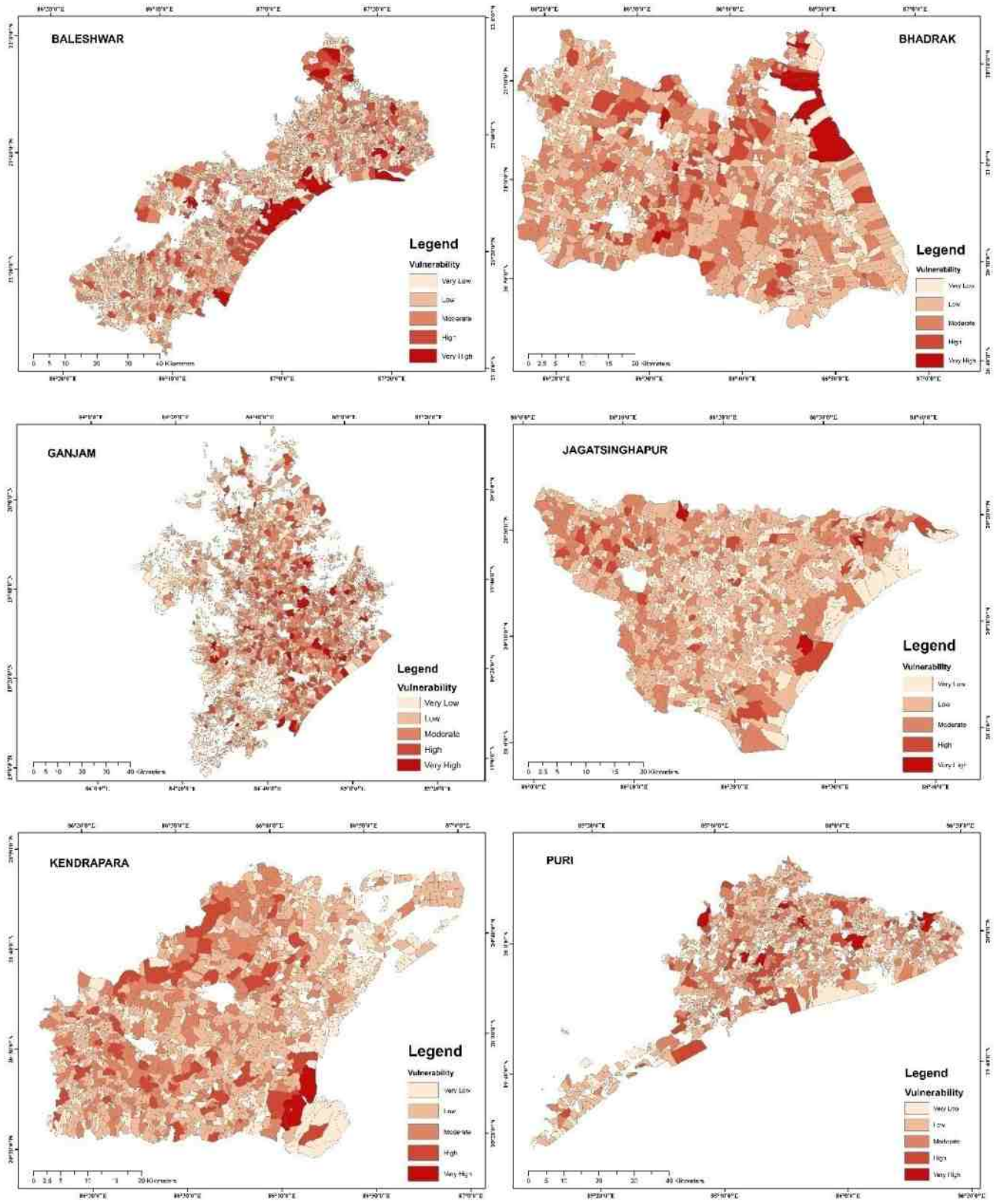


Fig.4 District wise household density vulnerability map

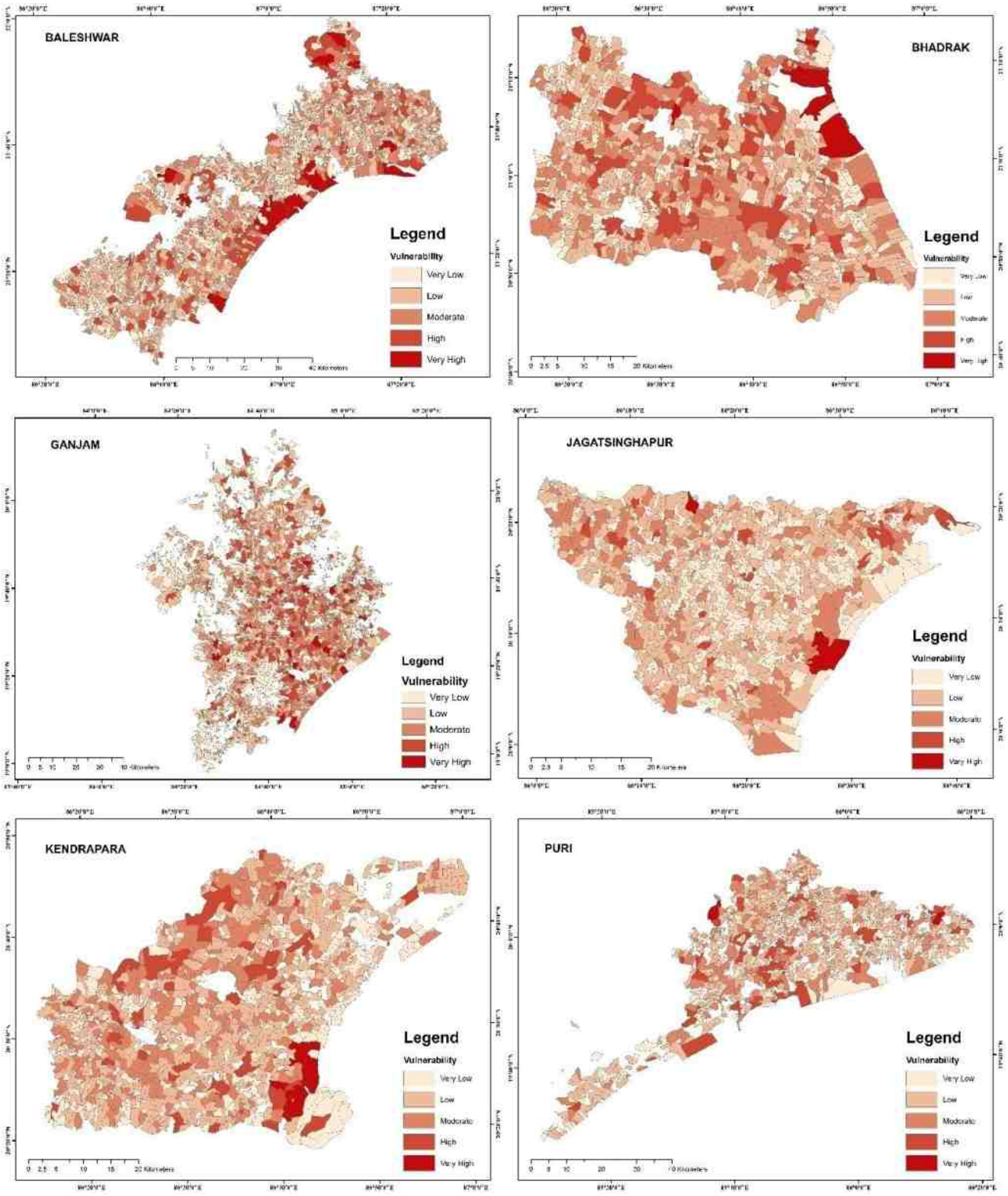


Fig.5 District wise Below 6 year population vulnerability map

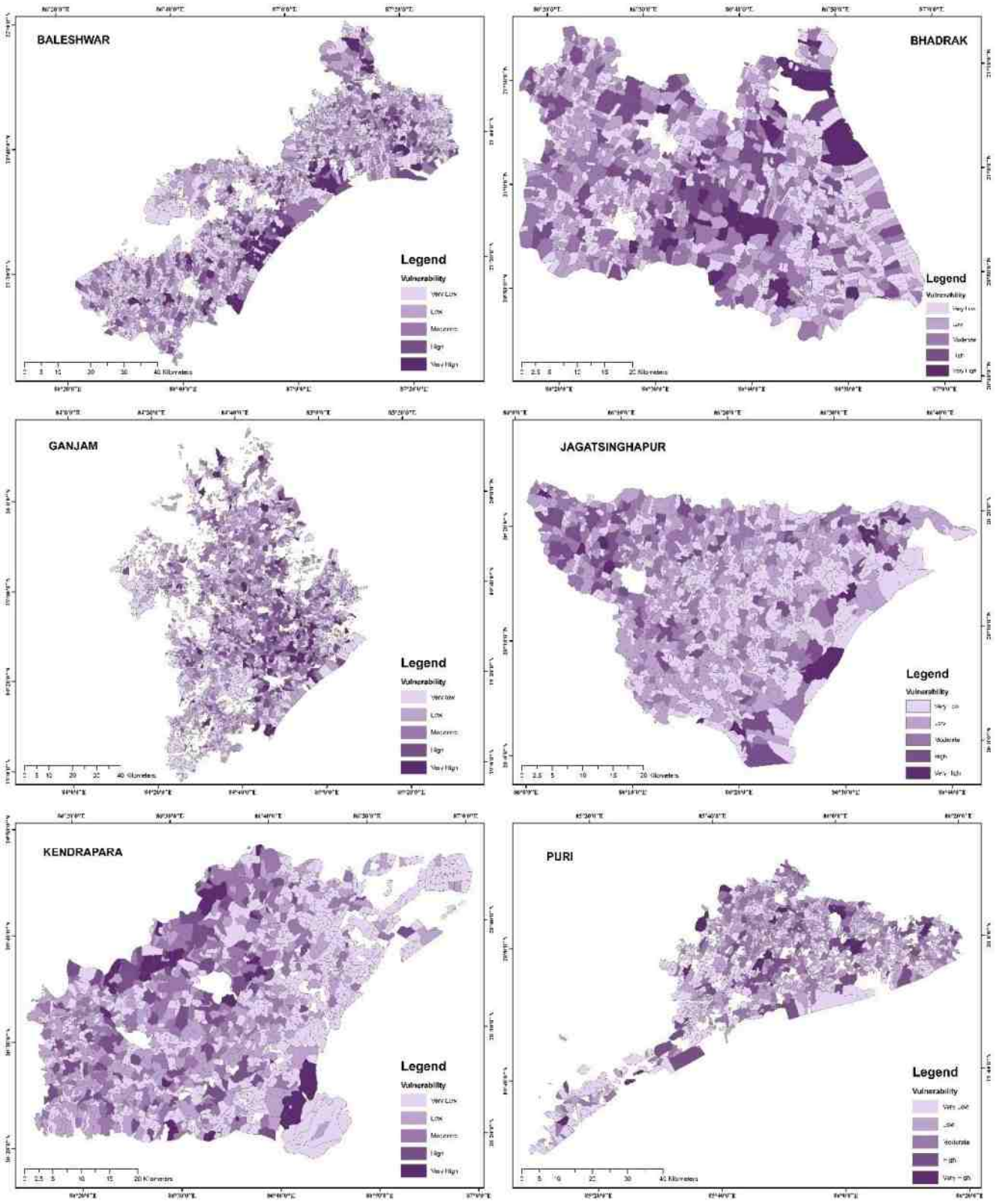


Fig.6 District wise SC population vulnerability map

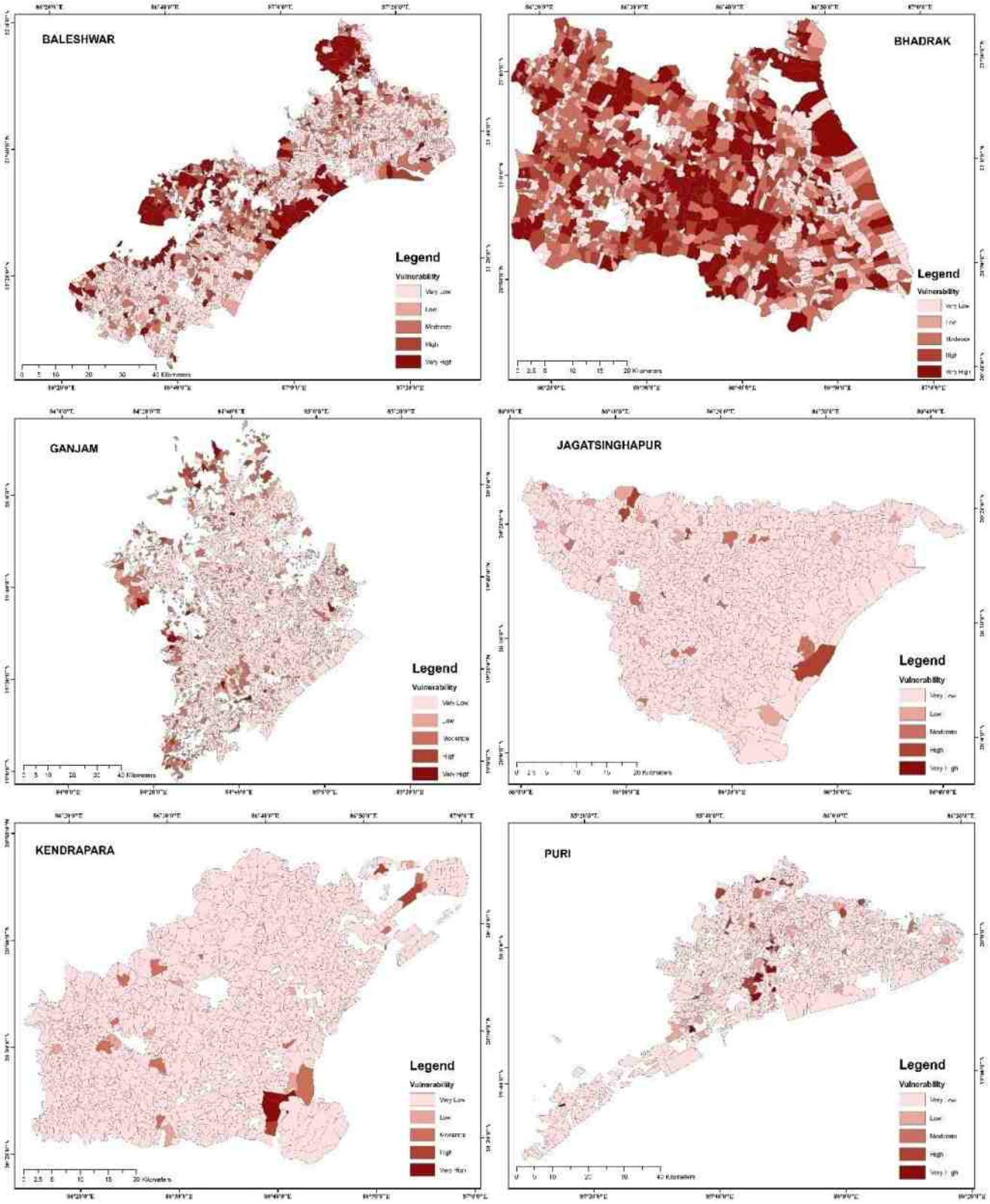


Fig.7 District wise ST population vulnerability map

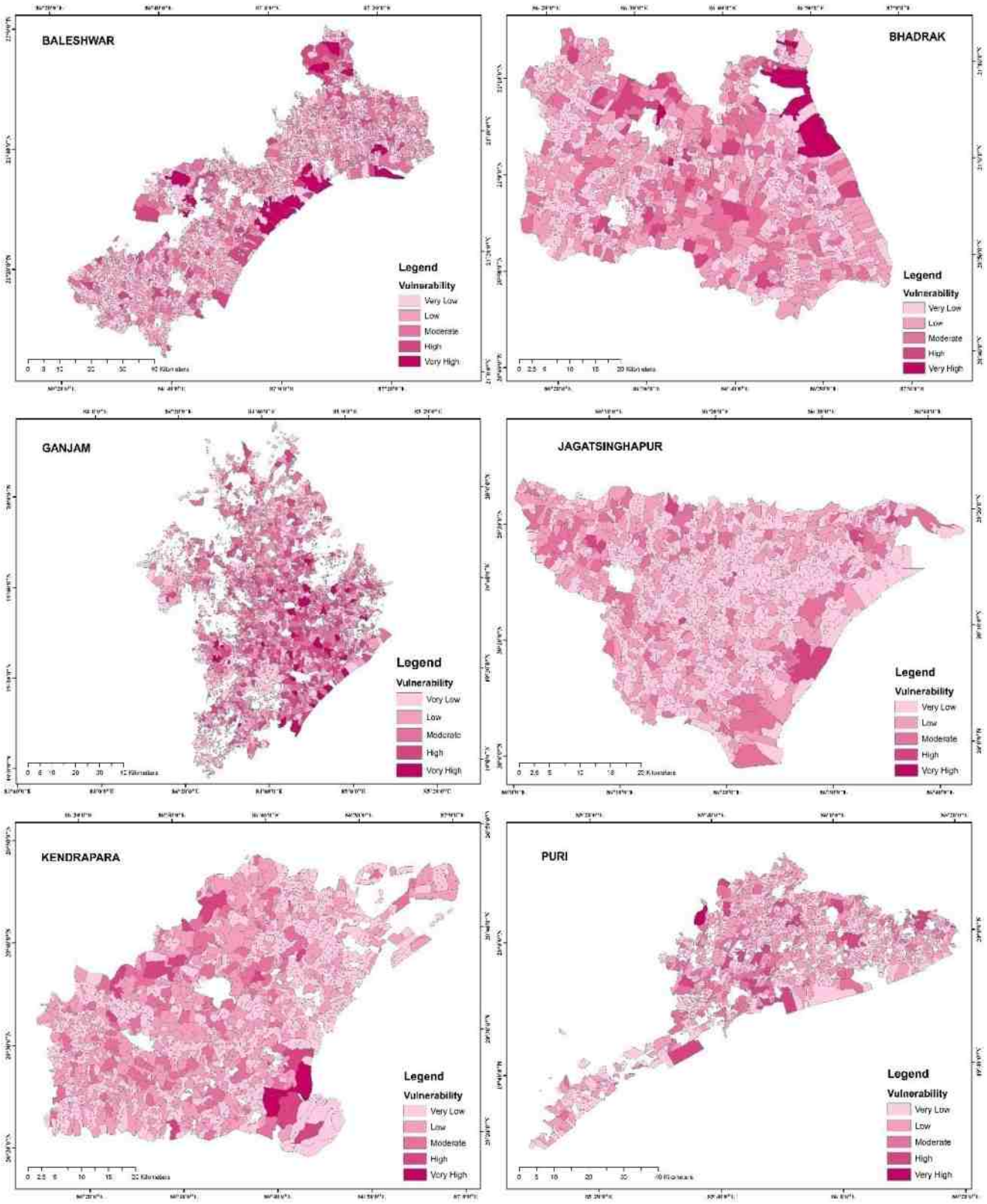


Fig. 8 District wise Illiterate population vulnerability map

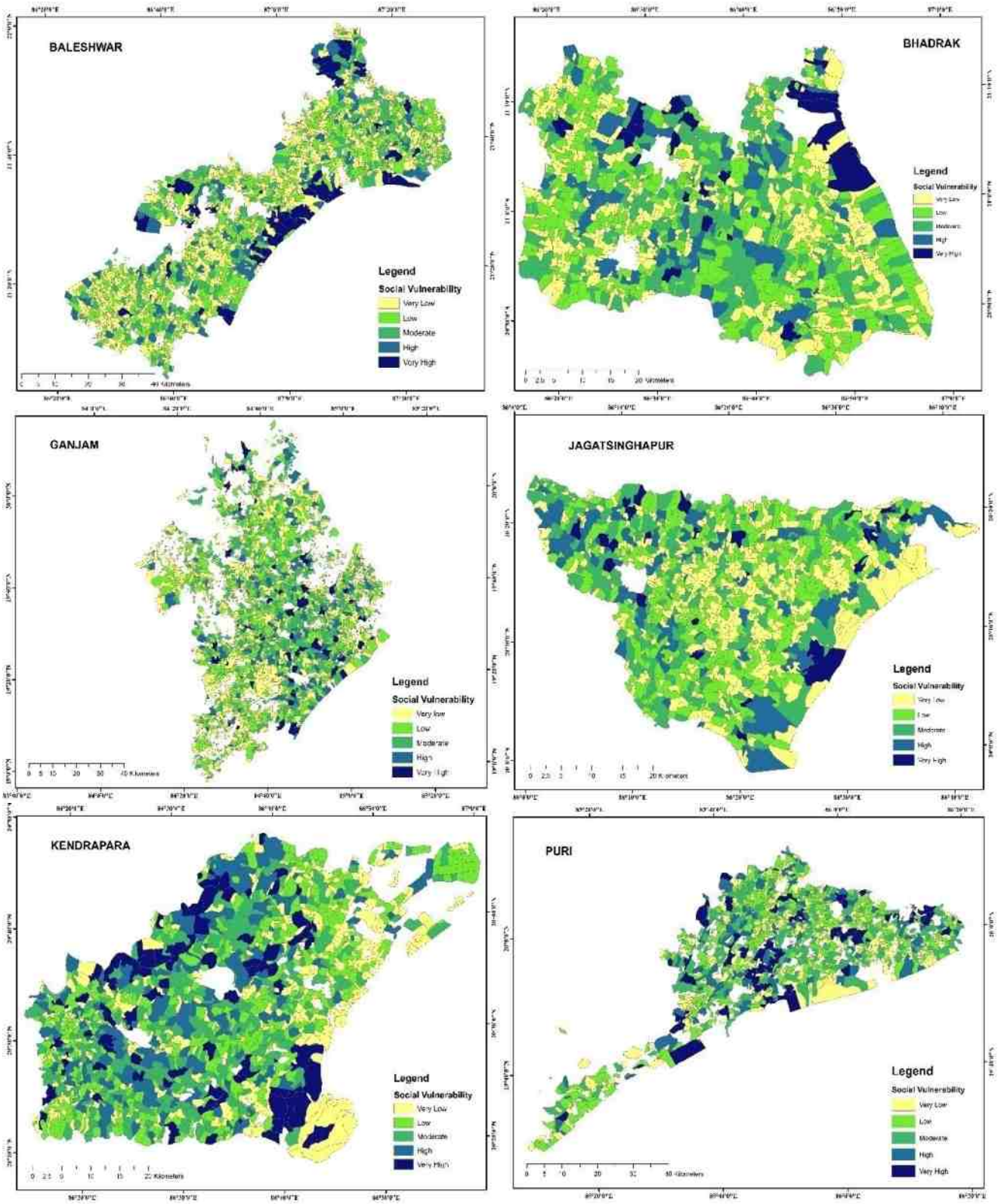


Fig. 9 District wise Social Vulnerability map

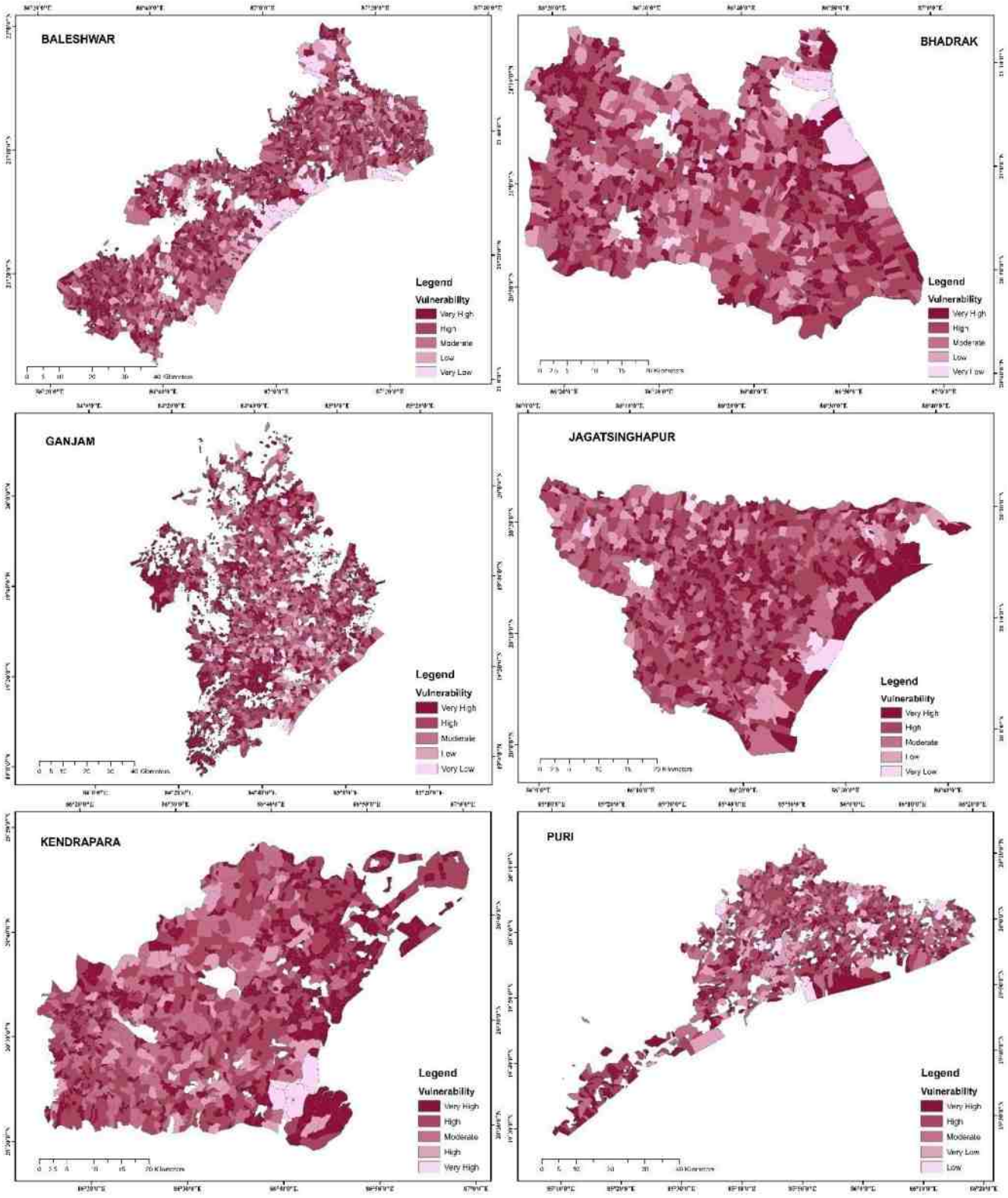


Fig. 10 District wise Main workers map

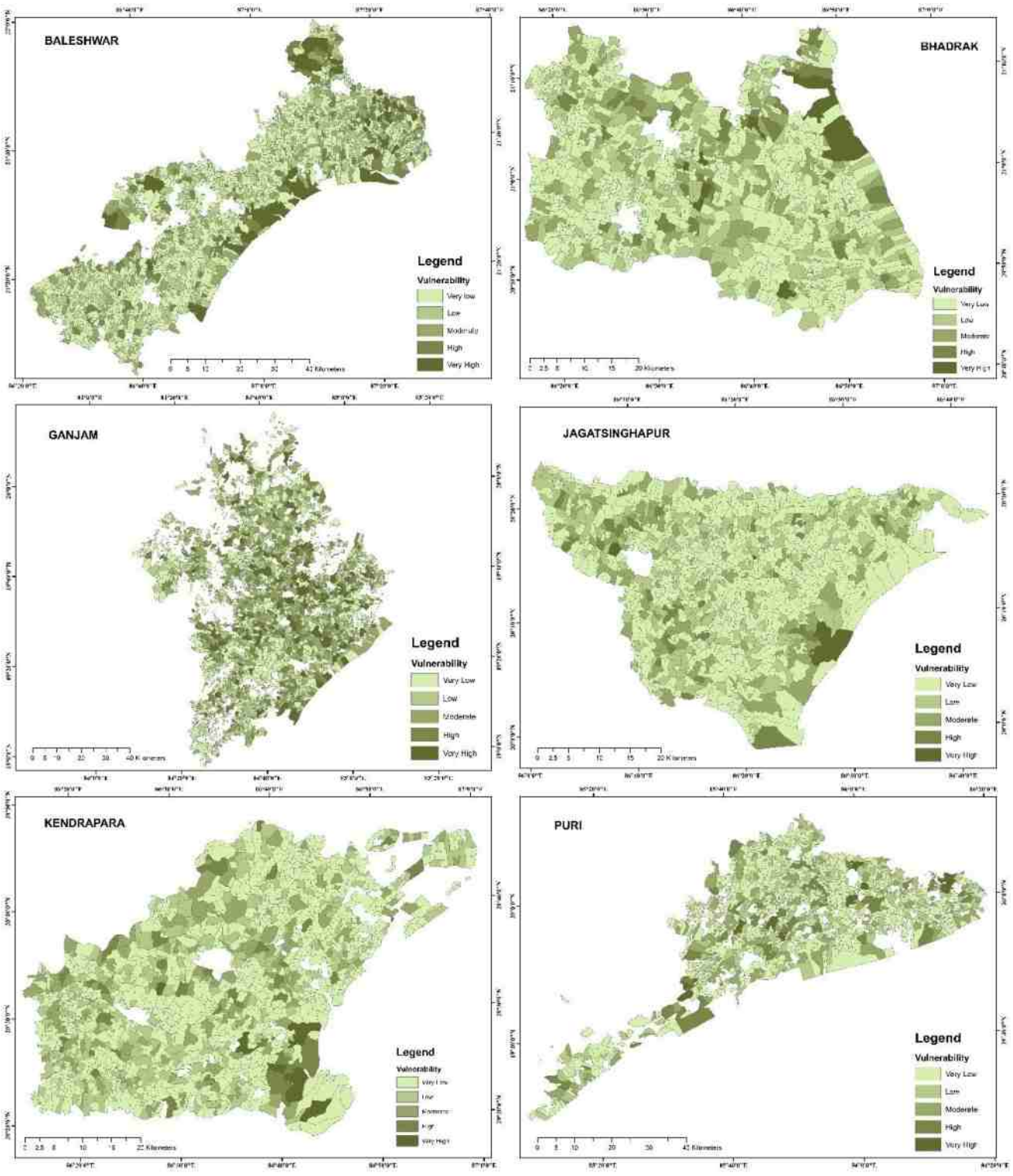


Fig. 11 District wise Marginal worker map

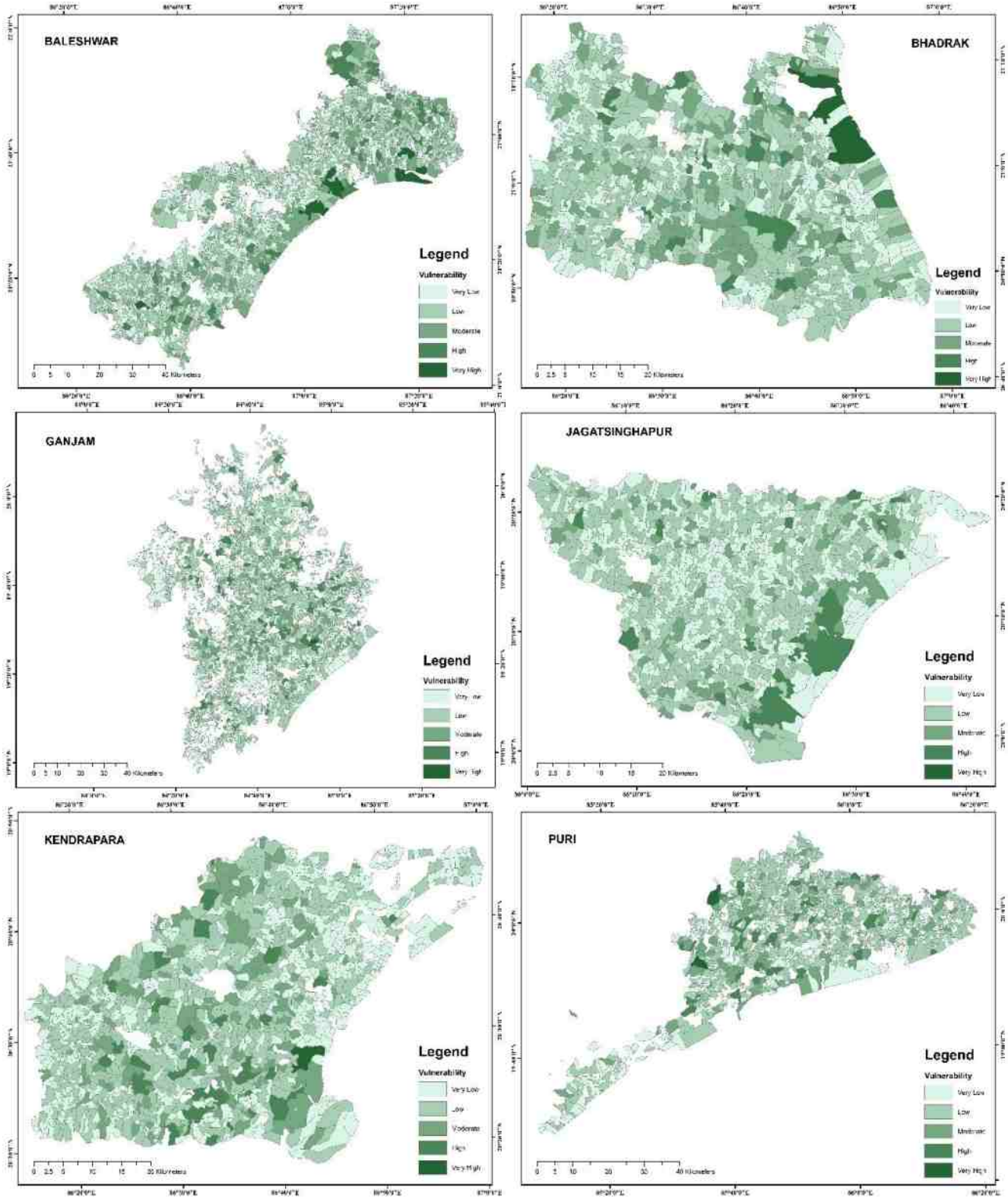


Fig. 12 District wise Cultivator map

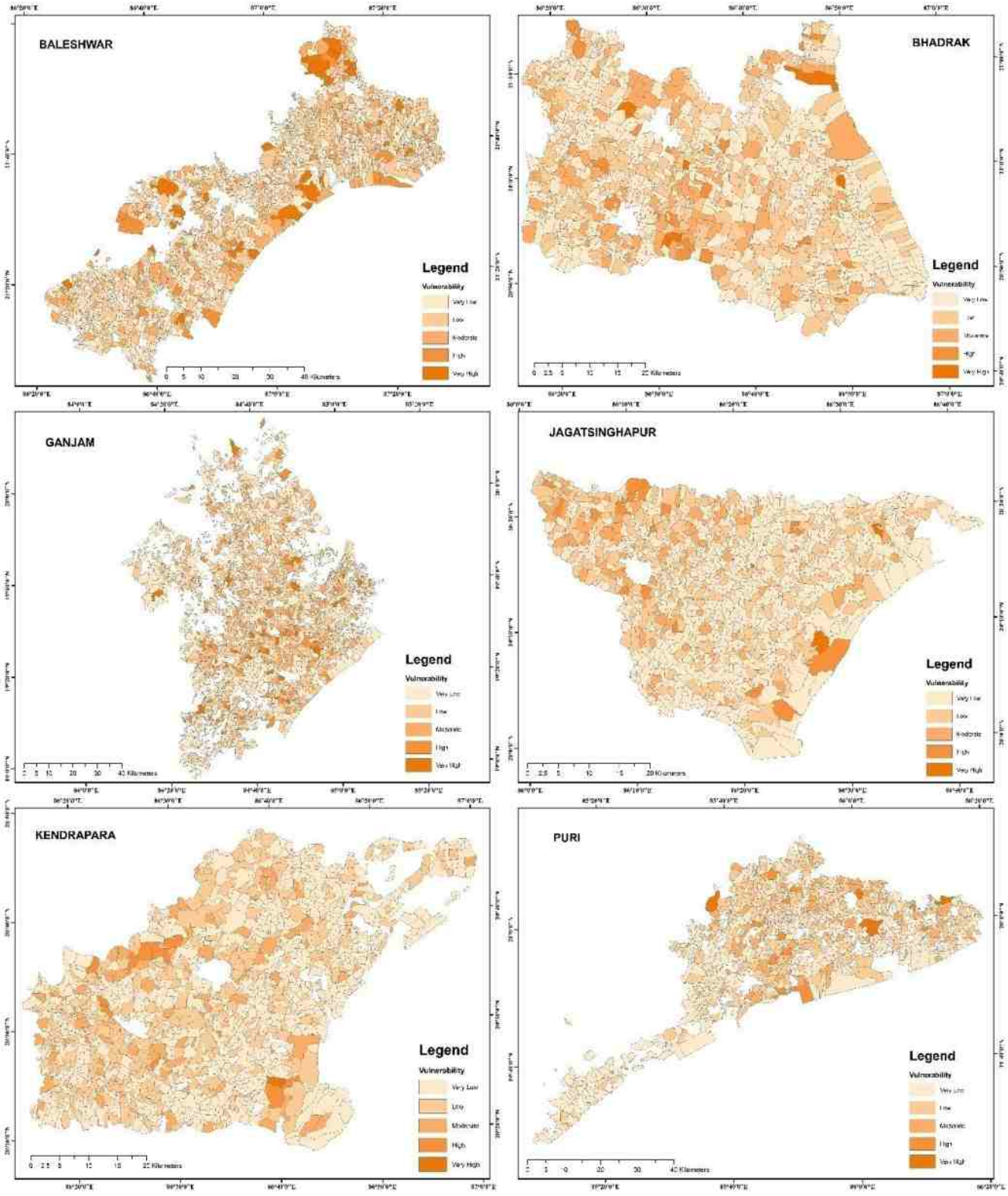


Fig. 13 District wise Agriculture labour map

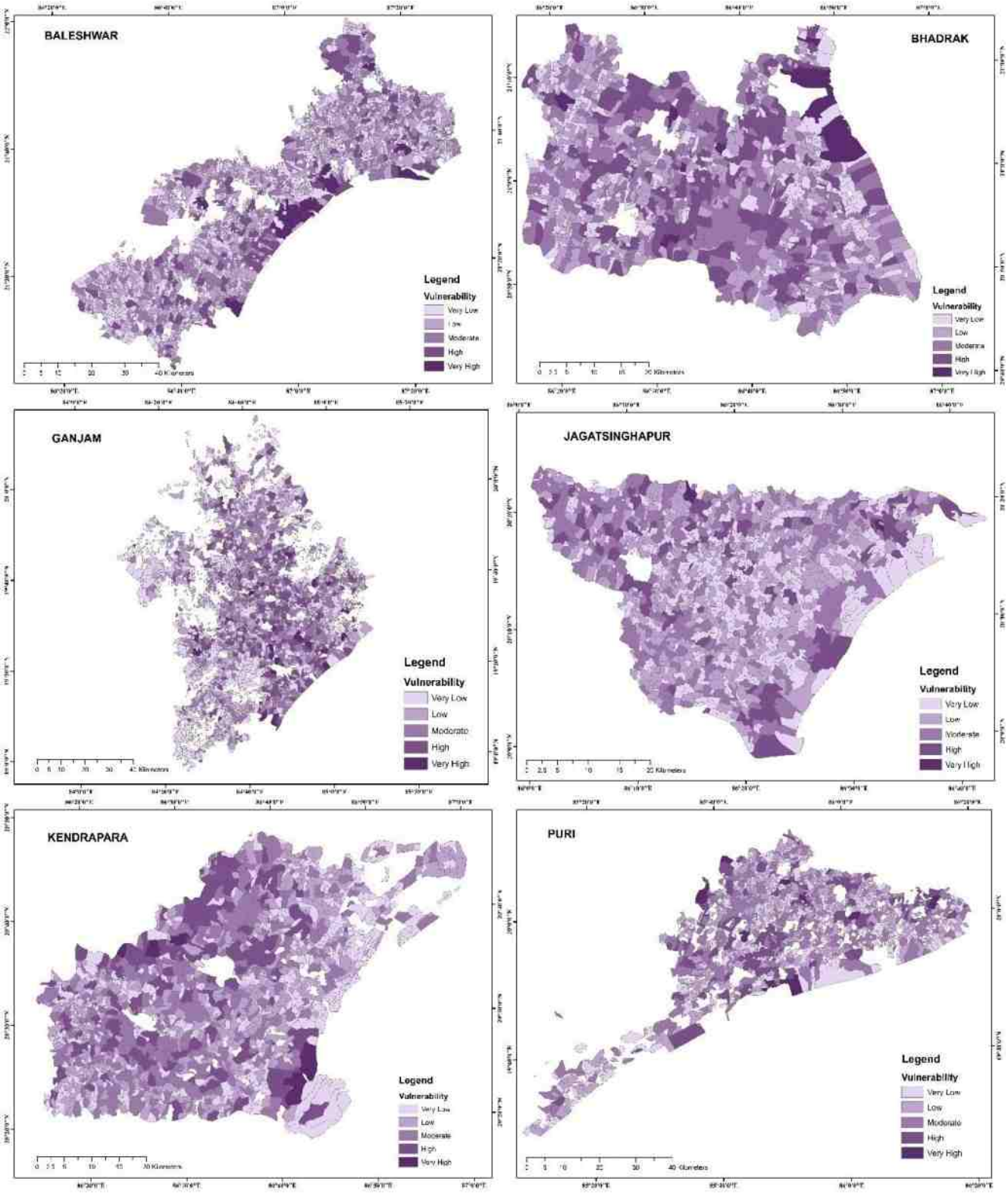


Fig. 14 District wise Non-workers map

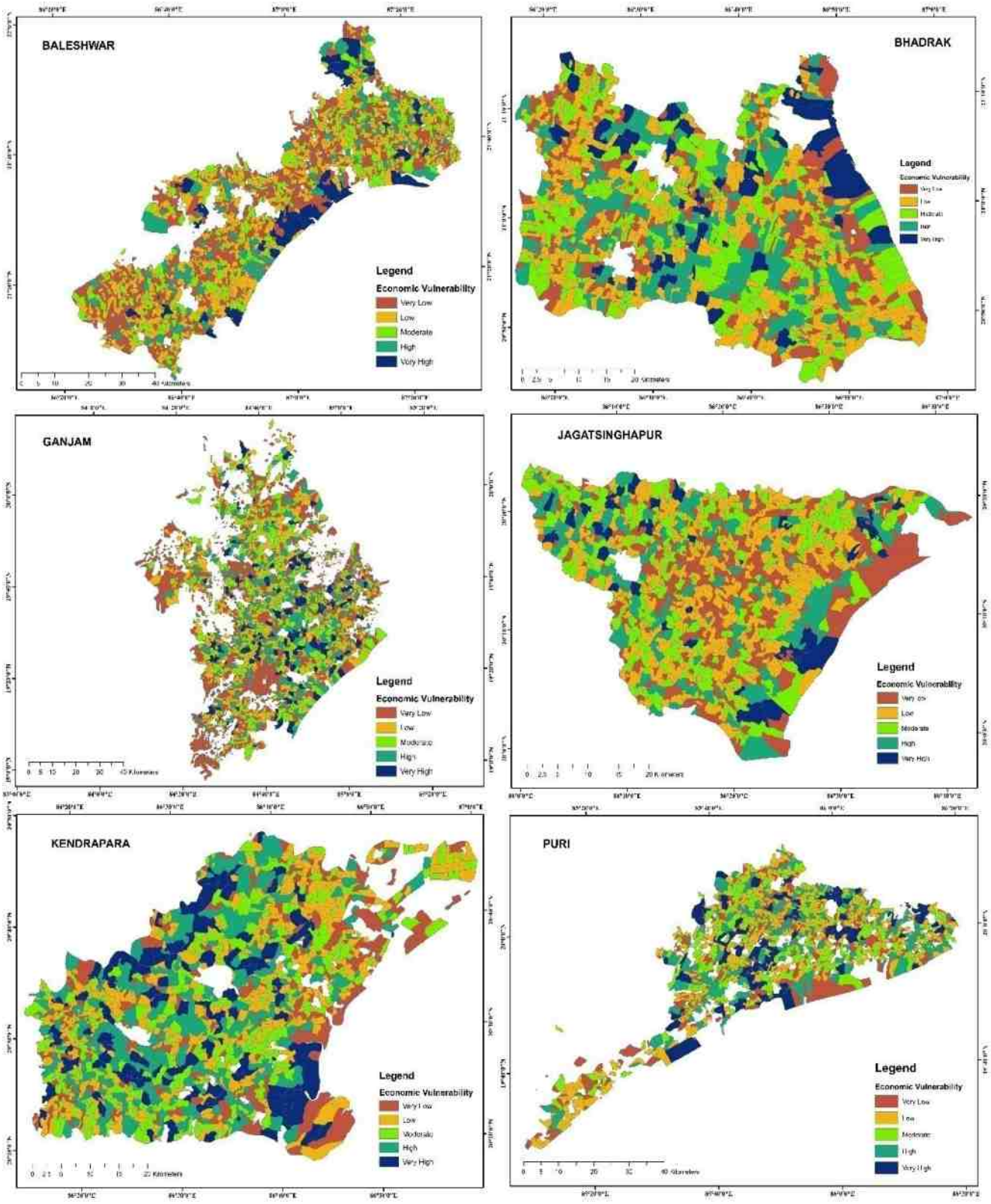


Fig. 15 District wise Economic Vulnerability map

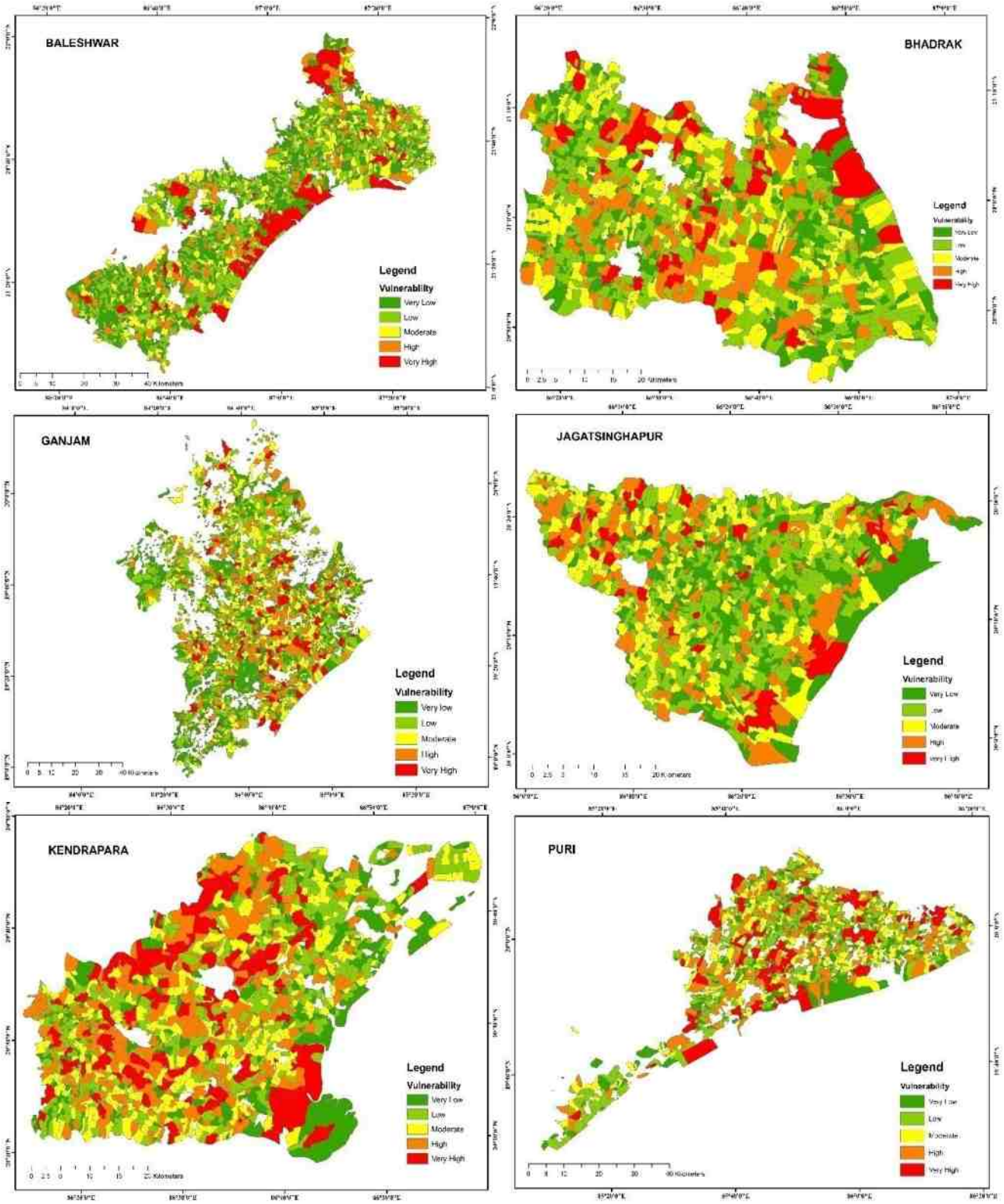


Fig. 16 District wise socio-economic vulnerability map

Feasibility study & water budgeting for water conservation and augmentation of ground water of Vikrampur Village of Panna, M. P.

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Abstract

Groundwater is the most critical resource for which a balanced development, optimum utilization and proper management is required to meet the growing need. The management of groundwater resources ensures its continuous and adequate supply to various users, without disturbing the balance of static and dynamic groundwater resources by over exploitation. Groundwater; hence its development requires scientific study and judicious planning. In this regard, with the objective to assess the groundwater potential of Vikrampur village of Gunnor Block of Panna district area to get the scientific and feasible solution for Natural Resource Management Study, including multidisciplinary approach to water conservation and other related groundwater augmentation activities to artificial recharge in scarcity suffering village.

Keywords: Groundwater, Vikrampur, exploration, scientific, augmentation activity, Natural Resource Management.

Objectives of the Study

The main objective of the study is to assess the groundwater potential in and around the project area through hydrogeological investigations to meet the water requirements of village from groundwater as well as from surface water. The other objectives include perceiving the feasibility of rainwater harvesting to recharge the groundwater and water budgeting in the area.

- The overall objective of the study to augment the water levels in the area by artificial recharge from excess runoff rainwater harvesting method
- Conduct well inventory of the selected villages to understand the ground water status and water level scenario to determine the characteristics of the aquifer and their recharge capability.
- Ground-truth of feasible locations for the construction of recharge structure in each village.
- Prioritization of village for artificial recharge based on need of water and feasibility matrix of the village and response of existing ground water structures, especially Hand Pumps and bore wells.

Methods and Materials

Planning and development of small development unit calls for rigorous understanding about the occurrence and movement of water in the surface and sub-surface systems along with soil and nutrient losses. The methodology application in the area is to collect baseline data and selection of area based on the priority. The further stepwise procedure where many tasks including database collection and action plan preparation, designing, drawing and cost estimation and site selection etc. area given below. The following activities are initial data collection and selection of structures and digitization of drainage lines, watershed boundaries and other basic information from topographical and satellite maps.

Feasibility Matrix

- The feasibility of the site shall be prepared for the purpose driven study.
- The Feasibility matrix and priority of recharge locations for village shall be given in tabular form.
- The Feasibility map of village.

In present study detailed project study has been carried out and analyzed. And based on the outcome of the study a plan was framed to the check the feasibility of the study for implementation.

With the help of secondary and primary database a feasibility matrix of the proposed recharge structures is prepared to choose most feasible site and methodology for recharge.

To prepare the feasibility matrix following data from study and primary data collection was used to understand the design of aquifer recharge system following considerations are studied:

The main components of methodology of the study

Data Acquisition:

The base maps and information such as following have been acquired:

- Toposheets
- Khasra (Cadastral) map of village

Remote Sensed data from ISRO/NRSA for the area of interest. (High Resolution multi-spectral data

Field Data Collection:

- Groundwater and surface water structures (Old + New structures)
- Lithology, landforms, slope, drainage network, river, flood line, village proximity etc.
- The field study is to be conducted in an unconfined and confined aquifer. The important hydro geologic characteristics of the study site can be determined by common practice of recharge tests and the slug test method is one of a number of different methods that are used to evaluate the permeability (or hydraulic conductivity) of a particular type of aquifer test via a well or boring into a subsurface interval of sediment, soil, or fractured rock.

Step wise approach

- Preparation of baseline digital database at cadastral level along with topographical information, aquifer, water level, groundwater flow, lithology, drainage, Landuse, contour, slope, water bodies, implications, analysis and deriving desired themes for action plan preparation road, rail, settlements etc.
- The remote sensing products shall be used to generate landuse, drainage lines and flood area corrections, water bodies, landforms, correction of lithological boundaries, etc.
- The base-maps shall be now added with layer of field information about the status of indicators to be used for evaluation and also the then (pre-programme) existing resources/structures. This type of map shall present a pre-project scenario. The necessary details shall have to be obtained from the Implementing PIA which should be of the Pre-Implementation time period.
- Preparation of feasibility matrix to propose suitable structure for groundwater augmentation.
- Detailed study based on the above methodology based on the primary and secondary data, maps, reports and primary filed investigations and interpretations.

Action Plan

- As the action plan map of the village suggests several recommendations that can be used for the treatment. Most of this requires manual intervention for processing, delineation etc.
- The recommended treatments are purely on scientific and technical basis, and these might not be acceptable to the villagers as it is. Hence to get their concurrence and to take up or not to take up any activity in light of their actual requirements, the inputs from villagers or their representatives play a very major role.

Identification of the Recharge Locations

The identification of the recharge points has been carried out by recharge interventions process based on the various indicators available for the identification of the artificial recharge sites. The possible recharge zones favorable for taking up artificial recharge measures the geomorphology, hydrogeology, groundwater fluctuation, soil type and soil depth were initially used to identify the artificial recharge zones. The recharge points for location of recharge structures have been identified based on the extensive field surveys and interaction with villagers. The feasible recharge interventions have been suggested as given in the attached **map** and **table**.

Water Budget

Water Availability

The source water in watershed area is rainfall. The project area on an average received about 1006.6 mm of rainfall annually. The monsoon, contributes about 90 percent of the total annual rainfall in the area, which is about 900 mm. Water Availability gives an account of status of water resources

The water availability is subdivided into sections

- Total water available from rainfall
- Groundwater availability
- Surface water available in storage

Total water available, rainfall and evapotranspiration are two important parameters used in the estimation of the water resources of the village. Evapotranspiration data is used in computing actual annual evapotranspiration

(AAET) and used for estimating evapotranspiration losses. The total water availability is computed using the parameters shown above. The total water available at village is calculated by adding total GW available (source-GEC, 2020) after GW recharges minus total discharges and total surface water storages minus losses.

The data/information on number and total storage capacity of surface structures is calculated for the village. Total storage capacity of water harvesting structure minus the losses (if any) becomes the quantum of surface water available for productive use. The total water available for utilization is the sum of groundwater available and total surface water available. However, not all the surface water will be available unless harnessed through water harvesting structures and made available from future use.Thesurfacewateravailablebyrainfallforfutureuseisalso computed in using following formula:

Utilizable rainfall runoff (Ha.m) = Rainfall available for future use ***X*** *weighted average runoff coefficient (0.30)*

Water Utilization/Draft

The total water balance is estimated simply by deducting the total water available. The utilization is further divided into four sub-modules

- Drinking/Domestic water utilization
- Irrigation water utilization
- Industrial water utilization
- Other uses (like recreational activities, etc.)

Water Balance:

The balance includes

- groundwater availability;
- groundwater utilization/draft;
- groundwater balance
- water budget

Water Budget:

A water budget is an account of the available water resources and their various uses. The purpose of the water budget is to assess surface and groundwater resources and identify current and future needs as a basis for planning. It will be updated on a regular basis if required. This calculates the future water allocation of ground and surface water for domestic/drinking and irrigation sector.

Domestic Water Budget

The decadal growth of population is computed based on the population data from Census of India 2011. As per the Jal Jivan Mission Norms of 55 liters per capita per day (lpcd) in rural areas aroused in computation of domestic water demand. Computation of projected (next 30 years) domestic water demand for projected populationasin2050 is done. However, as there is no urban habitation, in the study area, the computation was limited to projection of rural domestic drinking water only.

Irrigation Water Budget

The irrigation water budget is computed simply subtracting the total water balance available at village level with total water demand/budget calculated for drinking & domestic use in above section.

Crop water requirement is used to calculate the agricultural water demand for the irrigation water demand from agriculture department. The Indian Council of Agriculture Research (ICAR) Institution worked out on the Crop Water Requirements.

Runoff:

The principal function of run-off in erosion is transportation of detached soil material. The runoff water has two consequences. First, the more runoff the greater is the 'flash' flood in the river draining after the storm and, secondly, the greater the amount of silt deposited by the river after the floods. Hence, overland flow of water poses serious problems of flood hazard on the one hand and sedimentation on the other. Controlling the concentration of overland flow and minimizing its velocity can reduce the damage caused by overland flow. Controlling the length of the slope may regulate the concentration of velocity of overland flow. Hence, the fundamental principle of combating water erosion is to reduce the amount of run-off as much as possible.

The soils are well drained and have rapid permeability. They are mostly under cultivation to Kharif crops. These soils are prone to severe sheet erosion hazards and need adequate soil conservation measures for sustained agricultural use.

Proper soil conservation measures for arresting sheet erosion are warranted for their sustained use for optimum production. The soils are associated with problems of shallow depth, low available moisture and severe erosion hazards. They are suitable for forest and grassland development under adequate soil conservation measures.

Feasibility Study

The feasibility of the present village in Gunnor is prepared

channels are the geomorphic features that convey the flow of water. These are part of the earth's natural drainage system that has developed over the ages. After precipitation events, the part of stormwater1 that does not immediately infiltrate into the soil becomes runoff. This runoff flows over the land surface and moves to the nearest channel as sheet flow. Channel conveys this runoff to the lakes, ponds, or rivers and ultimately to the seas and oceans in the form of streams. Lineaments are defined as the significant lines of landscape, which reveals the hidden architecture of the rock basement. These are linear geomorphic features that are the surface expression of zones of weakness or structural displacement in the crust of the earth. Such features may represent deep seated faults, master fractures and joints sets, drainage lines and boundary lines of different rock formations. Lineaments provide the pathways for groundwater movement and are hydrogeologically very important. The land capability classification is one of a number of interpretive groupings made primarily for agricultural purposes. As with all interpretive groupings the capability classification begins with the individual soil-mapping units. In this classification the arable soils are grouped according to their potentialities and limitations for sustained production of the common cultivated crops that do not require specialized site conditioning or site treatment. The individual mapping units on soil maps show the location and extent of the different kinds of soil.

Suitability maps for aquifer recharge sites hold a strong potential for integration into sustainable groundwater management plans. An uprising method to identify sites suitable for aquifer recharge and soil conservation implementation is geographic information system based multi-criteria decision analysis. There is no common understanding on how suitability mapping should be conducted, and there is considerable variability as to what factors are assessed and how they are weighted. To increase the practice, a database has been built based on 16 thematic parameters in the context of aquifer recharge and soil conservation site selection. Information on the criteria, assigned weights, and methodologies has been retrieved from the thematic analysis of the database depicts the current state of art for suitability mapping methodologies as well as specific information for the different recharge methods.

Suitability mapping does not eliminate areas that are unsuitable for recharge and soil conservation implementation but rather ranks the study area regarding its suitability for the application recharge and soil conservation.

The final suitability map should be verified by a sensitivity analysis. As the criterion values and weights are the main sources of uncertainty in the process, conducting a sensitivity analysis allows for more robust decision-making.

Interventions

- **Supply Increasing Interventions**

  Check Dams

  Gully Plugs

  Farm Pond

  Gabion Structures

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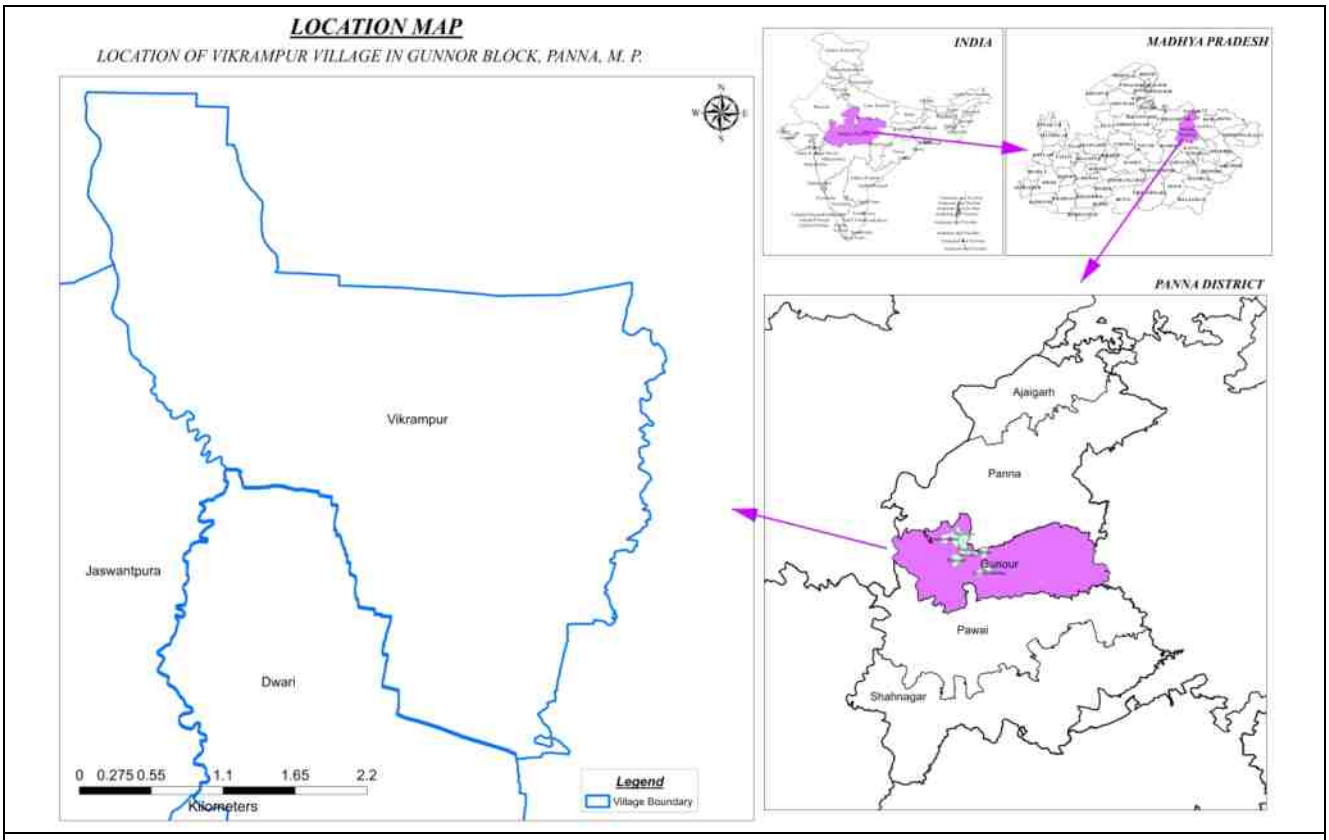

Fig. 1: Location Map

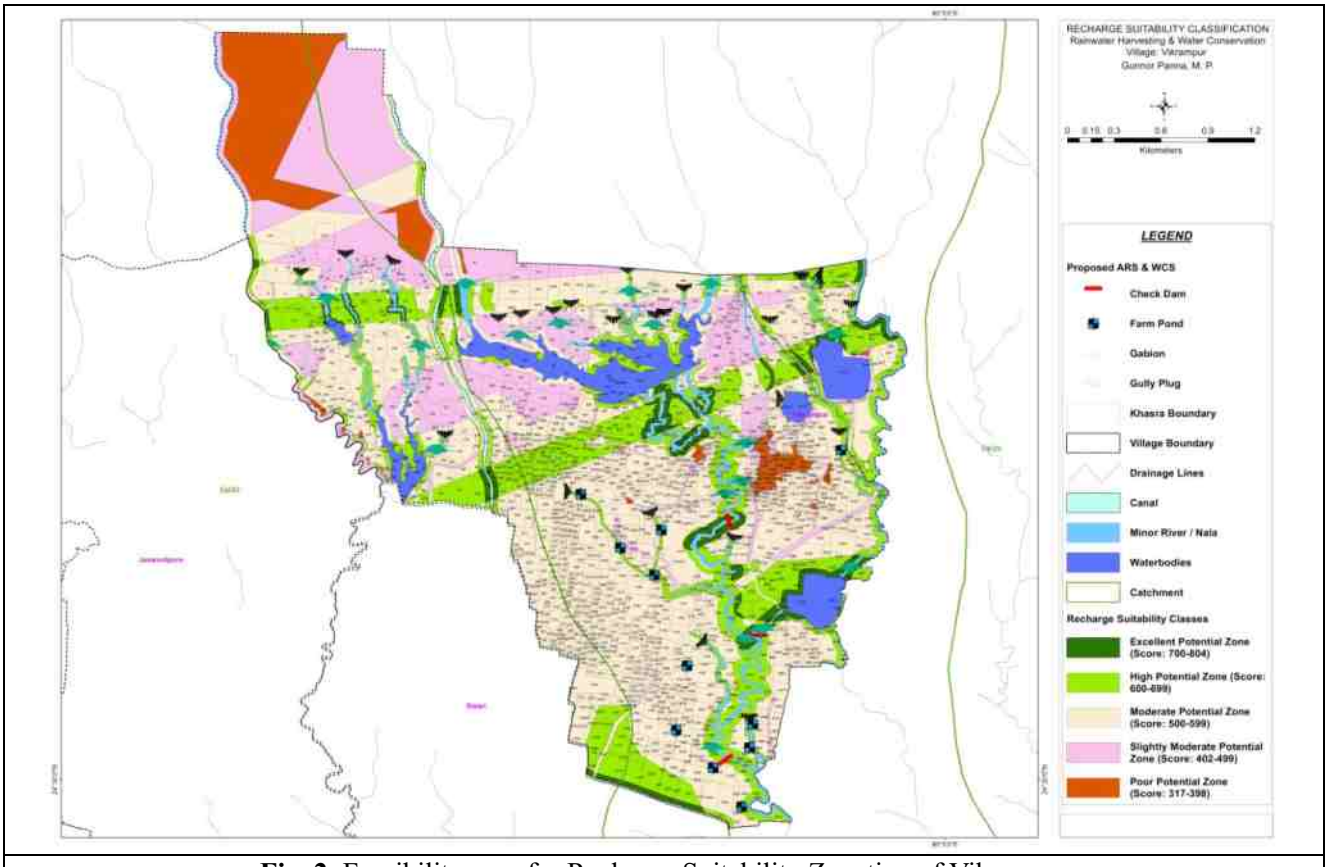

Fig. 2: Feasibility map for Recharge Suitability Zonation of Vikrampur

Table -1. Relevance of Thematic Mapping

S. No.	Theme	Need/Relevance
1	Drainage	Drainage texture, density, run off characteristics, erosion intensity, Groundwater Recharge & site selection
2	Land Parcel (Cadastral) Information	Identification of ownership details for intervention
3	Geomorphology/ Landforms	Land evaluation/capability, Ground water prospects, Soil water conservation site selection, Land use assessment/ soil mapping, Erosion prone & arable land identification.
4	Physiography / Contour	Land capability and arable land, Optimization of suitable land use, erosion intensity, siltation process, site selection for suitable soil and water conservation structures and artificial recharge or natural recharge site selection.
5	Soil	Site suitability selection for recharge, storage and cropping system
4	Geology / Lithology	Groundwater prospects, Geological structures, Inter relationship of litho-units to landforms, & land use, Ground water developments/ recharge site selection
6	Landuse	Information on present LU/LC classes and area coverage, Land identification & availability for different conservation structure.
7	Land Capability	Land suited to cultivation and other uses / land limited in use generallynot suited to cultivation / Slope and hazard of erosion, Soil depth, moisture-holding capacity
8	Erosion Classification	It locally support the land capability in terms of hazard of erosion
10	Groundwater potential, water Level & fluctuation	To check the validity of potential recharge map water level fluctuations during the pre and post monsoon period
11	Well Depth, Aquifer depth, Aquifer Thickness	Aquifer significant behavior to recharge due to relatively thick/thin unsaturated zone
12	Weathering Depth	Aquifer significant behavior to recharge due to relatively thick/thin unsaturated zone
13	Lineament and its Impact	Demarcating prospective sites for construction of artificial recharge structures
14	Climatic Data	Water balance study / available water for recharge
15	Surface Water Resource	Planning & conservation recharge activities on suitable places. Command Area identification for surface water bodies. Irrigation area determination.
16	Groundwater Resource	Water table map showing direction & gradient of ground water, Ground water exploitation status, Water level fluctuation, Water development facilities. Water balancing and budgeting.

Table 2: Water Available, Balance & Water Budget of Vikrampur

Village Details		
State	Madhya Pradesh	
District	Panna	
Block/ Taluk	Gunnor	
Village Name	Vikrampur	
Village ID	459069	
Block Area in Ha	115617	
Village Area (Ha)	974.65	
Water Shed Code	YMNL121	
Water Shed Name	Yamuna	
Water shed are Area (Ha)	967.078	
Sub- Basin code	1	
Sub- Basin Name	Yamuna Lower (Confluence with Ganga to Chambal)	
Basin code	34	
Basin Name	Yamuna Basin	
Parameters	**Data**	**Reference**
Water Availability		
Total Available Water From Rainfall		
Annual Rainfall (mm)	1006.6	Water Resources Department, M. P.
Estimated Volume of Rainfall (Ha.m)	981.08	
Evapotranspiration (mm)	189.18	INDIA WRIS Data
Estimated Evapotranspiration losses (Ha.m)	184.38	
Estimated Water available from Rainfall (Ha.m)	**796.70**	
Ground Water		
Recharge From Rainfall (Ha.m)		
Monsoon	61.42	Ground Water Resource Assessment 2020
Non-Monsoon	0.00	
Total (Ha.m)	61.42	
Recharge From Other Sources (Ha.m)		
Monsoon	2.21	Ground Water Resource Assessment 2020
Non-Monsoon	7.31	
Total (Ha.m)	**9.52**	
Losses due to Natural discharge	7.09	Ground Water Resource Assessment 2020
Total Ground Water Availability (Ha.m)	**63.85**	
Surface Water Storages		
No. of Surface Water Bodies	6	Satellite Data
Storage Capacity of Structures (Ha.m)	131.63	From Survey
Losses if Any (%)	10.000	
Surface Water Available (Ha.m) in storage	118.46	

Total Water Available for Utilization (Ha.m)	**182.31**	
Rainfall Available for Future Use (Ha.m)	**614.38**	
Weighted Average Run -off Coefficient	**0.30**	
Utilizable Rainfall Run off (Ha.m)	**184.32**	
Water Utilisation		
Drinking / Domestic use (Ha.m) (Human + Livestock)		
From surface Water	1.16	Census 2011 projected population by population growth rate
From Ground Water	2.72	Census 2011 projected population by population growth rate
Total	**3.88**	
Irrigated Agriculture (Ha.m)		
From surface Water	132.88	From Girdawari data, Govt. of M. P.
From Ground Water	173.55	From Girdawari data, Govt. of M. P.
Total (Ha.m)	**306.43**	
Industrial Use (Ha.m)		
From surface Water	0.00	
From Ground Water	0.00	
Total	**0.00**	
Other uses (if any) in (Ha.m)		
From surface Water	0.00	
From Ground Water	0.00	
Total	**0.00**	
TOTAL DEMAND OF WATER FOR ALL USES	**310.30**	
Water Balance		
Availability (Ha.m)		
From surface Water	118.46	
From Ground Water	63.85	
Total Availability	182.31	
Utilization (Ha.m)		
From surface Water	134.04	
From Ground Water	176.27	
Total	310.30	
Balance [Surplus (+) / Deficit (-)](Ha.m)		
From surface Water	-15.58	
From Ground Water	-112.42	
Total	**-127.99**	
Water Budget		
Allocation for Drinking & Domestic Requirements		
Present Population in 2022	1647	
Population Growth Rate (Decadal)	18.67	
Present Population 30 years From Date (As in 2050)	2583	
Per Capita Requirement (L)	55.00	
Allocation for Drinking & Domestic Requirements In 2050	5.1854	

From Surface Water (Ha.m)	1.56	
From Ground Water (Ha.m)	3.63	
Total (Ha.m)	5.19	
Water Available for irrigated Agriculture (Ha.m)		
From surface Water (Ha.m)	-17.13	
From Ground Water (Ha.m)	60.22	
Total (Ha.m)	**43.09**	

Table 3: Weight, Rank and Score of thematic data

1. Drainage and Waterbody Impact

S. No.	D_WB_Impt	DWI_Wt	DWI_Rank	DWI_Score
1	No	25	0	0
2	Yes	25	4	100

2. Lineament Impact

S. No.	Impact	Ln_Wt	Ln_Rank	Ln_Score
1	No	25	0	0
2	Yes	25	4	100

3. Land Capability Class

S. No.	Land_Capb	LC_Wt	LC_Rank	LC_Score
1	Forest Land	20	0	0
2	LCC-II: Land with Moderate limitations & require moderate conservation Practices	20	4	80
3	LCC-III: Land with severe limitations & require special conservation Practices	20	3	60
4	LCC-Misc: For commercial, plant, recreation, wildlife, water supply, esthetic purposes	20	0	0

4. Landforms

S. No.	Geom_ID	Landform	Geom_Wt	Geom_Rank	Geom_Score
1	DbIb	Denudational Slope	20	0	0
2	FA	Flood Plains and infilled Valleys	20	3	60
3	SAIb2	Lower Level Plateaus	20	1	20
4	FB	Older Flood Plains	20	4	80

5. Soil Types

S. No.	Soil Type	Soil Wt	Soil Rank	Soil Score
1	Fine Loamy Kaolinitic Soils	18	4	72
2	Fine Loamy Kaolinitic Soils	18	4	72
3	Fine Clayey Montmorillonitic Soils	18	1	18
4	Fine Loamy Mixed Soils	18	3	54
5	Loamy Kaolinitic Soils	18	4	72

6. Erosion Classes

S. No.	Erosion Category	Ero_Wt	Ero_Rank	Ero_Score
1	Moderate Erosion	15	1	15
2	Moderate to Severe Erosion	15	0	0
3	None to Slight Erosion	15	4	60

7. Landuse / Landcover

S. No.	Landuse	LU_Wt	LU_Rank	LU_Score
1	Canal	18	0	0
2	Cropped Land	18	4	72
3	Farm Houses	18	0	0
4	Forest	18	0	0
5	Ground	18	2	36
6	Horticulture	18	2	36
7	Orchard	18	2	36
8	Plantation	18	2	36
9	River / Nala	18	0	0
10	River Bank Greenbelt	18	1	18
11	Road / Rasta	18	0	0
12	Settlements	18	0	0
13	Settlements Mixed Plantation	18	0	0
14	Wasteland	18	2	36
15	Waterbody	18	0	0
16	Waterbody Bund	18	4	72

8. Lithology

S. No.	Lithology	Character	Litho Wt.	Litho Rank	Litho Score
1	Rewa Sandstone	Soft to medium hard sedimentary rock	15.0	3.0	45.0
2	Bhander Shale	Soft, purple and reddish brown thinly laminated to flaggy calcareous with thin bands of calcite, gypsum and with interbeds of purplish grey limestone	15.0	3.0	45.0
3	Bhander Shale interbeds within limestone	Fine grained. hard and compact, thinly bedded with few stramatolitic bands and with interbeds of khaki green shale	15.0	4.0	60.0
4	Bhander Limestone	Fine grained. hard and compact, thinly bedded with few stramatolitic bands and with interbeds of khaki green shale	15.0	4.0	60.0

9. Groundwater Potential

S. No.	GW_Poten	GeoH_Wt	GeoH_Rank	GeoH_Score
1	Poor G. W. Potential	10	4	40
2	Moderate G. W. Potential	10	2	20
3	Excellent G. W. Potential	10	1	10

10. Pre Monsoon Water level

S. No.	WL_Pre	WLPr_Wt	WLPr_Range	WLPr_Score
1	06.0-7.0	15	2	30
2	07.0-8.0	15	2	30
3	08.0-9.0	15	3	45
4	09.0-10.0	15	3	45
5	10.0-11.0	15	4	60
6	11.0-12.0	15	4	60

11. Post Monsoon Water Level

S. No.	WL_Post	WLPoM_Wt	WLPoM_Rang	WLPo_Score
1	3.8-4.6	10	0	0
2	4.6-5.4	10	0	0
3	5.4-6.2	10	0	0
4	6.2-7.0	10	2	20
5	7.0-7.8	10	2	20
6	7.7-8.0	10	2	20
7	7.8-8.6	10	2	20
8	8.6-9.99	10	4	40

12. Groundwater Fluctuation

S. No.	GW_Fluct	GWF_Wt	GWF_Rank	GWF_Score
1	0.35-1.15	10	1	10
2	1.15-1.95	10	1	10
3	1.95-2.75	10	2	20
4	2.75-3.55	10	2	20

13. Well Depth

S. No.	Well_Depth	WellD_Wt	WellD_Rank	WelD_Score
1	08.6-9.4	5	1	5
2	09.4-10.2	5	1	5
3	10.2-11.0	5	2	10
4	11.0-11.8	5	2	10
5	11.8-12.6	5	2	10
6	12.6-13.4	5	3	15
7	13.4-14.2	5	3	15
8	14.2-15.0	5	3	15
9	15.0-15.3	5	3	15

14. Aquifer Depth

S. No.	Aq_Depth	AqD_Wt	AqD_Rank	AqD_Score
1	2.8-3.6	15	4	60
2	3.6-4.4	15	4	60
3	4.4-5.2	15	3	45
4	5.2-6.0	15	3	45
5	6.0-6.8	15	2	30
6	6.8-7.6	15	2	30
7	7.6-8.4	15	1	15
8	8.4-8.94	15	1	15

15. Aquifer Thickness

S. No.	Aq_Thick	AqT_Wt	AqT_Rank	AqT_Score
1	0.25-1.0	20.0	1.0	20.0
2	1.0-1.75	20.0	1.0	20.0
3	1.75-2.5	20.0	2.0	40.0
4	2.5-3.25	20.0	2.0	40.0
5	3.25-4.0	20.0	2.0	40.0
6	4.0-4.75	20.0	3.0	60.0
7	4.75-5.5	20.0	3.0	60.0
8	5.5-6.25	20.0	3.0	60.0
9	6.25-7.0	20.0	4.0	80.0
10	7.0-7.75	20.0	4.0	80.0

16. Weathering Depth

S. No.	Weath_Dept	WD_Wt	WD_Rank	WD_Score
1	1.0-2.0	20	1	20
2	2.0-3.0	20	1	20
3	3.0-4.0	20	2	40
4	4.0-5.0	20	2	40
5	5.0-6.0	20	2	40
6	6.0-7.0	20	3	60
7	7.0-8.0	20	3	60
8	8.0-9.0	20	4	80

Table 4: Feasibility Classes for Recharge Suitability Zonation of the area

S. No.	Total Score Range	Suitability Zone
1	317-398	Poor Potential Zone (Score:317-398)
2	402-499	Slightly Moderate Potential Zone (Score:402-499)
3	500-599	Moderate Potential Zone (Score:500-599)
4	600-699	High Potential Zone (Score:600-699)
5	700-804	Excellent Potential Zone (Score:700-804)

Table 5: Proposed implementation of augmentation measures of village Vikrampur through Artificial Recharge and Water Conservation Structures:

S. No.	Structure ID	Structure Name	Longitude	Latitude	Storage Capacity (Ham)
1	CD	Check Dam	80.0726000	24.5080000	2
2	CD		80.0712000	24.5150000	2
3	CD		80.0705000	24.5014000	2
1	FP	Farm Pond	80.0700000	24.5007000	0.36
2	FP		80.0678000	24.5029000	0.36
3	FP		80.0685000	24.5066000	0.36
4	FP		80.0666000	24.5118000	0.36
5	FP		80.0646000	24.5134000	0.36
6	FP		80.0623000	24.5165000	0.36
7	FP		80.0670000	24.5144000	0.36
8	FP		80.0773000	24.5190000	0.36
9	FP		80.0716000	24.4984000	0.36
10	FP		80.0723000	24.5032000	0.36
11	FP		80.0721000	24.5019000	0.36
1	GB	Gabion	80.0478000	24.5278000	0
2	GB		80.0532000	24.5250000	0
3	GB		80.0541000	24.5191000	0
4	GB		80.0717000	24.5172000	0
5	GB		80.0720000	24.5081000	0
6	GB		80.0729000	24.5087000	0
7	GB		80.0700000	24.5019000	0
8	GB		80.0771000	24.5257000	0
9	GB		80.0708000	24.5165000	0
10	GB		80.0719000	24.5194000	0
11	GB		80.0558000	24.5286000	0
12	GB		80.0699000	24.5286000	0
13	GB		80.0652000	24.5282000	0
14	GB		80.0612000	24.5263000	0
15	GB		80.0666000	24.5262000	0
16	GB		80.0587000	24.5257000	0
17	GB		80.0779000	24.5123000	0
1	GP	Gully Plug	80.0515000	24.5300000	0
2	GP		80.0488000	24.5304000	0
3	GP		80.0462000	24.5293000	0
4	GP		80.0545000	24.5199000	0
5	GP		80.0694000	24.5080000	0
6	GP		80.0664000	24.5154000	0
7	GP		80.0615000	24.5166000	0
8	GP		80.0650000	24.5294000	0
9	GP		80.0617000	24.5275000	0
10	GP		80.0607000	24.5271000	0
11	GP		80.0642000	24.5266000	0
12	GP		80.0589000	24.5269000	0
13	GP		80.0576000	24.5267000	0
14	GP		80.0671000	24.5270000	0
15	GP		80.0666000	24.5269000	0
16	GP		80.0683000	24.5284000	0
17	GP		80.0761000	24.5291000	0
18	GP		80.0750000	24.5291000	0

19	GP		80.0779000	24.5274000	0
20	GP		80.0732000	24.5266000	0
21	GP		80.0738000	24.5220000	0
22	GP		80.0772000	24.5201000	0
23	GP		80.0711000	24.5140000	0
24	GP		80.0720000	24.5036000	0

Table 6: Demand Decreasing Interventions

High Water Crop Area (demand 650mm)	458.31
Actual water demand (mm)	297.9
Diversified area in Low water	229.15
Div. Crop W Demand Ham	80.2
Water Saving	**217.7**
Sprinkler Area	45.83
Sprinkler Demand (mm)	455
Actual Demand (ham)	29.79
Reduced Water Demand Ham	20.85
Water Saving	**8.94**
Drip Area	1.2
Drip demand	260
Actual Demand Ham	0.78
Reduced Water Demand Ham	0.312
Water Saving	**0.468**

Table 7: Supply Increasing Interventions

Type of Water Conservation Structure	WCS
Storage Capacity (Ham)	9.96
Effective Storage Available for Use	5.976
Number of Fillings (Kharif)	2
Number of Fillings (Rabi)	1
Recharge %	20
GW Recharge Kharif (Ham)	0.0239
GW Recharge Rabi (Ham)	0.012
GW Recharge Annual (Ham)	0.0359
Total GW Saved (Ham)	6.0119

Table 8: Water Balance after proposed Interventions

Availability (Ha.m)	a	From surface Water	118.46
	b	From Ground Water	63.85
	c	**Total Availability**	**182.31**
Utilization (Ha.m)	a	From surface Water	134.04
	b	From Ground Water	176.27
	c	**Total**	**310.30**
Balance [Surplus (+) / Deficit (-)](Ha.m)	a	From surface Water	-15.58
	b	From Ground Water	-112.42
	c	**Total**	**-127.99**
50% area under intervention	Crop Diversification (High water to low water crop		217.697
10% area under intervention	Sprinkler Irrigation (Saving of about 30% water)		8.937
100% area under intervention	Drip Irrigation (Saving of about 60% water)		0.468
Water Conservation through surface storage			5.976
Water Conservation Through artificial Recharge			0.036
Total water saving / conserved			**233.114**
Balance [Surplus (+) / Deficit (-)] (Ha.m) after interventions			105.12
Balance % of deficit			-82.13

Data Acquisition in Ka-band Frequency Range to meet Cartography Applications

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Abstract

Indian Space Research organization (ISRO) launched Cartography application Satellites by naming IRS-P5. Next generation remote sensing satellites for cartographic applications Cartosat-3 followed by Cartosat-3A & Cartosat-3B. These satellites transmit data to ground in Ka-band (25.5–27.0 GHz) and X band (7.8-8.5 GHz) with signals in Right Hand Circular Polarization (RHCP) and Left Hand Circular Polarization (LHCP) simultaneously. NRSC has the responsibility for acquisition of data from Cartosat-3/3A/3B Satellites, data processing, data product generation, dissemination as well as application development and capacity building. Accordingly, National Remote Sensing Centre (NRSC) is expert in S-band and Band data acquisition now. The new Ka band Reception system shall have the capability to track and receive data in both RHCP & LHCP polarizations in Ka and S band. The S/Ka Data Reception System shall have the capability to track the Low Earth Orbit (LEO) satellites in the polar sun synchronous orbit in the range of 400 KM to 1000 KM. Development of IRS Spacecraft technology is a multi-disciplinary domain and substantial progress has been made in several technologies during the past few decades, As the demand for "Four Resolutions" like Spatial, Spectral, Radiometric and Temporal increase, the complexity of imaging sensors and in turns the satellite systems. These CartoSat satellites support diverse user requirements and use cases from "Connecting the Unconnected "to provide resilient communications to user's community. The acquisition challenges and data ingest process will be discussed in this paper.

Keywords: Right Hand Circular Polarization, Low Earth Orbit, Spacecraft technology, Resolution, RF Systems and Digital Servo Control System.

Introduction

Data acquisition from cartography satellites:

There are hundreds of applications for satellite imagery and remotely sensed data. From the Indian remote Sensing satellite Series, nations used to use information derived from the satellite imagery for spying on each other under the guise of scientific experiments, industry has grown in leap and bounds and today every sphere of life, government decision making, civil defence operations, police, you name the sphere of life, every one of which is influenced by satellite imagery in particular and Geographic Information Systems (GIS) in general. Earth Observation by Remote Sensing Satellites by NRSC began by commissioning an integrated facility with Data acquisition and Product generation at Shadnagar for Landsat MSS data in 1979. This was followed by development of LANDSAT-TM data processing and establishment of SPOT data processing & product generation facility.

Development of IRS Spacecraft Technology Remote sensing is a multi-disciplinary domain and substantial progress has been made in several technologies during the past few decades. As the demand for "four Resolutions" – Spatial, Spectral, Radiometric and Temporal increase, the complexity of imaging sensors and in turns the satellite systems. While reliability calls for heritage systems, lessons learnt and the new requirements warrant new technology developments. A brief overview on these technology developments is given in the following paragraphs.

Data Reception and Archival is located at Shadnagar Ground Station complex and has three data reception terminals, to receive Image data in X-Band and telemetry data in S band. These three terminals are configured to track and receive data from several National and international satellites (~18 passes in a day). Configuration supports mission clashes and redundancy for important data reception. The Ground station has the capability to receive and demodulate the signals of up to 105 Mbps data rate. The feed and demodulators are upgraded for dual polarization and to cater for higher data rates. It has a Bore sight test facility to evaluate the total data reception chain for all three terminals.

Cartography Satellite, IRS-P5: Cartosat-1 is the first dedicated stereoscopic mission of ISRO, offering 2.5

m resolution in panchromatic band. Weighing 1560 kg at lift off, Cartosat-1 was launched into a 618 km Sun Synchronous Polar Orbit (SSPO) by PSLV-C6 on 5th May 2005. Cartosat-1 mission objectives are directed at geo-engineering (mapping) application, for high resolution panchromatic imagery with high pointing accuracies. The spacecraft features two high-resolution panchromatic cameras for in-flight stereo imaging.

Brief description of the ground station for data reception from irs-p5

The ground station system configuration is explained with reference to the block diagram in Figure.1.2. The system consists of a diametric parabolic reflector antenna with cassegrain feed, mounted over an Elevation over Azimuth driven pedestal. The feed and front-end system realizes single channel monopulse signal tracking and data reception in X -Band frequencies. The sum and difference channel signals from the front-end system are fed to a five channel synthesized down converter are driven to the control room, wherein, after the amplitude equalization, the sum channel is fed to the data demodulation while the difference channel signal is fed to the tracking receiver. The data and clock signals from the demodulator and Bit synchronisers are fed to the archival systems during the pass. The tracking video output, corresponding to the antenna offset information in Azimuth and Elevation axes, from the tracking receiver is fed to the antenna control unit. The antenna control unit has several operational modes to control the antenna movement. The unit drives the antenna in auto track mode during the satellite pass with programme tracking mode operating as backup. The servo system [11] is a dual drive system with torque bias arrangements to avoid antenna backlash during tracking. Initially the systems for receiving data from: CartoSat-1 - formerly IRS-P5 (Indian Remote Sensing Satellite-P5). IRS-P5 is a spacecraft of ISRO (Indian Space Research Organization), Bangalore, India. The objectives of the IRS-P5 mission are directed at geo-engineering (mapping) applications, calling for high-resolution panchromatic imagery with high pointing accuracies. The spacecraft features two high-resolution panchromatic cameras that may be used for in-flight stereo imaging. Prior to launch, ISRO renamed the IRS-P5 spacecraft to **CartoSat-1,** to describe more aptly the application spectrum of its observation data. In this mission, the high resolution of the data (2.5 m GSD) is being traded at the expense of multispectral capability and smaller area coverage, with a **swath width of 30 km. The data products are intended to be used in DTM (Digital Terrain Model)/DEM (Digital Elevation Model) generation in such applications as cadastral mapping and updating, land use as well as other GIS applications.**

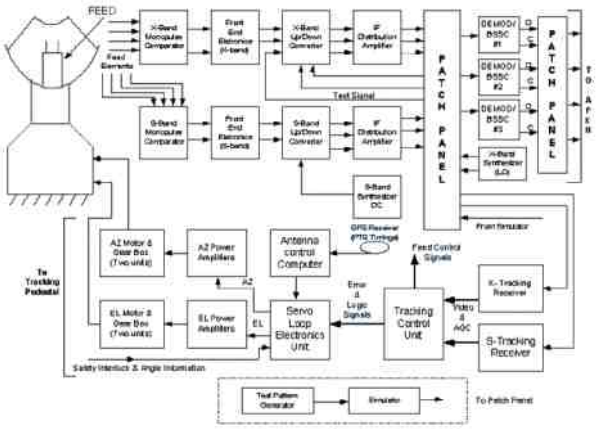

Fig.1 Ground Station Block Diagram

Present Ground Station Scenario (IMGEOS)

As the numbers of remote sensing missions have increased, and the scopes of supporting emergency requirements and disaster monitoring have increased, present mission specific model has several short comings. Hence there is a need to process re-engineer the entire chain, adopting an integrated multi-mission approach in order to minimize the satellite launch-to-product delivery and for improving the turn-around-time from data acquisition to product delivery to the user in near real time. To meet these objectives, an Integrated Multi-mission Ground segment for Earth Observation Satellites (IMGEOS) is proposed to be implemented at Shadnagar complex of NRSC.

The ground station configuration is shown in Figure 1-2. Four 7.5 meter antenna systems are used to track and receive data from different remote sensing satellites. There will be one antenna control computer (ACC) for each antenna systems and common station control computer (SCC) to perform the ground station operations.

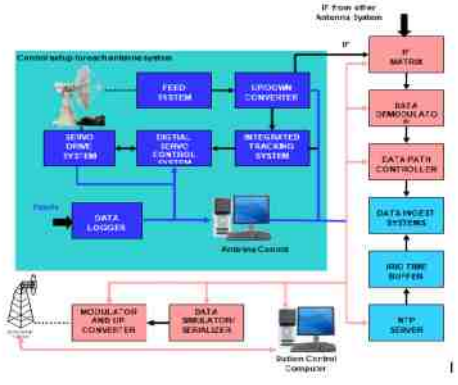

Fig. 2: Present Ground Station Block Diagram

Payload pass schedules & state vectors will be received through Sky-link on to SCC. After resolving the clashes, the SCC will assign the antenna systems for all scheduled passes after subjecting to acquisition strategies and archival policies. The SCC will configure base band systems automatically as per the schedules for all the four antenna systems and communicates its readiness to the ACC of the respective antenna system. The ACC in turn will configure the RF and IF sub systems before satellite pass tracking.

In real-time, the SCC and ACC monitor the required parameters from the base band and RF & IF systems respectively. The ACC will monitor all the parameters pertaining to RF & IF chain. In addition, it does program tracking which acts as a backup to the auto track mode. Subsequently it sends acquisition status to the SCC after the pass. During real-time, the Data Receivers log the data on to SAN based RAID system after doing demodulation and frame synchronization. The pre-processing system will provide the sub sampled quick look display in real-time. The station operations are planned to implement in fully automated environment aiming towards unmanned operations. The main objectives of the station automation are

- ✓ Visibility clash and elevation analysis
- ✓ Providing centralized control & configuration of the station
- ✓ Monitoring and control of the sub systems
- ✓ Building up of operational database
- ✓ Modularity for easy upgradeability to future missions

In multi-mission scenario, around 20 passes will be acquired covering both Indian and foreign satellites from four different Antenna Systems. These antenna systems will be operated simultaneously to acquire the data from different/ same satellites based on the clash scenario. In the operational scenario, it is required to reconfigure the chain and get ready for the next pass within 2 minutes. Around 25 parameters shall be monitored/ configured on various subsystems for each pass. Some of these important parameters are

Configuration parameters

- ✓ Local oscillator frequency and its output level of Down converter
- ✓ Gradient selection from Tracking servo control system
- ✓ Digital Phase shifter selections
- ✓ Routing of IF to different Data demodulators
- ✓ Demodulator, clock lock, polarity, data rate, output level, output mode

Monitoring parameters

- ✓ Auto errors, DC errors, Azimuth & Elevation Tacho
- ✓ AGC levels, Acquire/lock status from X & S bands
- ✓ Sector (CW/CCW) and limit checks of antenna
- ✓ Received signal strength C/No
- ✓ Quality factor (E_b/N_o)
- ✓ Demodulator and Bit Synchronizer (BSSC) lock status

2.2 System Configuration

The configuration has been worked out keeping in view of t

the simultaneous operations of all four antenna systems to track different satellites and is shown in figure 1-3. Automation point of view, the total sub systems in the Data Reception System are divided into two categories- RF & IF systems (all the sub systems up to down converter in the data receive chain) and base band systems (from IF matrix onwards).

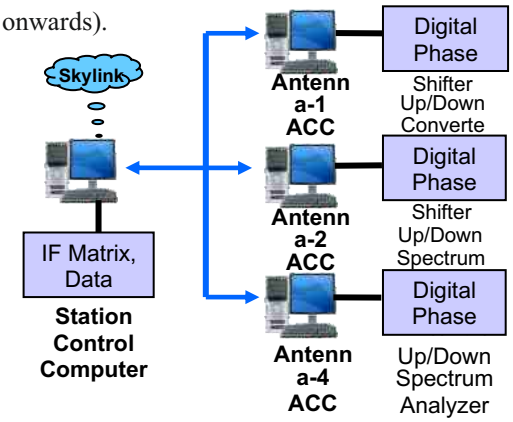

Fig. 3 Station Automation Configurations

The RF & IF systems are dedicated to one antenna systems and there will not be any switching between the antenna systems in the operations scenario. The automation of these systems is carried out by the antenna control computer of the respective antenna system along with the program tracking of the satellite. Similarly, station control computer carries out the automation of base band systems. These systems include IF matrix, Data Demodulators, Data Simulators etc.

Data Ingest

Station workflow manager will initiate data ingest operation for archival of satellite data based on Payload pass schedules. For each antenna systems one data ingest system is configured. One additional ingest system is also

configured as standby. Ingested satellite data will be qualified for quality in terms of data losses. Data ingest systems in the context of ancillary data processing and storage systems are shown in figure 1-4.

Ancillary Data Processing

In near real time, the ancillary data processing systems (shown in figure 1-4) will generate ADIF, Browse and Histogram files for each pass. The generated ADIF will be populated on to the respective database for subsequent access and pre processing of data. The browse images are screened for quality & cloud automatically with a provision for manual certification before putting on to the Internet.

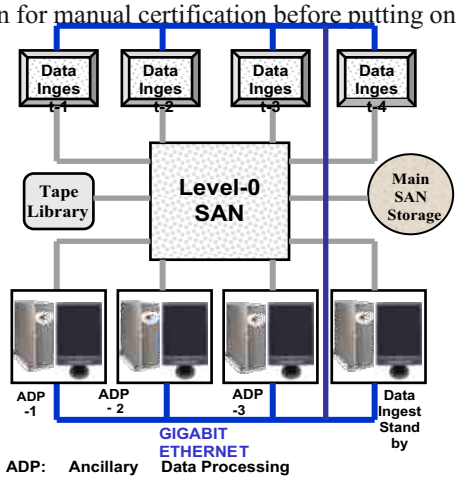

Fig. 4: Ancillary Data Processing Systems Configuration

Storage Architecture

The Storage sub system is a Storage Area Network having an estimated storage of 25.0TB for acquisition & Level-0 processing, 15 TB for DP working area and around 720 TB of existing data of all satellites is archived on DLT/SDLT media (as on 31-Dec-2008).

Data is stored online in 3 tier SAN storage. Provision is made for 100 TB (usable) accounting for three months of all satellites data in high performance storage. 400 TB (usable) accounting for 18 months data in medium performance SATA storage. All the data acquired and available archived data will be stored in Tape library in duplicate for backup and one more copy for vaulting. This 3 tier configuration is optimized for product generation and for data availability.

The following points are considered for selection of tiered storage

- ✓ For online processing or archival
- ✓ High performance vs. cost effectiveness
- ✓ Write once/ read many or continuous read/ write
- ✓ Frequently accessed or infrequently accessed
- ✓ File data or RDBMS data
- ✓ Heterogeneous platform access
- ✓ Multiple users or single user/ limited users
- ✓ Scenarios

- Archival data is mainly write-once read-many

The storage is scalable to meet ever increasing data volumes with time. Storage architecture is shown in Fig. 1.5.

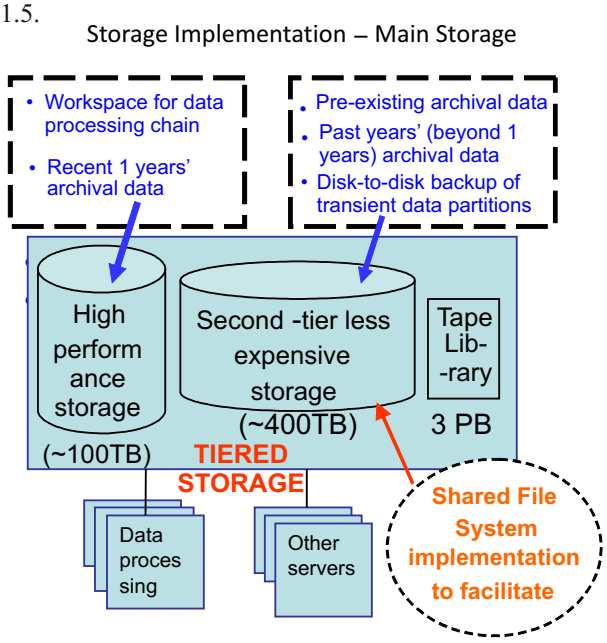

Fig 5: Storage Implementation-Main Storage

Carto. Sat	Data Rate	Streams	Total Volume Data Acquired
Cartosat-01	105Mbps	Two	33.075
Cartosat-02	105Mbps	Two	14.175
Cartosat-2A	105Mbps	Two	3.938
Cartosat-2B	105Mbps	Two	33.075
Cartosat-2C	105Mbps	Two	33.075

Data Archival for one day

Cartosat-3 transmit parameters in ka band

Orbit Height	:	450 Km
Modulation Scheme	:	8 PSK
Dual Polarization	:	RCP & LCP
Transmission Data Rate	:	3.8 Gbps

Conclusion

The Advances in satellite communications technology in recent years have led to a significant increase in throughput delivered from a raft of new 'High Throughput Satellite' (HTS) systems. Carto 2 Series satellites have been launched in recent years and several more will go into orbit in the coming years. These satellites support diverse user requirements and use cases

– from 'connecting the unconnected' to providing secure and resilient communications to industries. The satellite communications industry supports a wide range of customers whose varying use cases and deployment locations place exacting requirements that must be fulfilled. Connectivity must be delivered to consumers located beyond the reach of traditional terrestrial networks and yet also to business and corporate clients requiring bespoke systems to support critical communications needs.

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Hydrographic Surveys and Mapping for Coastal Zone Management

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Abstract

Coastal zone management provides for a worldwide vision of sustainable development framework flexible enough to cater for unique emerging requirements of coastal environment. Integrated coastal zone management (ICZM) as a concept was first introduced in Earth Summit at Rio de Janeiro in 1992. The dynamic processes that occur within the coastal zones produce diverse and productive ecosystems which have been of great importance historically for human populations. Coastal zones contribute to 8% of global area but significantly contribute to 25% of global productivity. Stress on this environment comes with 70% of world population being within immediate neighbourhood of coastlines wherein 2/3rd of world's biggest settlements or cities occur. The increasing impact of technological advancements are making our coastlines vulnerable to natural hazards such as Tsunamis and extreme weather phenomenon which have a direct and far-reaching effect on coastal communities. Hydrographic survey provides information that is essential to enable proper planning to ensure that coastal zones are effectively and sustainably managed. The contribution of Hydrography to the Coastal environment maintenance, both coastal and offshore is paramount. The construction of appropriate port infrastructure is directly linked to the economic and social development of a coastal state. Investments in port projects and hydrographic surveys concern society as a whole and not a specific group of citizens or a professional guild. In particular, investments in hydrography save human lives and support the national economy by rationally managing development in a coastal zone, giving the corresponding environment a sustainable behaviour. Inaddition, Hydrography serves a noble cause in dealing with issues of national concern such as disaster management and environmental protection while at the same time dealing international issues viz. maritime law, control of maritime borders and issues related to cooperation between neighbouring coastal states. Ventures in hydrography and its allied services is the undisputed solution to the coastal ecosystem management problems.

Keywords: Coastal, Zones, regulation, CZM, hydrography, remote sensing

Introduction

Coastal zone management provides for aworldwide vision of sustainable development framework flexible enough to cater for unique emerging requirements of coastal environment. Integrated coastal zone management (ICZM) as a concept was first introduced in Earth Summit atRiodeJaneiroin1992.Thedynamicprocessesthat occur within the coastal zones produce diverse and productive ecosystems which have been of great importance historically for human populations. Coastal zones contribute to 8% of global area but significantly contribute to 25% of global productivity. Stress on this environment comes with 70% of world population being within immediate neighbourhood of coastlines wherein 2/3rd of world's biggest settlements or cities occur.

The pressure on the living and non-living resources of the coastal zone is expected to further increase, due to growing urbanization, industrialization, and transportation. This section considers physical structures and land use modification in the coastal zone, and anticipated future developments (e.g.,off-shore airports, wind-energy parks, land reclamation, etc.), due to an increase in human demography and increased use of coastal areas. The tremendous population increase puts a heavy burden on the coastal zone requiring careful management. The obvious global demand for proper guidelines to cope with these increasing pressures presents the science community with a major challenge, namely to supply scientific information on possible solutions, and on the predicted effects of the different measures. There is a need for systemic studies of the ecosystems associated with large coastal urban agglomerations. The increasing impact of technological advancements are making our coastlines vulnerable to natural hazards such as Tsunamis and extreme weather phenomenon which have a direct and far-reaching effect on coastal communities. Below are four identified goals of ICZM :-

(a) Maintaining functional integrity of coastal resource systems

(b) Reducing resource use conflicts

(c) Maintaining health of environment

(d) Facilitating the progress of multisectoral development.

Indian Coastal Regulation Zone Act and Relevance of Hydrography.

In 1991, the Government of India issued a notification under the Environment Protection Act, 1986 administered by the Ministry of Environment and Forests (MoEF) to protect and conserve the environment and ecosystem on the coastline of the country. According to the notification, the coastal land up to 500m from the High Tide Line(HTL) and a stage of 100m along banks of creeks, estuaries, backwaters and rivers subject to tidal fluctuations, is called the Coastal Regulation Zone (CRZ). The Coastal Regulation Zone Notification 1991 has undergone changes in 2011 and futher in- depth analysis of Shailesh Nayak led committee incorporated changes to suit the evolving coastal environment. In 2019, Ministry of Environment Forest and Climate change issued the CZM notification describing coastal regulation zones as briefly tabulated below: -

Ser	Category	Description
(a)	**CRZI A**	Areas that are ecologically sensitive and essential for maintaining the ecosystem on the coast such as mangroves, corals, sand dunes, mudflats, marshes, nesting grounds etc. Permissions: (i) Ecotourism activities such as mangrove walks, nature trails subject to approved CZMP. (ii) Construction of roads by way of reclamation in exceptional cases for defense, strategic purposes and public utilities as recommended by State CZMA.
	CRZIB	The intertidal zone i.e., the area between Low Tide Line and High Tide Line (i) Land reclamation activities, bunding etc shall be permitted for projects related to ports, defence. Roads, Erosion control, maintenance of water ways, petroleum and non-conventional energy sources etc. (ii) Hatcheriesand modernisation of fish processing units. (iii) Projects related to atomic minerals
(b)	**CRZII**	Areas that are developed up to the shoreline of the coast. Permissions: (i) Some construction as per the guidelines only. (ii) Reconstruction of the authorized building without a change in the existing use.
(c)	**CRZIIIA**	Relatively undisturbed land areas where population density is more than 2161 per sq km that don't fall under CRZI and CRZ-II come under CRZ-III; area upto 50meters from the HTL on the landward side shall be earmarked as the 'No Development Zone (NDZ) PROVIDED Coastal Zone Management plan(CZMP)has been drawn failing which 200 meters from HTL shall form NDZ
	CRZIIIB	All other CRZ III areas with population density less than 2161 per sq km wherein a NDZ of 200 meters from HTL shall apply.

etc.

		Activitiesas permittedin CRZ IB, shall be permissiblein CRZ III. Permissions in NDZ: (i) Only certain activities related to agriculture, horticulture, gardens, pastures, parks, playfields, forestry and salt manufacture from seawater. (ii) No construction shall be permitted in this zone except for repairs of existing authorized structures. (iii) Construction of only public facilities and temporary tourism facilities.
(d)	**CRZIV A**	The water area and the seabed area between the Low Tide Line up to 12 nm on seaward side shall constitute CRZIVA Permissions: (i) Corals and sand from the beaches and coastal waters shall not be used for construction and purposes. (ii) Dredging and underwater blasting in and around coral formations shall not be permitted.
	CRZIV B	These areas shall include the water area and the bed area between LTL at the bank of Tidal influenced water body to the LTL on the opposite side of the bank, extending from mouth of water body at the sea up to the influence of tide, i.e., Salinity of five parts per thousand (ppt) during the driest season of the year Permissions: (i) Traditional fishing and allied activities undertaken by local communities. (ii) Land reclamation activities, bunding etc shall be permitted for projects related to ports, defence. Roads, erosion control, maintenance of waterways, petroleum and non-conventional energy sources etc. (iii) Storage of non-hazardous cargo, transfer of hazardous substances from ships, pipeline and overhead cable laying. (iv) Setting up of weather radars.

The Coastal Regulation Zone Notification 2019 has designated National Centre for Sustainable Coastal Management (NCSCM), Chennai as spearhead of the organizational framework for coastal zone regulation and management. It shall identify Ecologically sensitive area (ESAs) and demarcate HTL/LTL of coastline of the country. It is also one of the many agencies responsible for drawing up coastal zone management plans (CZMPs) as notified by MoEFCC. Production of CZM maps forms the foundation of drawing up sustainable CZMPs. Multiple stakeholders come into play in preparation of CZM maps wherein data sourced from Survey of India (SoI), National Hydrographic Office (NHO) and NCSCM are integrated to produce large scale maps of 1:25000. Accurate demarcation of HTL/LTL, hazard lines, CRZ zones and hydrographic data of coastal water bodies are the stringent requirements of these maps. Continuous monitoring via satellite imagery/remote sensing

techniques and periodic re- evaluation of data to keep up with the ever- changing coastal environment is an essential part of CZM process.

Following steps are involved in production of CZM Maps: -

Step 1: Base Maps of 1:25,000 scale shall be acquired from the Survey of India (SOI) and wherever 1: 25,000 maps are not available, 1: 50,000 maps shall be enlarged to 1: 25,000 for the purpose of base map preparation and these maps will be of the standard specification as given in CRZ 2019 notification.

Step 2: Topography in the SOI maps will be updated using latest satellite imageries or aerial photographs

Step3:Variousregulatorylinesviz.atadistanceof 20 metres, 50 metres, 200 metres and 500 metres from HTL respectively, as applicable in various CRZ categories, and the Hazard line shall be demarcated and transferred to the CZM maps.

Step 4: HTL, LTL and CRZ boundaries, as applicable, shall also be demarcated in the CZMthe organizational framework for coastal zone regulation and management. It shall identify Ecologically sensitive area (ESAs) and demarcate HTL/LTL of coastline of the country. It is also one of the many agencies responsible for drawing up coastal zone management plans (CZMPs) as notified by MoEFCC. Production of CZM maps forms the foundation of drawing up sustainable CZMPs. Multiple stakeholders come into play in preparation of CZM maps wherein data sourced from Survey of India (SoI), National Hydrographic Office (NHO) and NCSCM are integrated to maps along the banks of tidal influenced in land water bodies.

Step 5: Classification of different coastal zones shall be done as per the CRZ notification and Standard national or international colour codes shall be used. Local level CZM Maps are for the use of local bodies and other agencies to facilitate implementation of the Coastal Zone Management Plans. Cadastral (village) maps in 1:3960 or the nearest scale, as available with revenue authorities shall be used as the base maps. HTL,LTL, other CRZ regulatory lines and the Hazard line shall be demarcated in the cadastral maps and classifications shall be transferred into local level CZM maps.

Relevance of hydrography in enforcing reforms in these zones are as follows:-

Ser	Category	Application of Hydrography
(a)	**CRZI B**	(i) Calculate area and volume (ii) Determine extent of scouring and silting in subaqueous floors (iii) Calculate area and volume (iv) Determine extent of scouring and silting in subaqueous floors (v) Undertake underwater investigations to collect data for designing port and harbour facilities. (vi) Plan engineering projects such as bridges, reservoirs and laying of pipelines. (vii) Determine the shorelines of water bodies.
(b)	**CRZ II, IIIA& III B**	Accurate demarcation of HTL and delineation of coastlines are of utmost importance in this aspect. Moreover, periodic monitoring of changes to coastline will enhance Environmental Impact Assessment (EIA) Studies which have detailed landward and seaward components. EIA report forms a basis for obtaining CZM clearance for development projects.
(c)	**CRZIV**	Bathymetric data combined with sub - seabed information are vital to offshore development in a sustainable manner taking due cognizance of ecologically sensitive areas such as coral formations.

Under new reforms vide 2019 Notification of in Coastal Zone regulation Act, new amendments such as reduction in no development zones and further splitting of CRZ III have been undertaken to cater to evolving coastal zone requirements. Hydrographic surveying and mapping in Coastal zones in the face of ever-changing coastal regulation zones is of high significance. It is essential to keep the pace of hydrographic surveying in littoral waters with the evolvingCoastal scenario in order to meet the stringent norms promulgated from time to time.

Surveying requirements of CRZ IV areas The defining difference between the two applications is the significance of water depth. As is discussed below, the requirements for nautical charting are depth dependent; the requirements for offshore developments and coastal zone management are independent of depth. Seabed construction
activities generally require the same type and quality of' measurement'(positioning, geological sampling, etc),as similar activities onshore. The amount of water above an area does not 'lessen' such requirements; in this respect, the water column should be considered as an additional, and cost-increasing, obstacle-the more water the worse the effect.

When coastal construction is being planned in a new area, planning begins based on existing information, i.e. nautical charts. Subsequently, however, more detailed information is required; for example, water depths beyond that required for nautical navigation convenience and security. In addition, types of data not normally required for nautical charts may be required for coastal development activities, for instance sub-seabed geology etc. The differing requirements for nautical charting and for coastal engineering can be most readily appreciated where sub-sea construction activities are involved. Nautical charting requirements tend to be depth dependent (i.e. IHO charting standards). The requirements for construction activities, on the other hand, remain the same independent of depth. Seabed surveying and mapping for such construction activities has, so far, had to be based on industry standards/guidelines developing in co-operation between construction companies and hydrographic surveying firms. The more detailed and reliable such seabed documentation is, the more optimised construction design and operations can be, thereby positively effecting construction safety as well as total project costs. Types of data such as seabed geology, u/w current studies, wave impact studies are critical to coastal engineering developments. Also, bathymetry, metocean, geotechnical and shallow geophysical data – environmental data in the broad sense of word- is important so that seismic surveys, well drilling production and pipeline activities can be properly designed, installed and operated. Non-conventional methods such as LIDARs and AUVs are a boon to offshore surveying.

Hydrography in Environmental Impact Analysis : Case study of Udupi Coast

Udupi coast in Karnataka state, along the west coast of India is well known for sandy beaches, aquaculture ponds, lush greenery, temples and major and minor industries. It lies between 13°00′00″–13°45′00″ north latitudes and 74°47′30″–74°30′00″ east longitudes, the length of the coastline is 95km, and is oriented along the NNW–SSE direction. It is vulnerable to accelerated sea level rise (SLR) due to its low topography and its high ecological and touristy value.

A study was carried out in with a view to calculate the coastal vulnerability index (CVI) to know the high and low vulnerable areas and area of inundation due to future SLR, and land loss due to coastal erosion. Both conventional and remotely sensed data were used and analysed through modelling technique and geographical information system applications. The rate of erosion was found to be 0.6018km^2/yr during 2000–2006 and around 46km of the total 95km stretch is under critical erosion. Out of the 95km stretch coastline, 59% is at very high risk, 7% high, 4% moderate and 30% in the low vulnerable category, due to SLR. Results of the inundation analysis indicate that 42.19 km^2 and 372.08 $km^2$of the land area will be submerged by flooding at 1 m and 10 m inundation levels. The most severely affected sectors are expected to be the residential and recreational areas, agricultural land, and the natural ecosystem. As this coast is planned for future coastal developmental activities, measures such as building regulation, urban growth planning, development of an integrated coastal zone management, strict enforcement of the Coastal Regulation Zone (CRZ) Act 1991, monitoring of impacts and further research in this regard are recommended for the study area.

Above mentioned case study reveals that proper modeling of the environmental consequences of proposed

man-made features along a coast must be conducted to avoid potentially significant economic impacts due to loss of shoreline and beaches. Hydrographic survey provides information that is essential to enable proper planning to ensure that coastal zones are effectively and sustainably managed.

CRZ Notification 2019 has designated Critically Vulnerable Coastal Areas (CVCAs) such as Sunderbans in West Bengal, Gulf of Khambat and Gulf of Kutchh in Gujarat, Achra Ratnagiri in Maharashtra, Karwar and Coondapur in Kranataka, Vembanad in Kerala, Gulf of Mannarin Tamil Nadu, Bhaitarkanika in Odhisha, East Godavari and Krishna in Andhra Pradesh owing to their ecologically sensitive environment.

Similar studies using physical and remote sensing techniques supported by GIS softwares will help monitor coastal Erosion /accretion patterns and set up a robust mechanism for regulation of CVCAs.

Maradu Demolitions in Kochi, Kerala

The Supreme Court had on May 8, 2019, ordered the demolition of the four apartment complexes that were built by violating the Coastal Regulation Zone (CRZ) norms, at Maradu municipality in Kerala's Ernakulam district. The flats were built along the coastal region that falls under the CRZ-III category with strict curbs on construction activities. In such areas, constructions are not allowed within 200 metres from the coastline, being No Development Zone (NDZ). Maradu panchayat had issued the building permit without the permission of the Kerala Coastal Zone Management Authority (KCZMA), in contravention to 1991 CRZ notification and the 1996 Kerala Coastal Zone Management Plan (KCZMP). In, early January 2020, the buildings were demolished to the utter dismay of hundreds of its residents. In the recent light of these events, it can be judged that Coastal Zone Management is being viewed as a matter of national importance and grave concern.

Technologies used in Coastal Surveying

The usual survey-measurement equipment used consists of acoustic systems, main representatives being Single beam and Multibeam Echosounders, while optical bathymetry methods using LIDARsor bathymetric extraction from multispectral or SAR satellite images are more cost effective and time-efficient methodologies in coastal surveying. In special research cases, such as for laying of underwater pipelines, in addition to the above bathymetry systems, additional seabed relief research systems such as Side Scan Sonar-SSS, magnetometers, seismic systems and sea bed samplers are used. Together with advancement in GIS techniques and predictive modeling applications, Hydrographic surveying is a pathfinder in coastal zone management.

Profile surveys are carre combined, processed and analysed to study erosion/accretion patterns along coastal zones. These surveys form foundation of EIA studies which is prerequisite to Coastal development activities.

Conclusion

The marine environment is not independent of land. Coastal or littoral areas are transition zones between land and sea, where many people live and where very important economic activities take place. So, why separate land from sea? There is continuity after the zero depth beyond the shoreline, and these adjacent areas cannot be ignored and should be part of the hydrographic data coverage. Tides and currents not only affect navigation, they also have an impact on the littoral areas; a Digital Elevation Model (DEM) is not truncated at the zero depth, in simple terms it is the prolongation of the seabed above water; and the slope and morphology combined with other parameters determine how this ecosystem works and how it can be developed. Hydrographic data is vital for that determination.ried out as two components Viz., Beach Profile surveys (land part) using RTK GPS System and Nearshore Bathymetric Survey (Sea Part) using multi-beam echo sounder system. These datasets aThe marine environment is not independent of land. Coastal or littoral areas are transition zones between land and sea, where many people live and where very important economic activities take place. So, why separate land from sea? There is continuity after the zero depth beyond the shoreline, and these adjacent areas cannot be ignored and should be part of the hydrographic data coverage. Tides and currents not only affect navigation, they also have an impact on the littoral areas; a Digital Elevation Model (DEM) is not truncated at the zero depth, in simple terms it is the prolongation of the seabed above water; and the slope and morphology combined with other parameters determine how this ecosystem works and how it can be developed. Hydrographic data is vital for that determination.

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to enable proper planning to ensure that coastal zones are effectively and sustainably managed. The contribution of Hydrography to the Coastal environment maintenance, both coastal and off shore is paramount. The construction of appropriate port infrastructure is directly linked to the economic and social development of a coastal state. Investments in port projects and hydrographic surveys concern society as a whole and not a specific group of citizens or a professional guild. In particular, investments in hydrography save human lives and support the national economy by rationally managing development in coastal zones, giving the corresponding environment a sustainable behaviour. In addition, Hydrography serves a noble cause in dealing with issues of national concern such as disaster management and environmental protection while at the same time dealing international issues viz. maritime law, control of maritime borders and issues related to cooperation between neighbouring coastal states. Ventures in hydrography and its allied services is the undisputed solution to the coastal ecosystem management problems

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Brahmaputra River Channel Shift and LULC ChangeDetection Mapping using Multispectral Satellite Imagery

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Abstract

One of the enormous alluvial rivers, the Brahmaputra River originates from the Kailash ranges of the Himalayas and flows through Arunachal Pradesh before meeting Bay of Bengal. The change in channel pattern and shift in bank line is the major cause of floods with high magnitude and frequency in northeastern parts of India. Floods in Assam are recurring due to the unstable and dynamic change in Brahmaputra River channel. The course of Brahmaputra River in Assam has been studied using remote sensing approach. The major factors for river channel shift and meandering are decreasing slope which causes deposition, erosion of soft rocks due to rapid flow of the river, deforestation, etc. This study aims to map and detect the shift in the river channel for the period 1980-2021 using spectral indexes. And, to analyze the vulnerability in the nearby land use classes. The river channel has been extracted from Landsat satellite imageries using ArcGIS Pro software for different years.

Keywords: GIS& Remote Sensing, Brahmaputra, Landsat, multi-temporal analysis, river channel shift, LULC

Introduction

The Brahmaputra river supports the lives and livelihoods of millions of people, in other words, it is one of the means of survival innortheastern India for decades. Due to its enormous size, this alluvial river has drawbacks such as recurring floods, and erosion-deposition related to it. The river has a plaited channel in most of the alluvial plains of Assam (Archana, S., et al., 2012). The lateral changes in channels affect severe erosion along the banks leading to a considerable loss of good fertile land each year.The mixture of young and delicate geology and intense monsoon rainfall leads to high rates of erosion and sediment deposition in the Indo-Gangetic Plain, thus subsequently shifting the river channels(Nepal, S., & Shrestha, A. B., 2015). Most of the basin is strongly influenced by the summer monsoon with the eastern part receiving the highest rainfall. The complications in measuring variation or change are combined by the fact that the river channels originate in high mountain ranges, and the impact of climate change in these zones, in addition to the implications for downstream water accessibility, are complex. The flood control measures adopted in the basin since the early fifties are all of a short-term and ad-hoc nature and in fact, no proper flood plain management program is being implemented (N.N. Bhattachaiyya & A.K.Bora, 2009).The devastation of wetlands and swamps, and mismanaged embankments are also recently added causes and effects of flooding. This resultsin overtopping or breaching and stagnant water in nearby areas for continuous days causing extensive damage (Das, J. D., & Saraf, A. K. 2007). The other most importantstudydue to the impact of flooding is the risk and vulnerability of the various land use classes. It affects stronglythe lives of people and causeslong-term damage. Hence the change detected by the LULC maps analyseshas been added in this current study.

Remote sensing-based approaches are widely used for change detection due to their high-resolution flexibility, time-saving, and cost-efficient procedure. The change detection will help in the management of resources and mitigatethe futureimpact of climate change(Vivekananda, G. N., 2020). The satellite data gives the privilege of continuous dataset availability and information on channel geography can be deduced easily. Thususeful and in abundant need of data for studying river morphology and its impact on land, stable and unstable reaches of the river banks, changes in the main channel of the Brahmaputra River, etc.

Assam faces floods almost every year due to high precipitation in the monsoon season, which causes a shift in the river channel.This study aims to map and monitor the changes in river channels for the period 1980-2021. And to detect the change in land-use/land-cover maps of the nearby channel area.It is envisioned that the usage of the materialproduced out of this study with other ground-based data will helpconsiderably in an additional meaningful approach towards planning and execution of means and measures to combat frequent floods and erosion.

Study Area

The Study area is the course ofthe Brahmaputra river channel near Tezpur district of Assam, India.Thearea surrounding the river channel has been considered in the LULC maps.The Brahmaputra river can also be called an

enormous moving ocean thatflows across Himalayan ranges.The Brahmaputra river channel is very dynamic due to the high erosion rate because the river has soft bedrock. The Brahmaputra river basin also faces floods almost every year due to heavy rainfall means the river has a high level of sediments, before Assam the river flows over a steep slope and as it enters Assam the river flows overa comparatively gentle slope due to which the study area also has high accretion or deposition rate. As the study area has both high erosion as well as high accretion rate this makes the Brahmaputra river channel very dynamic and the river changes its channel almost every year. Due to the dynamic nature of the river channel to study the changes in LULC over time is very important. The study area also faces floods almost every year soidentifying the most vulnerable LULC classes plays a vital rolein creating better government policies as well as robust disaster management and rescue plan.Fig .1 shows the location of the study area.

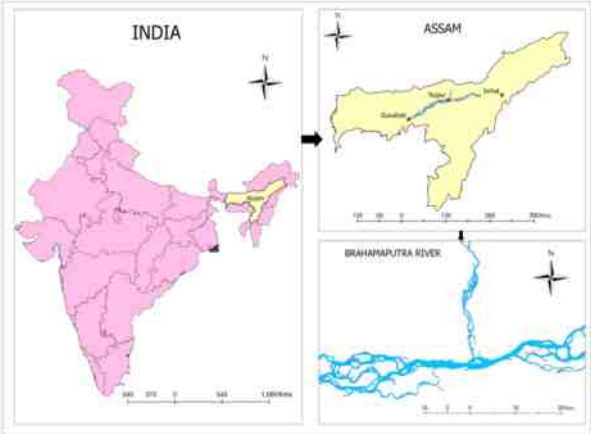

Fig .1: Study Area

Materials & Methods

Data Used

Satellite Data Used: The Landsat (2-8) ranging between 1980-2021 has been used.The Landsat data was downloaded from USGS earth explorer website. The Landsat imagery will used to extract river channel for different years and alsoto create LULC maps.

Methodology

For this study data of Landsat 2-8 was used. The data was downloaded from USGS earth explorer for the period of 40 years from 1980 to 2021.

The first objective of this study was to extract river channels from multispectral Landsat imageries using the band ratio technique. For Landsat-2 NDWI was calculated as Landsat-2 doesn't cover the SWIR spectrum of the EMR spectrum. Landsat 7 has a scan line error and the error was removed using preprocessing technique.For Landsat 5-8 MNDWI spectral index was used which can differentiate between permanent waterbodies and water content in vegetation more accurately in comparison to NDWI. The MNDWI is better than NDWI because it uses the SWIR band instead of the NIR band.

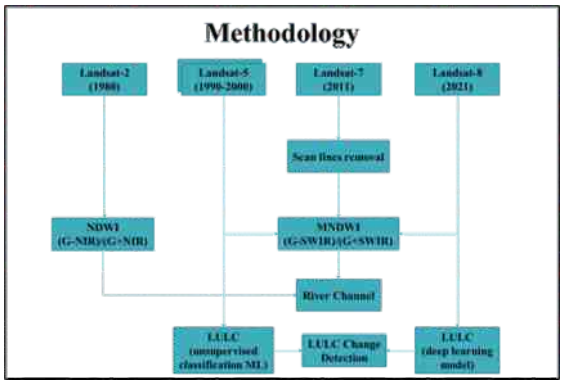

Fig.2 : Study Methodology

The second objective was to map the changes in the channel and monitor the changes in the area of the river channel. The extracted river channels of the different periods were overlayed and decadal changes in terms of area (sq. km) were calculated.

The third objective of the study was to estimate and study the changes in the Land Use and Land Cover of the study area from 1995 to 2021. Landsat imageries of the year 1995 (Landsat5) and 2021 (Landsat8) were used to create LULC level-1 maps. For the year 1995 LULC map was created using the traditional machine learning classification technique using ArcGIS Pro. For the year 2021, the LULC map was created using a pre-trained deep learning model from ArcGIS Living Atlas of the World. Change in terms of area (sq. km)for each LULC class was alsocalculated and a confusion matrix was prepared.

Results and Discussion

The objectives of this study are to map the river channel for every decade from 1980-2021. Then to map the changes in the channel and monitor the changes in the area of the river channel. And lastly, create the LULC maps for the years 1995 and 2021. These LULC maps were then used to study the change in land use classes between the two years and to analyze how the classes have been changed from of modernization and recurring floods.

The Fig. 3 shows the river channel mapping between the

years 1980-2021. During 1980, the channel width was wide with few channels, with time the width of channels decreased and the number of sub-channels has been increased.

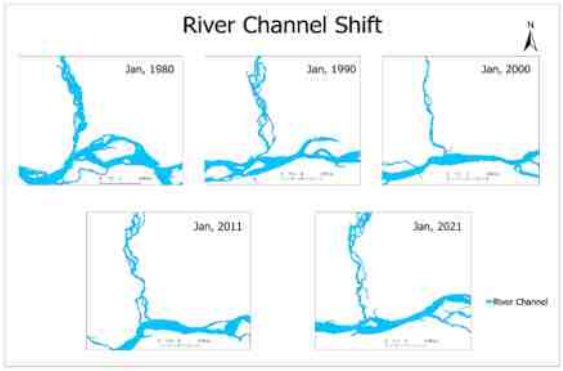

Fig .3: River Channel Mapping (1980-2021)

The Table .1 shows the area coverage by the channel in different years.

Table .1 Area of the river channel

Year	Area (sq. km)
1980	34.3
1990	28.5
2000	17.5
2011	21.02
2021	23.05

The change in the river channel decade-wise is shown in Fig .4. It can be visually interpreted that the channels don't have much common area, most of the channels are not overlapping, which illustrates the dynamic nature of the Brahmaputra river.

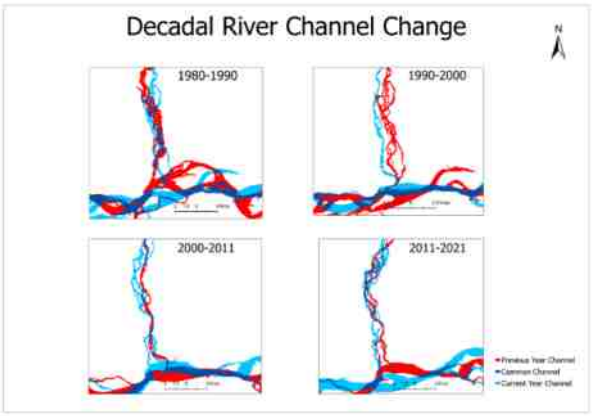

Fig. 4: Decadal River Channel Change

The change in the Kameng river channel between 1980-2021 is shown in Fig. 5. It has been analyzed that the Kameng river has shifted approximately 3 km towards the west where the capital city Tezpur is situated.

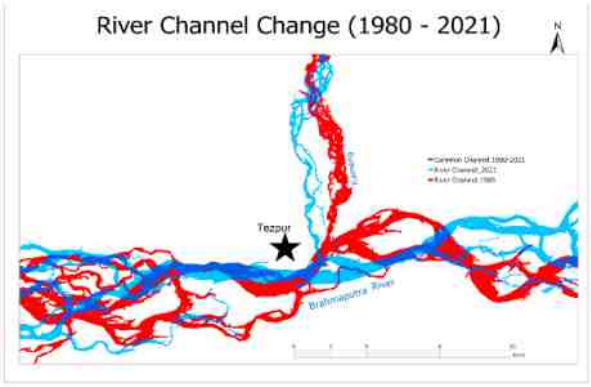

Fig .5: Kameng River Channel Change

The below-generated maps shown in Fig. 6 and 7 are the land use/land cover maps of the study area for the years 1995 and 2021. The classes considered were open water, built-up, agricultural land, shrub land, and forest area.

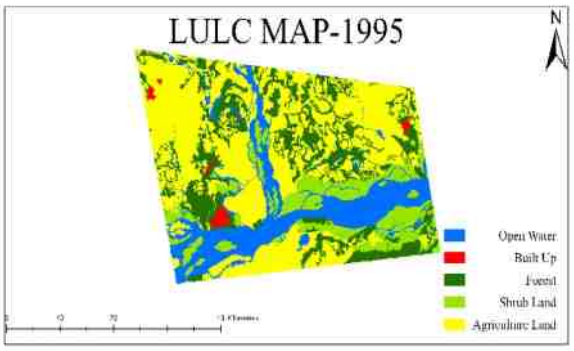

Fig .6 : LULC Map of the year 1995

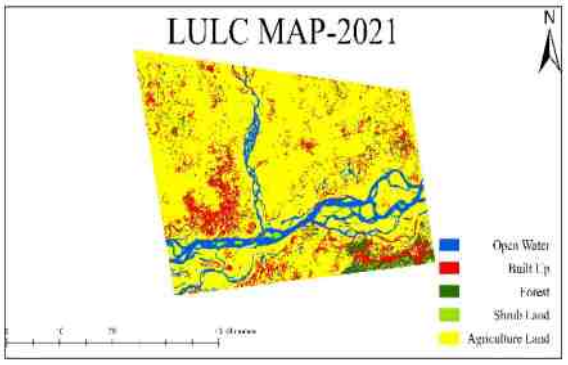

Fig .7: LULC Map of the year 2021

Throughout the study area, anthropogenic activities have had an obvious effect. The width of the river channel has changed very significantly over the two years.

According to the comparison, the changes occurring between the two study years are presented quantitatively in the Table. 2. The vertical column is from 1995 and the horizontally shown is for the year 2021.

Table .2 Change in the area (in square kilometers)

1995 \ 2021	Open Water	Forest	Agricultural Land	Built-up	Shrubland
Open Water		0.34	190.65	6.79	5.29
Forest	2.65		277.05	38.72	4.17
Agricultural Land	18.91	11.48		64.14	1.44
Built-up	0.14	0	5.62		0
Shrubland	30.37	7.44	154.4	31.27	

Table .2 shows that the area of Agricultural Land increased drastically also the area under the Forest class decreased over time. The Built-up area also increased over the last 40 years. In Fig.4.5 it can be seen that the river channel also changed in the year 1995 the river channel was wide with fewer tributaries and in the year 2021 it is very difficult to identify the main river channel and it also has a high number of tributaries which also affected the area under Open Water class.

The map below in Fig. 8 shows a general analysis that how the river channel is changing within a year after the flood. The one-year change analysis is helpful to understand the vital and vigorous nature of the channel. And thus, calls for more attention and analysis.

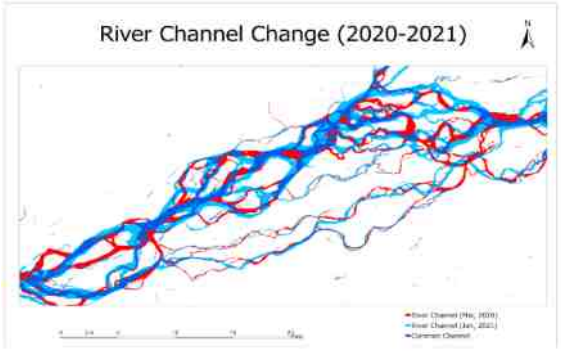

Fig. 8: Decadal River Channel Change

Conclusion

The Brahmaputra is a highly dynamic river that changes its channel every year. Flood is one of the important factors which causes river channel shift. Satellite data plays an important role in studying the nature of rivers due to its high spatio-temporal coverage. By mapping the change in river channels through historical time series data it can help in future flood zone delineation and hazard mapping for Disaster Risk Reduction. Every year our country faces high economic losses. loss of life both humans and wildlife and ecological damage due to the occurrence of floods. These kinds of studies can help in floodplain management and minimize losses.This study considers the static data associated with flooding and land cover distribution and therefore it can be easily customized.

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Coastline Extraction using Multispectral Satellite Imagery and Band Ratio

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Abstract

Coastal zones are changing throughout the world, due to anthropogenic activities, climate change and natural processes i.e., changes in sea level, sedimentation, and wave energy. Increase in population of coastal regions makes them vulnerable and hence, strong environment planning is required to control the degradation. Coastline, being a contact line between sea and land, is an important linear feature on earth's surface with dynamic nature. Traditionally, the coastlines are manually digitized which is time and labor-intensive. Remote sensing is a suitable alternative to extract coastlines using satellite imagery, this way both temporal and spatial aspects can be covered. The main objective of this study was to create an automated workflow which can be used throughout the world for extraction of coastlines. The whole workflow was created using ArcGIS API for Python. This technique can be used to extract coastlines for entire world.

Keywords: Coastline extraction, Band ratio, Multispectral Satellite Imagery, Change Detection, ArcGIS Python API

Introduction

Due to anthropogenic activities and natural processes i.e., changes in sea level, sedimentation and wave energy, coastlines are changing throughout the world. Hence, it is important to have updated data of coastlines for designing coastal defence strategies, future coastline position predictions, environment protection planning, hazard hotspots identification and sustainable management of coastal resources (Maiti & Bhattacharya, 2009). Coastline is contact line between sea and land, it is an important linear feature on earth's surface with dynamic nature. Traditionally, the coastlines were manually digitized which was time-consuming and labour intensive. Remote sensing is a good alternative to extract coastlines using satellite imagery, this way both temporal and spatial aspects can be covered.Satellite imagery of visible range can be used for interpretation and can be easily obtained. But the imageries covering infrared wavelength is best to extract boundary between land and water. So, the satellites which covers both visible and infrared spectrum are widely accepted for coastline extraction and mapping. Landsat satellites provides data of optical and infrared spectrums, the infrared band can be processed using thresholding to differentiate between land and water and generate coastline data. (Aedla, et al., 2015)

Recent widely accepted approach is to automate the extraction process using algorithms using different electromagnetic bands, these approaches are easy to use and gives accurate results with fast computation time (Niya, et al., 2013).(Louati, et al., 2014), created coastlines by doing image correction of Landsat imagery, used band ratioing to generate a binary image, reclassified raster and did some post processing on vector coastlines.

The objective of current study is to create a workflow for coastline extraction using Landsat-8 multispectral imagery which can be used for any part of the world and to extractcoastlines for different time and analyse the changes in the coastline over time. Landsat-8 data was used as it covers a wavelength ranging from 0.43 to 12.51 micrometres, and hence suitable for coastal and aerosol studies.

Study Area

Tamil Nadu is one the southern states of India and is the tenth largest state of India interms of area which is 130,058 $km^{2.}$ The state has second largest coastline in the country. The state's topography can be classified into two broad categories the hills in the east and north and the coastal plains in the east.

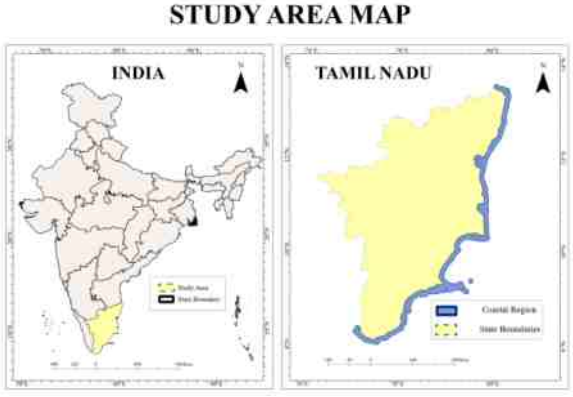

Fig.1: Location Map

The state has large coastline which is an important factor for natural resources, mining & mineral extraction, and commercial purpose. Due to anthropogenic activities, increase in urbanization, climate change and sea-level rise the coastline of the state is at risk of coastal erosion which directly affects the coastal ecology. By analyzing and monitoring the changes in the coastline over the past a robust management plan can be made and executed for coastal area management.

Materials & Methods

Data Used

ArcGIS online Multispectral Landsat imagery layer includes Landsat GLS and Landsat 8 imagery for use in visualization and analysis. This layer is time enabled and includes several band combinations and indices rendered on demand. The Landsat 8 imagery includes eight multispectral bands from the Operational Land Imager (OLI) with 30m spatial resolution and two bands from the Thermal Infrared Sensor (TIRS) of 100m spatial resolution. It is updated daily with new imagery directly sourced from the Landsat on AWS collection

Methodology

Multispectral imagery layers consist of data for whole world. First step is to filter out the cloud free data for the study area which will be used in the analysis. The buffer feature of 20 km was created from world boundaries. This feature layer geometry was used to get the Landsat-8 tiles of coastal areas.

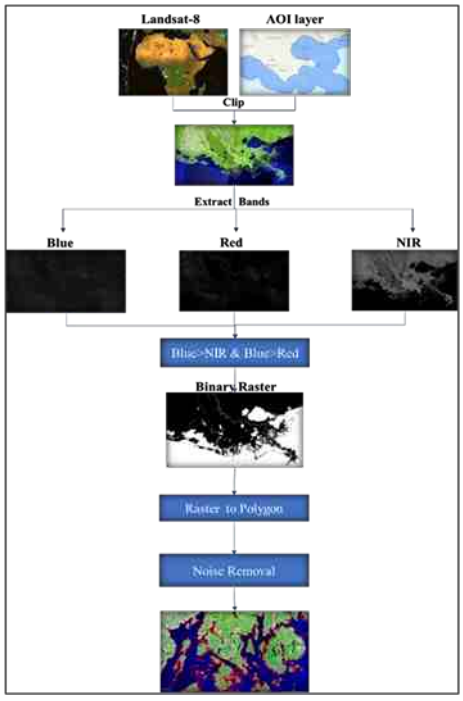

Fig.2 : Methodology

Mosaic of Landsat-8 tiles of study was created and Blue, Red and NIR bands were extracted from the mosaic raster. Second band of landsat-8 represents blue spectrum and covers 0.45 - 0.51 micrometer. Water has high reflectance in blue spectrum. Fourth band represents red spectrum and covers 0.64 - 0.67 micrometer wavelength of EMR spectrum. Red spectrum is highly absorbed by vegetation and this is useful to delineate between soil and vegetation. Landsat-8 fifth band covers 0.85 - 0.88 micrometers of EMR spectrum. NIR band is best for delineating land and water interface. Due to high absorption of water in NIR spectrum the reflectance of water is around zero whereas vegetation and land has high reflectance value. In NIR imagery the water appears black and land & vegetation appears bright grey to white which makes it easier to delineate land and water boundary.

A recent remote sensing technique to extract coastline is Band Ratio. In this technique the DN values of bands are divided to create a binary raster. NIR, Red and Blue bands were used for creating the binary raster. NIR band is selected as it can delineate water-land boundary, Red band is important for vegetation and water content and Blue band has high reflectance in water bodies. In the current study the following band ratio formula was used:

Blue>NIR & Blue>Red

The output of this formula is a binary raster which has 0 and 1 pixel value. 1 represents water (white pixels) and 0 represents land (black pixels) i.e. bare surface, vegetation etc. The binary raster was clipped out using buffered world boundary feature layer geometry to clip out the extra area and to minimize the processing time. The binary raster was converted to polygon, polygon with largest area was selected and other polygons were removed. Polygon was converted to line. Noise was removed using a mask of binary raster, to remove the extra lines a negative buffer of 10 meter was created. The remaining lines represents coastline.After getting the coastlines, next step is to map and analyse the change occurred in the coastline over the time from 1990 to 2021.The extracted coastlines for both years were overlayed to analyse the changes.

Results and Discussion

In this study, band ratioing technique using Landsat-8 imagery was used to extract coastline. The approach gave very accurate results, and it is easy to compute. The results were generated for the Indian state of Tamil Nadu. The results were generated for different type of topography to see the performance of the workflow and it gave

satisfactory results on all test areas.

First objective of this study was to extract coastlines accurately using Landsat-8 imagery.

Fig.3: Extracted coastline

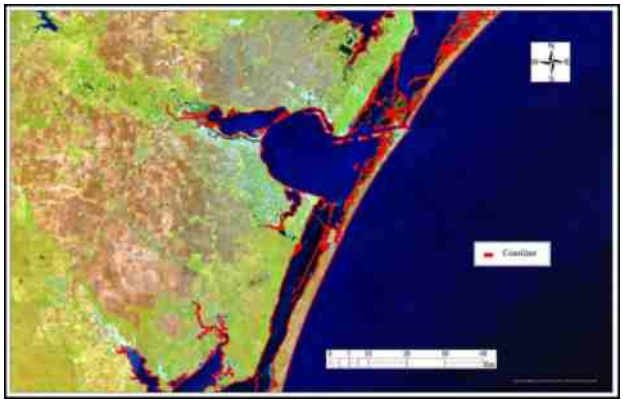

Fig.4: Extracted coastline

In the Fig.3 and Fig.4 two different coastal area can be seen, and the workflow was able to identify and extract the coastline.

Fig.5: Extracted coastline

In several papers it was mentioned that sometimes the waves are also gets identified as the coast. Fig.5 shows that by using this approach waves and coast can be differentiated accurately.

Second objective of the study is to extract coastlines and map the changes occurred in the the last 30 years. Coastlines for Tamil Nadu were extracted using band ratio technique for 1990 and 2021, the extracted coastlines were overlayed to analyse the temporal changes in the coastline. According to the literature both erosion and accretion takes place over the period. In the study area both cases were found, areas with high erosion rate and areas with high accretion rate.

Fig.6: Change Detection (Accretion) Map (1990-2021)

Fig.6 shows few test areas with high accretion rate. Here, the coastline moved towards the sea from 1990 to 2021 because in these areas the deposition rate of sediments is higher than the erosion rate.

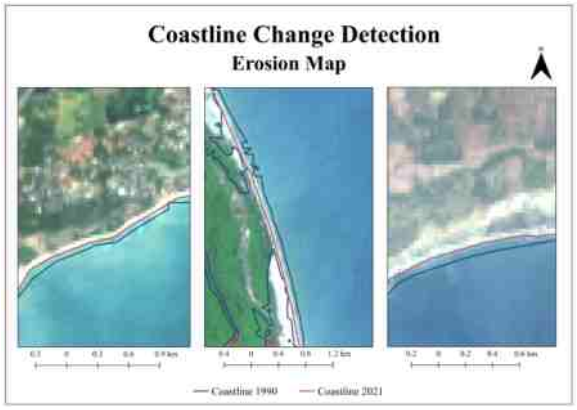

Fig.7: Change Detection (Erosion)Map (1990-2021)

Fig.7 shows few test areas with high erosion rate. Here, the coastline moved towards the land from 1990 to2021.

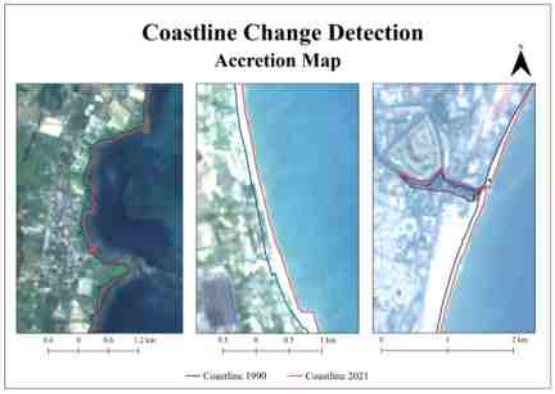

Fig.8 : Coastline Change Map (1990-2021)

Fig.9: Coastline Change Map (1990-2021)

Fig.10: Coastline Change Map (1990-2021)

Fig.11: Coastline Change Map (1990-2021)

Fig.8 - 11 shows the areas where the erosion rate was higher than the deposition/accretion rate of sentiments. These are the few areas where the change in coastlines is very prominent, in most of the areas whole land mass got eroded and a pass got created.

Conclusion

Band Ratio technique is an efficient method, which gives highly accurate results with less processing time, and it can cover both temporal and spatial aspects of coastline changes. Band Ratio technique is an easy to calculate method which gives highly accurate results with less processing time. The workflow can be applied on any area using multispectral imagery i.e., Landsat-8, Sentinel-2, etc.

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Smart Solutions to Develop Smart City using RS and GIS – A Case Study of Tumakuru, Karnataka

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Abstract

Artificial intelligence and technology are potent tools to aid planners and developers in optimally utilizing resources and manpower to deliver world class solutions to the variety of ills that plague urban and rural life in India. Geomatics although a relatively new branch of technology is a powerful Decision Support System for all infrastructure planning and implementation programmes. Digitally enabled organizations extending technology driven systems, processes and solutions to the citizen for accessing and addressing their utilities and services is the way to fast track controlled and planned development geared at transforming semi-urban towns into urban hubs of industry and commerce. The main aim of this study is to provide smart solutions to make Tumakuru as a Smart City by using geospatial data. The main pillar of this study is roof top Rain Water Harvesting (RWH) technique, through which rain water is captured from the roof catchments and stored in reservoirs. Building foot prints have been collected in GIS by digitizing geographical data from the Drone image. As per the results obtained, 690 ML of water is available by the Rain water harvesting from all sources in Tumakuru, out of which the residential buildings contribute the maximum. The estimation of roof top Solar Photo Voltaic (PV) potentialis the next pillar. By considering the efficacy factor and cost of panels the mono-crystalline solar panels proved to be economical and yielding good results. The last pillar is Continuous Water Supply System by distribution network to make Tumakuru a smart city. In order to avoid contamination into the water pipe lines from outside, a continuous pressurized water supply system is proposed as the part of smart solutions.

Keywords : Smart City, RWH, Solar Photo Voltaic (PV) potential, RS & GIS

Introduction

Urbanization is a worldwide phenomenon where all mega cities are rapidly developing due to various factors including population increase, industrialization and rural-urban migration. Though urbanization is a worldwide phenomenon, it's more prevalent in India due to high growth rate over last few decades (*H. Taubenbock, 2008*). Rapid urbanization and urban sprawl have significant impact on pressure over land, water and environment. Urban planning is a complex phenomenon hence accurate and updated information is needed to develop strategies for sustainable development.

In the approach of the Smart Cities Mission, the objective is to promote cities that provide core infrastructure and give a decent quality of life to its citizens, a clean and sustainable environment and application of 'Smart' Solutions. The focus is on the sustainable and inclusive development and the idea is to look at compact areas, create a replicable model which will act like a lighthouse to other aspiring cities. The Smart Cities Mission of the Government is a bold, new initiative. It is meant to set examples that can be replicated both within and outside the Smart City, catalysing the creation of similar Smart Cities in various regions and parts of the country(*Ministry of Urban Development, 2015*).

Geomatics is the branch of science that deals with the collection, analysis, and interpretation of data relating to the earth's surface. Geomatics is a natural consequence of the accelerated development of information technology; it's a combination of the basic concepts of Geodesy and Geoinformation. Geomatics encompasses a wide range of fields, including tools and techniques used in surveying, mapping, remote sensing, Geographic Information System (GIS), Global Navigation Satellite System (GNSS), Photogrammetry, Geography and other forms related to the mapping of the Earth. GIS is a very potent tool for decision making in almost all areas like infrastructure, environment, demography, urbanism, health, sociology, economics, tourism, administration, transportation and many others.

Study Area

Tumakuru is an industrial city located at 13°20'N longitude and 77°06'E latitude in the state of Karnataka as shown in figure 1. It has an average elevation of 822 meters (2696 feet). It is situated at a distance of 70 km northwest of

Bengaluru. Tumakuru is the headquarters of Tumakuru district. The city is well known for the Siddhaganga Mutt and education facilities. The Tumakuru district known for the production of coconut is called as "Kalpataru Nadu". The city has a population of 305,821 as per 2011 census.

The City Municipal Council jurisdiction extends upto an area of 75 square kilometres, within 35 wards. Recently, Government of Karnataka has accorded Tumakuru the status of city corporation and the city is now poised for rapid growth necessitating improvement in infrastructure and in particular ensuring safe and sustainable water services.

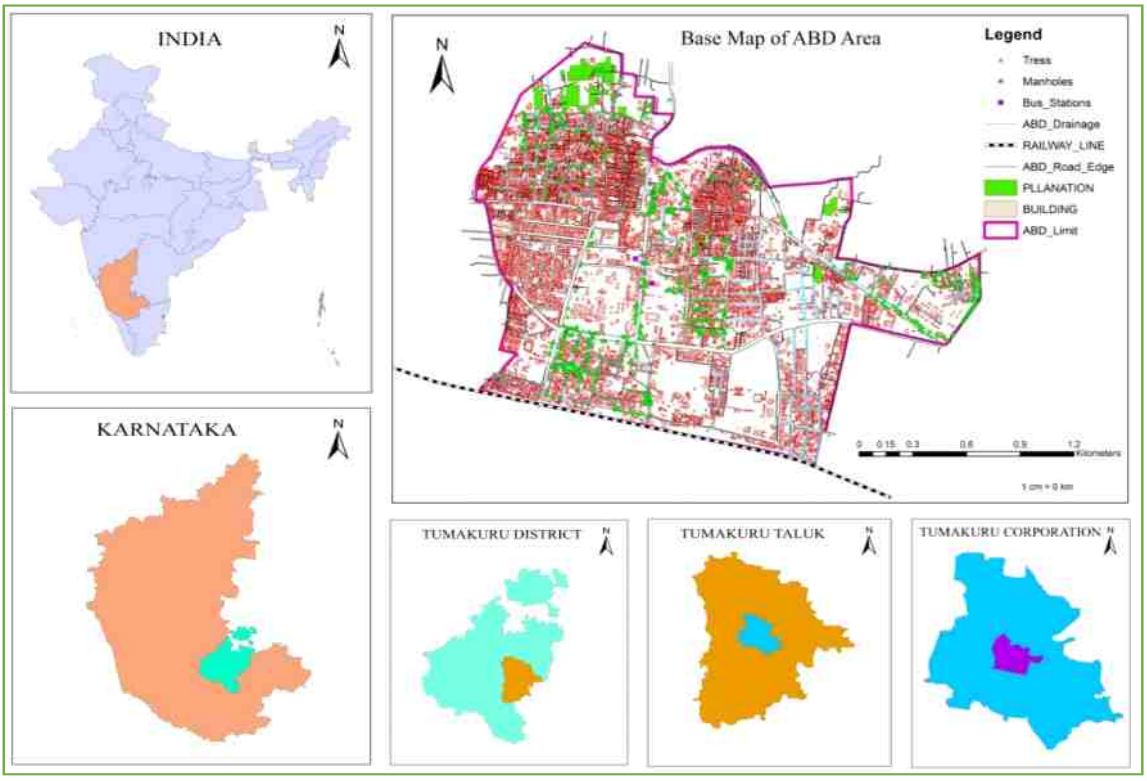

Fig.1 : Location Map of Study Area

Data Collection

The base materials include various raster data of the following:

I. Toposheet: 57G3 of the year 1973 and updated OSM sheet of 2005.
II. Satellite data downloaded from the Indian satellite website bhuvan.nrsc.gov.in with a tile no: D43R03.
III. Master Plan (2031) of Tumakuru city collected from Tumakuru Urban Development Authority (TUDA).
IV. Ward Maps from City Municipal Corporation of Tumakuru (CMC).
V. Area Base Development (ABD) Area from Tumakuru Smart City Ltd.
VI. Water Supply of Tumakuru from Karnataka Urban Water Supply and Drainage Board.

Methodology

The methodology for this study is depicted in figure 2 which involves the image processing and the generation of vector maps. It also involves the calculation of Rooftop solar photovoltaic potential, rainwater harvesting potential and generation of accurate GIS map containing the feature collection of rooftops, vacant land, water bodies as well as slope of the study area. Feature extraction of water supply network, nodes, input points etc are done to depict the continuous pressurized water supply system. Attribute data for the GIS map such as consumption of water and electricity at the household level, rainfall data etc are integrated into the study to obtain the percentage saving / generation of resources to provide a smart solution for environment friendly, optimum sustainable utilization of available infrastructure and resources. Having classified and categorized with available geographic and attribute data, it is harmonized and analyzed using suitable algorithms to obtain Geomatics solutions for sustainable utilization of resources and implementation of the same with reference to cost and infrastructure efficiency.

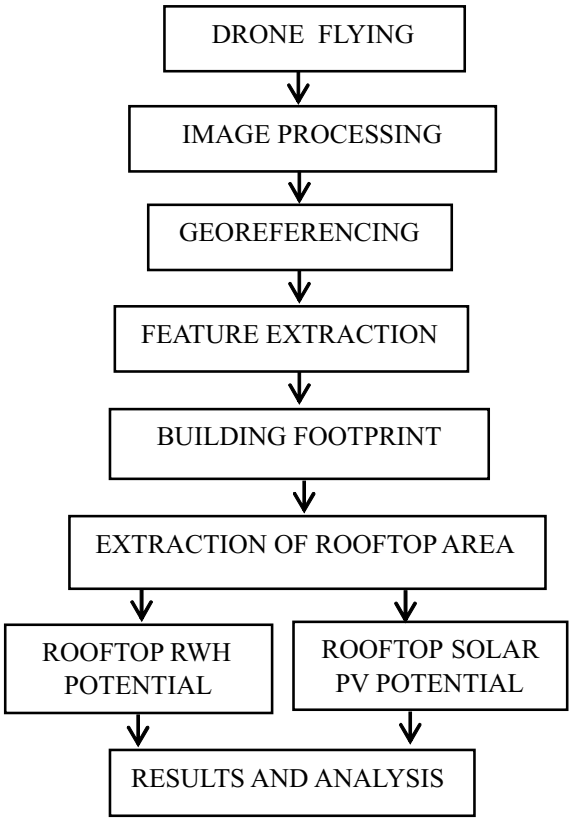

Fig. 2: Flow Chart for Methodology

Results and Discussions

While analyzing data and providing smart Geomatics solutions to develop Tumakuru into a smart city, the approach is to trace the change in use of land as that is the first index of development. The changing land use pattern throws light on the rate of growth that the city has experienced thus far. Addressing the need for improvement in infrastructure, Rain water harvesting potential, Solar PV generation potential and potential for equal pressure water supply are considered.

Household Level Water Harvesting

Most Indian Cities suffer from acute water shortage and one of the reasons is water loss caused from leakage occurs during the transportation of water from the source to the end user. A solution to the problem could be "Installing Rain Water Harvesting (RWH) System" at building level. Rooftop rainwater harvesting is the technique through which rain water is captured from the roof catchments and stored in reservoirs. Harvested rain water can be stored in sub-surface ground water reservoir by adopting artificial recharge techniques to meet the household needs through storage in tanks. Rainwater is collected in built-up tanks. This water not only can be used for direct consumption but also for recharging groundwater through simple filtration devices.

Roof Area for harvesting

The roof area available for Rain Water Harvesting (RWH) is the total roof area of the buildings.The rooftop polygons of buildings are categorized into four types based on their type of roofs which are galvanized iron sheet, asbestos sheet, tiled roof and concrete roof. These data are added in the attributes field while digitizing the rooftop polygons.

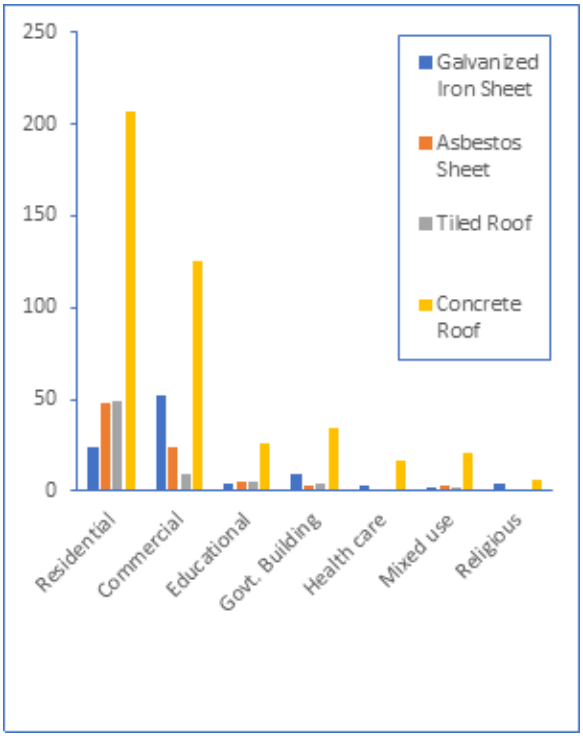

Fig. 3: Roof Area Available for Rainwater Harvesting.

The Rooftop polygons are categorized into seven different property categories viz. Residential, Commercial, Educational, Govt. Building, Health Care, Mixed use and Religious. The area is obtained from the Arc map with help of selecting the attributes for each and every property categories and type of the roof. The overall view of the area of roof is shown in Fig.3.

Assessment of collection of rainwater

For the successful implementation of Rain water harvesting, an estimation of the volume of roof water is necessary. The volume of roof water available from water harvesting is calculated and shown in Table 1.This can be calculated using the following equation:

Water available from Roof (W) in cubic metre = T * A * R

Where:

T = Total Roof area (Sq.m)

A = Average Rainfall (m)

R = Runoff Coefficient

Table 1 Water Available from Roof in MLD (cu.m)

Details	Galvanized Iron Sheet	Asbestos Sheet	Tiled Roof	Concrete Roof	Total (Cu.m)
Residential	23.57	47.80	49.21	207.16	327.74
Commercial	51.64	23.75	9.73	125.75	210.87
Educational	4.33	4.64	5.63	25.88	40.48
Govt. Building	9.62	2.96	3.57	34.60	50.75
Health care	3.06	0.92	0.21	16.95	21.14
Mixed use	1.62	2.72	1.97	21.11	27.42
Religious	3.56	0.71	0.53	6.41	11.21
Total	97.40	83.50	70.85	437.86	689.61

In this study around 48 % of the roof area is obtained from the residential buildings, 30% of the roof area from commercial buildings, 6% roof area from educational, 7% area fromGovt. buildings, and 3% area from health care, 4% area from mixed use and 2% area from religious. The total water demand in the study area is 3810 ML. The rain water harvesting from the galvanized iron sheet results in around 2.56 percent reduction in the water demand, Asbestos Sheet is 2.19 percent, tiled roof is 1.86 percent and concrete roof is 11.5 percent. The overall water reduction from the rain water harvesting can be observed as 18.1 percent. As per the results obtained 690 ML of water is available from the rain water harvesting from all sources which is depicted in Table1. Implementation of rain water harvesting at the household level will yield 18.1 % (690 ML) which can be stored in individual storage tanks. The rain water harvesting potential large areas like commercial buildings, govt. buildings, educational institutes and health care can be harnessed to recharge the ground water table. This amounts to 46% of the demand (323 ML) which almost matches with the household potential. Thus, even if rain water harvesting is not implemented at the household level, a matching reduction in demand can be affected by implementing rainwater harvesting in commercial, government, educational and health care facilities.

Rooftop Solar Photo Voltaic (PV) Potential

Solar energy is one of the major sources of renewable energy and because of its geographical location like India,the domestic electricity demand in India can be met by installing solar PV modules in an outdoor area or using rooftop PV modules. Rooftop PV system generates Direct Current (DC) electrical power using photovoltaic effect. This power can be stored in a battery or used as per the requirement. It uses a part of roof area (depending upon the PV module size and output) for installing PV modules which acts as an energy source. The generated electricity is stored in batteries, used directly or fed to the grid using inverter circuit.

Estimating Availability of Rooftop Area

Having obtained total roof area for a region, it is necessary to reduce this area that which could be available for solar photovoltaic applications, in order to determine potential power output. There are many factors which influence the fraction of availability of the total roof area, E.g.: 1) Shading from other parts of the roof or from neighboring buildings and trees; 2) Use of roof space for other applications/elements, such as ventilation, heating/air conditioning, dormers or chimneys; 3) Orientation of pitched roofs; and 4) The installation and racking of the PV panels themselves; 5) practice of using part of the roof for many household activities, including evening sit-outs, sleeping at night, clothes drying etc.

Thus, the roof area available for PV installation (APV) is the total roof area (A Roof) multiplied by the reported and chosen fraction as indicated below:

$APV = 0.3 * A\,Roof$

APV = 0.3*1240623 sqm

APV= 372187 sqm

Thus, for the Test area, APV = 372187sqm = 0.37 sqkm

Estimating Rooftop Solar PV Potential of the Test Area

Solar Photovoltaic (SPV) technology is primarily a solid-state semiconductor-based technology, which converts a fraction of the incident solar radiation (photons) into direct electricity. Solar PV system an deliver electric energy to a specific appliance and/or to the electric grid. Photovoltaic systems are flexible and modular; hence the technology can be implemented on virtually any scale size, connected to the electricity network or used as stand-alone or off grid systems, easily complementing other energy sources.

Potential Energy output/day is calculated as:

E = APV*GHI*Npv*Npcu

Where:

APV = Area available for PV installation (APV)

GHI = Global Horizontal Insulation (kWh/m2)

Npv = Module efficiency

Npcu = Efficiency of the power conditioning unit including the inverter

(The efficiency of the power conditioning unit including the inverter for Grid Tie Solar Inverter is considered as 85%.)

In this study around 164304 sqm of the roof top area is available for Solar PV installation from residential buildings, 102638 sqm from commercial buildings, 20133sqm from educational, 25111sqm fromGovt. buildings, 10623 sqm from health care, 13907 sqm from mixed used and 5378 sqm from religious are available. In this study grid tie invertor is considered for estimation of rooftop solar PV potential its capital cost is around Rs. 50,000 to Rs. 70,000. Four different panels such as Mono-crystalline Solar Panels, Polycrystalline Solar Panels, Thin-Film: Amorphous Silicon Solar Panels and Concentrated PV Cellsare used based on the study with respect to its module efficacy and cost. By considering the efficacy factor and cost of panels, the Mono-crystalline Solar Panels give good results and found to be economical.

Continuous Pressurized Water Supply

Continuous water supply system means, water is available in the tap round the clock on all days on a continuous basis as in case of electric supply. In a continuous supply, the distribution system remains continuously pressurized so that no contamination can enter the water pipelines, even when there are small leaks in the system. If water with sufficient pressure is available, it can flow automatically upto third floor of the houses without any in-home storage or pumping. And more importantly, water will be free from contamination that can be consumed right from the tap without fear of illness.

Water Distribution Network Map

The water distribution network map has been prepared for the total Area Based Development(ABD) area. The water distribution network map which consists of the distribution pipe line, node points/junctions, overhead tank, Bulk flow meter, sluice valve, critical pressure monitoring point and DMA boundaries which cover total area of 4.3 sq km. In this study area, total 6 No. of overhead tanks are available with different storage capacity. Bulk flow meter is mainly used to measure accuracy of flow rates in this study which consists of 14 No.of bulk flow meters which are mainly fixed for main supply line. Sluice valve or gate valve is used to start or stop the water flow through water supply system. In this water supply network, 150 sluice valves are available. Critical pressure monitoring points are mainly used to measure the pressure readings of the flow in the water supply network, 31 critical pressure monitoring points are adopted. This water supply network which is having total length of 100.08 km in which there are 2026 no. of nodes available and the link pipes between the nodes are 1748 nos.

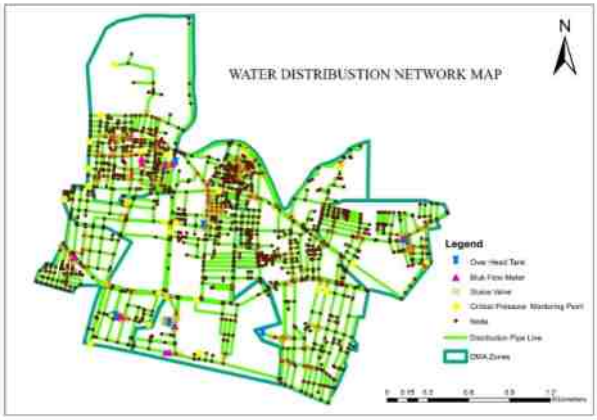

Fig. 4 : Water Distribution Network Map

The water distribution network map has been prepared based on the data collection from the Karnataka urban water supply & Drainage Board, Tumkur which is shown in figure 4. The water distribution network map includes major components such as Node/Junctions and the Pipeline/Links, etc. The EPANET software is designed as research tool for distribution system analysis. The EPANET software is having .INP file format. In this study the water distribution network map will act as backdrop for the new network preparation in the EPANET software. For the hydraulic simulation in the EPANET the DMA 12 is taken as the sample study. From the DMA 12 water distribution network map, the junctions and pipeline links are drawn using the EPANET software. The input data are also provided while drawing the network. Finally, after completion of the water distribution network the model is run for the analysis. The hydraulic simulation results are expressed in various reports which are like junction report, pipe report, nodal pressure results, flow rate and velocity reports.

Junctions are points in the network where links join together and water enters and leaves the network. The basic inputs required for the junctions are elevation and water demand. The elevation values for each junction are added based on the contour line readings which are displayed in meters. The water demand readings are obtained from the Karnataka urban water supply & Drainage Board for each junction. The output results are computed at junctions by hydraulic simulation which

consist of the hydraulic head in meters and pressure values for each junction.

Conclusion

In this study an attempt was made to provide smart solutions to make Tumakuru a smart city. One of the important solutions for water scarcity in the city is Rooftop Rain water harvesting. In this study around 48 % of the roof area is obtained from the residential buildings, 30% of the roof area is commercial buildings, 6% roof area is educational, 7% area is govt. buildings, and 3% area is health care, 4% area is mixed used and 2% area is religious are available. As per the results obtained, 690 ML of water is available from the rain water harvesting from all sources. In this study around 164304 sq m of the roof top area is available for Solar PV installation from residential buildings, 102638 sq m from commercial buildings, 20133sq m from educational, 25111sq m from Govt. buildings, 10623 sq m from health care, 13907 sq m from mixed use and 5378 sq m from religious are available. In Continuous water supply system, i.e., water available in the tap round the clock on all days on a continuous basis as in case of electric supply, the distribution system remains continuously pressurized so that no contamination can come into the water pipelines even when there are small leaks in the system. If water with sufficient pressure is available, it can flow automatically upto the third floor of the houses without any in-home storage or pumping.

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Mapping Agricultural Vulnerability of Coastal Areas in the Context of Climate Extreme: A Post Yaas Cyclone Assessment of Purba Medinipur, East Coast of India.

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Abstract

The increasing trend of climate variability and climatic extremes is diametrically impeding the agricultural sector in the context of climate change. The agriculture and livelihood of coastal communities are on the front line of this situation. Therefore, analysis and zoning of vulnerability and its severity at the micro level could help the policymakers and local community to manage the situation. The present study examined the agricultural vulnerability of the Purba Medinipur coastal area, a part of India's east coast, in the context of cyclone "Yaas", considering different dimensions of vulnerability, i.e., exposure, sensitivity and adaptive capacity. The study assigned a weightage to each selected indicator according to importance to calculate the vulnerability by applying the Analytical Hierarchical Process (AHP) and mapped the result. The result shows that the highest vulnerable zones are situated nearer to the coast, substantiating a strong association between agricultural vulnerability and the distance from the coast.

Keywords: Cyclone Yaas, agricultural vulnerability, coastal area,Analytical Hierarchical Process, agricultural community, Purba Medinipur coast.

Introduction

Tropical cyclones are considered as one of the most devastating extreme climatic events. The frequency and intensity of tropical cyclones are increasing in the present day as a result of climate change and global warming (IPCC, 2012). Tropical cyclones have some immediate impacts, such as the destruction of properties and life due to high-velocity wind. However, these events also have long-term effects, like the inundation of cropland, fishing ponds, drinking water sources, etc., due to torrential rain and storm surges that may last weeks and months. Moreover, these cyclonic events have the maximum impact on coastal regions, the transitional zone between land and water mass. According to several studies, the east coast of India is more vulnerable to cyclonic disturbances than the western coast– –(Mohapatra & Vijay Kumar, 2017; Singh, 2007; Singh et al., 2000; Vissa et al., 2013). West Bengal coast is the easternmost coastal part of India and is highly susceptible to cyclones, with the second highest number of the landfall of pre-monsoon cyclones.

Tropical cyclones frequently strike the low-laying coastal area of West Bengal and damage lives and properties (Hazra, 2012)" (Halder et al., 2021; Kumaresh & Chandrabose, 2014). The coastal West Bengal comprises three coastal districts, Purba Medinipur, South 24 Parganas and North 24 Parganas, where most of its population depends on agriculture. Thus, the devastating and long-term effects of cyclonic events can be observed in this sector (Kumaretal.,2021:UNICEF Kolkata,2021)

The last cyclone on the list that devastated the West Bengal coast was cyclone "Yaas." Cyclone Yaas was a Very Severe Cyclonic Storm (VSCS) that formed and dissipated between May 23 and May 28, 2021. Although this VSCS made landfall near Dhamra port, Odisha, it severely impacted the three coastal districts of West Bengal. Heavy cyclonic rainfall and storm surge causes flooding in the coastal districts of West Bengal. According to some reports and news articles, the destruction was relatively high in the district of Purba Medinipur than in the other coastal districts of West Bengal "(The New Indian Express, May 27,2021; UNICEF Kolkata,2021) . The inundation of agricultural fields and fishing lands causes a substantial economic loss which sustains even after a long event. Moreover, Strom surge flooding is responsible for saline water intrusion in the agricultural fields and may cause longtime damage, which may distress the livelihood of the local farming community.

Assessment and mapping of Agricultural Vulnerability is a helpful tool to identify the zones where agriculture is

vulnerable and the magnitude of its vulnerability'—(Bjarnadottir et al., 2011; Mudasser et al., 2020; Rajesh et al., 2018). Through this vulnerability assessment, the impact of different climatic events on agriculture is quite popular among researchers. Remotesensing plays a vital role in studying various climatic hazards and collecting information. The researchers widely use high-resolution Synthetic Aperture Radar (SAR) data to identify the inundated areas after the cyclone's landfall"(Borah et al., 2018; Halder et al., 2021; Kussul et al., 2011), which makes the assessment process more accurate. The current study aimed to analyse the agricultural vulnerability of the Purba Medinipur coastal area after the cyclone Yaas by applying Analytical Hierarchy Process (AHP) with geospatial techniques.

Study Area

Six coastal administrative blocks in the Purba Medinipur district of West Bengal were selected as the subject of the study (Figure 1& 2). The study area is located Between 21°36′39″ to 22°05′33″ North and 87°29′01″ to 87°58′39″ East. The geographical coverage of the study area is 1078.08 square kilometres, of which 68.47% is predominantly used to practice rain-fed Aman Paddy cultivation. The tropical climate characteristics prevail in the area with the occasional occurrence of cyclones. The average temperature ranges from 25.50°C to 38.60°C, with an average rainfall of 1,752.6 mm. The “coastal saline” agro-climatic zone encompasses the region where loamy and fine soil set an excellent background for agriculture.

Database and Methodology

Three major dimensions of vulnerability analysis, e.g., exposure, sensitivity, and adaptive capacity, were analysed separately to assess the agricultural vulnerability of coastal areas with respect to cyclonic events. Several parameters were considered under each major dimension. For Exposure analysis, elevation, slope, coastal erosion, land use and land cover were selected. Whereas the population engaged in agricultural activity, the amount of agricultural land and amount of inundated land due to Yaas cyclone were taken to analyse the sensitivity index. In the same way, literacy, income, and land with double cropping were considered for adaptive capacity assessment.

Finally, the Agricultural Vulnerability was calculated using the following equation-

$$Agricultural\ Vulnerability\ Index = \frac{(Exposure \times Sensitivity)}{(Adaptive\ Capacity)}$$

Where exposure is the extent to which the agricultural system is subject to the adverse impacts of climate change (IPCC 2012). Sensitivity is the degree to which the agricultural system is affected by, or responsive to, climate stimuli (IPCC 2012). Adaptive capacity is the ability or potential of the agricultural system to respond successfully to climatic events and includes adjustments in behaviours, resources and technologies (Adger et al. 2007).

Analytical Hierarchy Process (AHP) was applied to give weightage to each parameter of exposure, sensitivity and adaptive capacity index. The Analytic Hierarchy Process (AHP) approach is one of the most widely used methods for evaluating and ranking alternatives. To establish the relative value of these variables, we organised all the data into a hierarchical structure and conducted paired comparisons using human cognitive ability.Numerous specialists with backgrounds in agriculture, meteorology, economics and human resource management were considered. Finally, a primary survey was conducted to know farmers' perceptions in the region before allotting the weightage. The weightage which was assigned in the same process for each parameter is given below (Table 1)-

The mapping of the distribution of different parameters and Vulnerability Index (VI) were prepared using ArcGIS. The identification and mapping of inundated areas after the Yaas cyclone were made by using SNAP software. The following data sets were used to do the whole work (Table 2).

Result and Discussion

Exposure

A total of five parameters were selected for the exposure assessment (Figure 3). Geomorphological characteristics, elevation and slope, were the physical parameters for exposure analysis in the coastal area. In coastal geomorphology, younger coastal plains are considered vulnerable due to their dynamicity and activeness. The elevation and slope of coastal areas are also important parameters for coastal exposure. The region's maximum area belongs to the low elevation and gentle slope category, which increases the chance of inundation from torrential rain and storm surge. Another important aspect of coastal vulnerability is coastal erosion. The part of the coast where coastal erosion is predominant could face the most severe damage from the cyclonic events. Here, the rate of coastal erosion is highest on the West Bengal coast among all the other coastal areas, making the region very exposed.

Land use and land cover is another critical factor

influencing the exposure of the coastal area. For example, in the Purba Medinipur coastal area, most of its land use belongs to agricultural land, making it very sensitive to cyclones and storm surges.

Exposure Index

The Adaptive Exposure Index result shows that nearly 40% of the area belongs to a very high to high adaptive capacity zone (Figure 4). Most of the Khejuri II, Nandigram I, Ramnagar I and Ramnagar II block area belongs to this high exposure zone due to its landuse land cover pattern, low elevation and high coastal erosion.

Sensitivity

A total of three parameters were considered to analyse the sensitivity of Purba Medinipur coastal area (Figure 5). The number of the population engaged in agricultural activity is regarded as one of the important parameters for sensitivity. More engagement in agricultural activity means more dependency on agriculture which causes high sensitivity. The amount of agricultural land available in the area is selected as the second parameter of the sensitivity. Finally, the area inundated by cyclone Yaas is considered one of the most critical parameters for the sensitivity analysis in the study area. It identifies the inundation zones which were flooded due to torrential rain and storm surges.

Sensitivity Index

The sensitivity index has found nearly 40% of the area with high to very high sensitivity (Figure 6). Most of the very high sensitive zones are situated in the study area's eastern part, mainly in Khejuri II and Nandigram I blocks. Ramnagar II and Contai I block also have a large share of very high sensitive zones. Due to cyclonic rainfall and storm surges from Yaas, a vast inundation and the presence of many agricultural lands make them so sensitive.

Adaptive Capacity

Three major parameres were selected to evaluate the adaptation capability in agriculture in the study area (Figure 7). First, income was considered one of the essential components of adaptive capacity. the area was divided into five categories, i.e., very lower, lower, lower middle, middle and upper middle income, where higher income means higher adaptive capability. Literacy makes a farmer wise and confident to take any adaptation decision. Thus, the literacy rate is a positive factor for the adaptive capacity of an area or a community. Finally, the amount of double-cropping land was considered an essential determinant of the area's adaptive capability. A higher amount of double or multiple cropping land means a higher chance of overcoming the loss of a particular crop for a specific time. For instance, in the study area, only a few amounts of land are available for producing both the summer and winter paddy; thus, if any extreme climatic event (i.e., cyclone) damages the winter paddy, they can not overcome the loss.

Adaptive Capacity Index

The Adaptive Capacity Index result shows that nearly 38% of the area belongs to a very high to high adaptive capacity zone (Figure 8). Most of the Khejuri II and Ramnagar I block area belongs to this high adaptive capability zone because of the availability of double cropping land high income. On the other hand, most areas with low to very low adaptive capacity fall into Deshapran, Nandigram I, and Ramnagar II blocks, which are more than 20% of the total area. Overall, the Purba Medinipur coastal area shows moderate adaptive capacity against cyclone vulnerability in the agricultural sector.

Agricultural Vulnerability Index

After assessing the Agricultural Vulnerability of the Purba Medinipur coastal area, the result found that 42.77% of the total area has a high to very high vulnerable category (Figure 9). The very high to high vulnerable zones were found in the coastal part of Nandigram I, Ramnagar I &II, and in the interior portion of the Deshapran block. The inundation due to the Yaas cyclone and the absence of double cropping lands played a vital role in these areas' becoming highly vulnerable agricultural zones. On the contrary, despite having high inundation area, Khejuri II belongs to a low vulnerable zone because of its high adaptive capacity. another vital aspect of the result is the nearness to the coastal erosional zones making agriculture more vulnerable to cyclonic events like Yaas.

Conclusion

The various climate reports and scientific research claim that the frequency and intensity of severe tropical cyclones like Yaas are increasing significantly. In the Indian subcontinent, the Bay of Bengal is one of the leading breeding grounds for such devastating tropical cyclones. The scenario would be more critical in the coming decades, which would cause more damage in the coastal areas of surrounding regions, especially on the east coast

of India. The agricultural vulnerability analysis and mapping could be crucial in identifying areas where agriculture could be devastated if a cyclone strikes the coastal zone. This vulnerability assessment becomes more important for coastal regions like Purba Medinipur, where highly fertile agricultural lands are available, and a significant portion of its population solely depends on agriculture. This study would help the agrarian stakeholders and policymakers to develop a better strategy and planning for better management of such harsh situations.

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Table 1: Data source and details

Parameters	**Data source**	**Details**
Elevation and Slope	Shuttle Radar Topographic Mission (SRTM) Digital Elevation Model (DEM)	Date: 11.02.2000; resolution: 30m
Land use and land cover, Agricultural land detection	Landsat 8 (OLI)	Date: 28.03.2020; resolution: 30m
Coastal erosion	Landsat 8 (OLI) and Google Earth image	years: 1990 to 2020
The inundated area due to Yaas	Sentinel-1A SAR data	Date: 29.05.2021; Resolution: 5m
The population engaged in agriculture, literacy, income	Census of India	Year: 2011

Table 2: Assigned weightage

Dimension	**Parameters**	**Weightage**
Exposure	Slope	0.190635
	Elevation	0.120499
	LULC	0.27071
	Coastal erosion	0.418156
Sensitivity	The population engaged in Agriculture	0.136505
	Agricultural land	0.238491
	The inundated area due to Yaas	0.625005
Adaptation Capacity	Income	0.276351
	Literacy rate	0.128271
	Double cropped land	0.595378

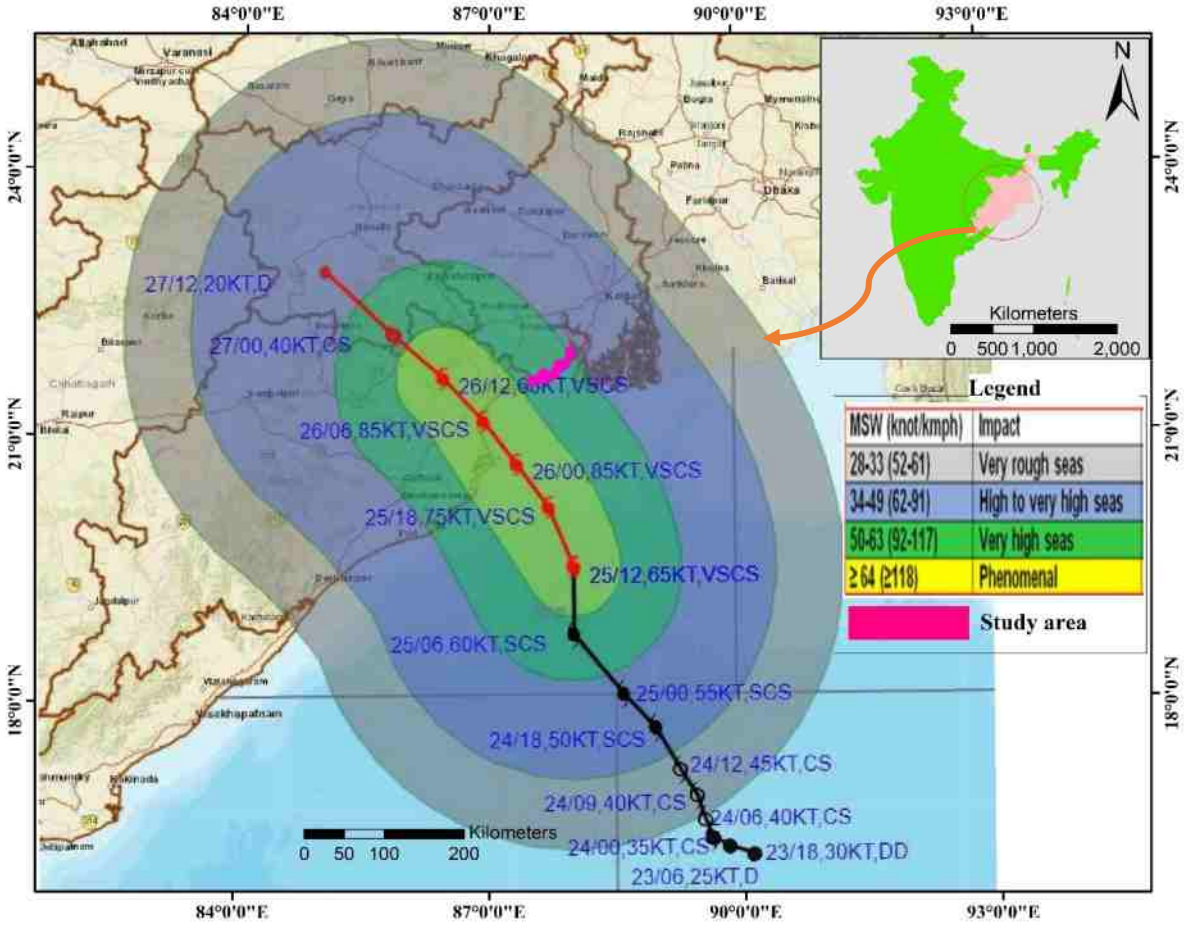

Fig. 1: Study area with cyclone Yaas's track; Source:RSMC-Tropical Cyclone, New Delhi .

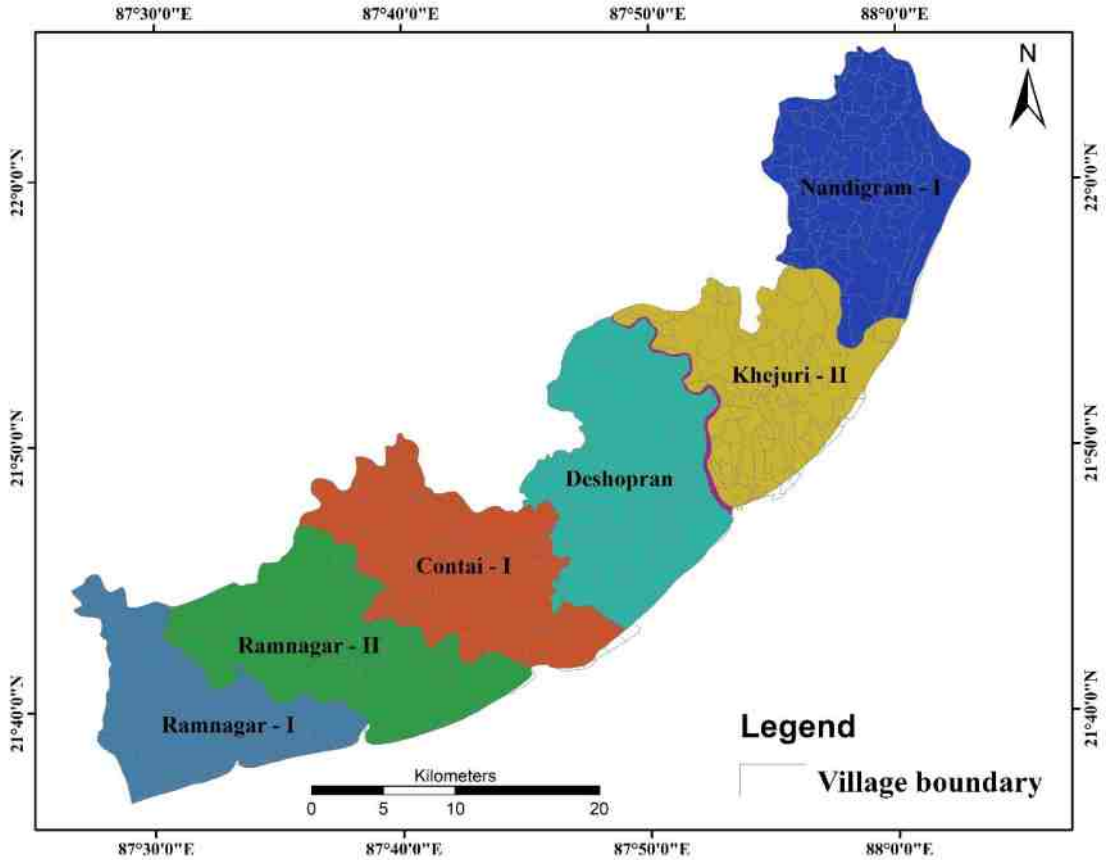

Fig.2: Adminastrative blocks of the study area with village boundaries.

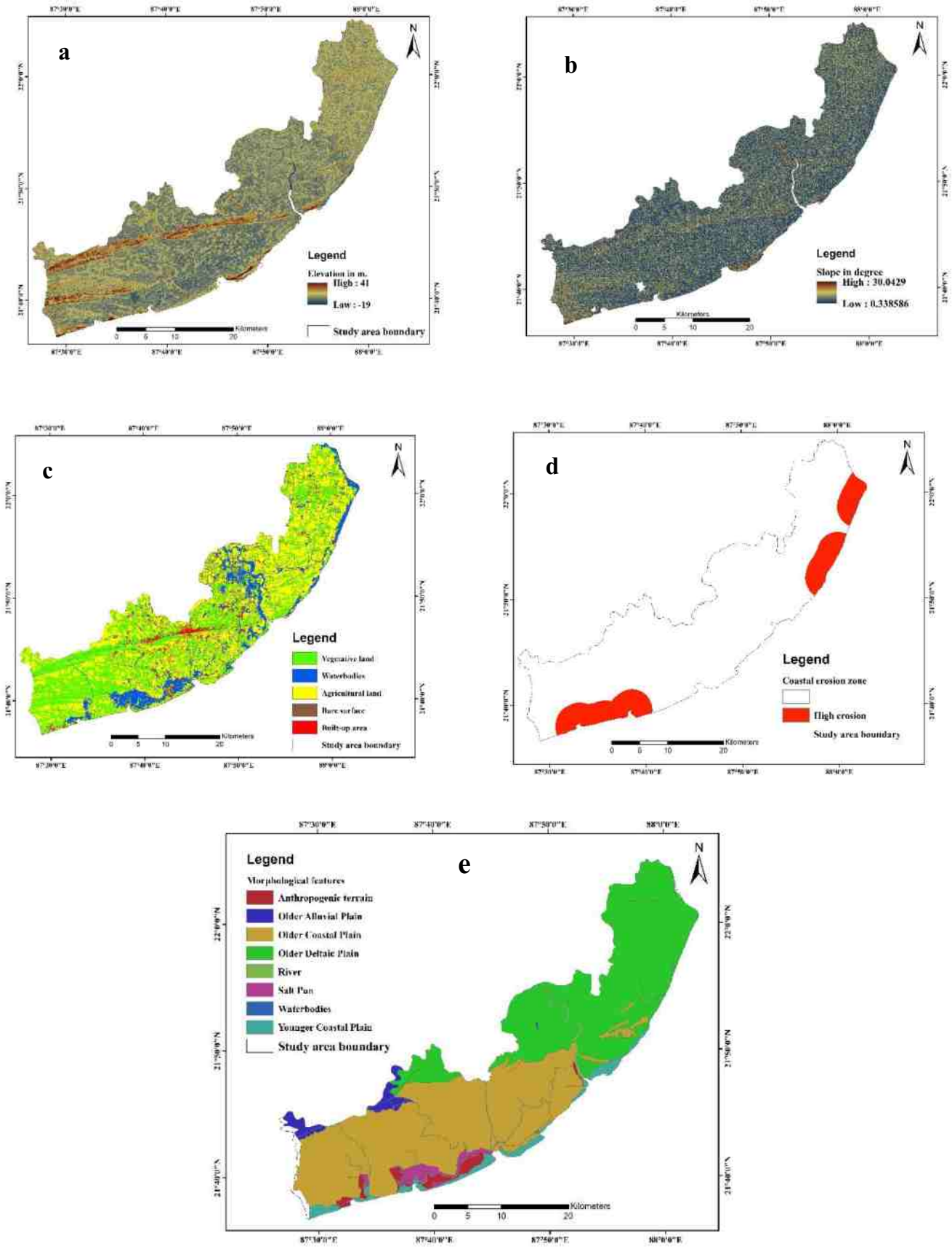

Fig. 3: Parameters for calculating exposure index; a:DEM; b: slope; c:LULC; d: Coastal erosion; d: Geomorphology

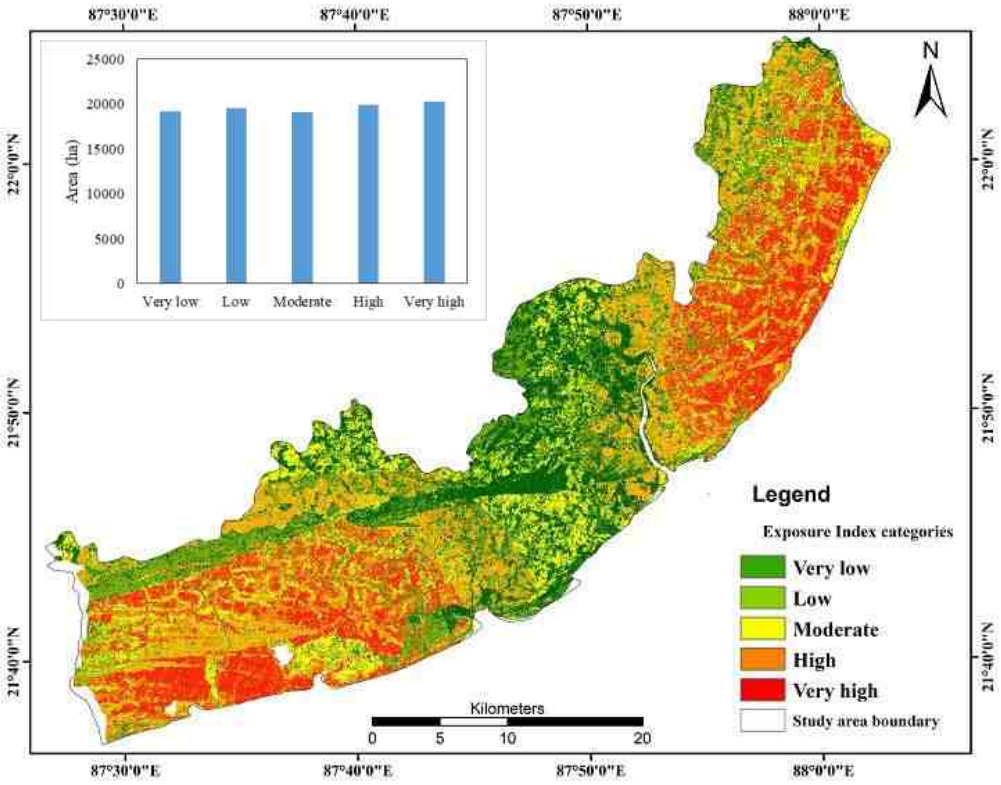

Figure 4: Exposure Index

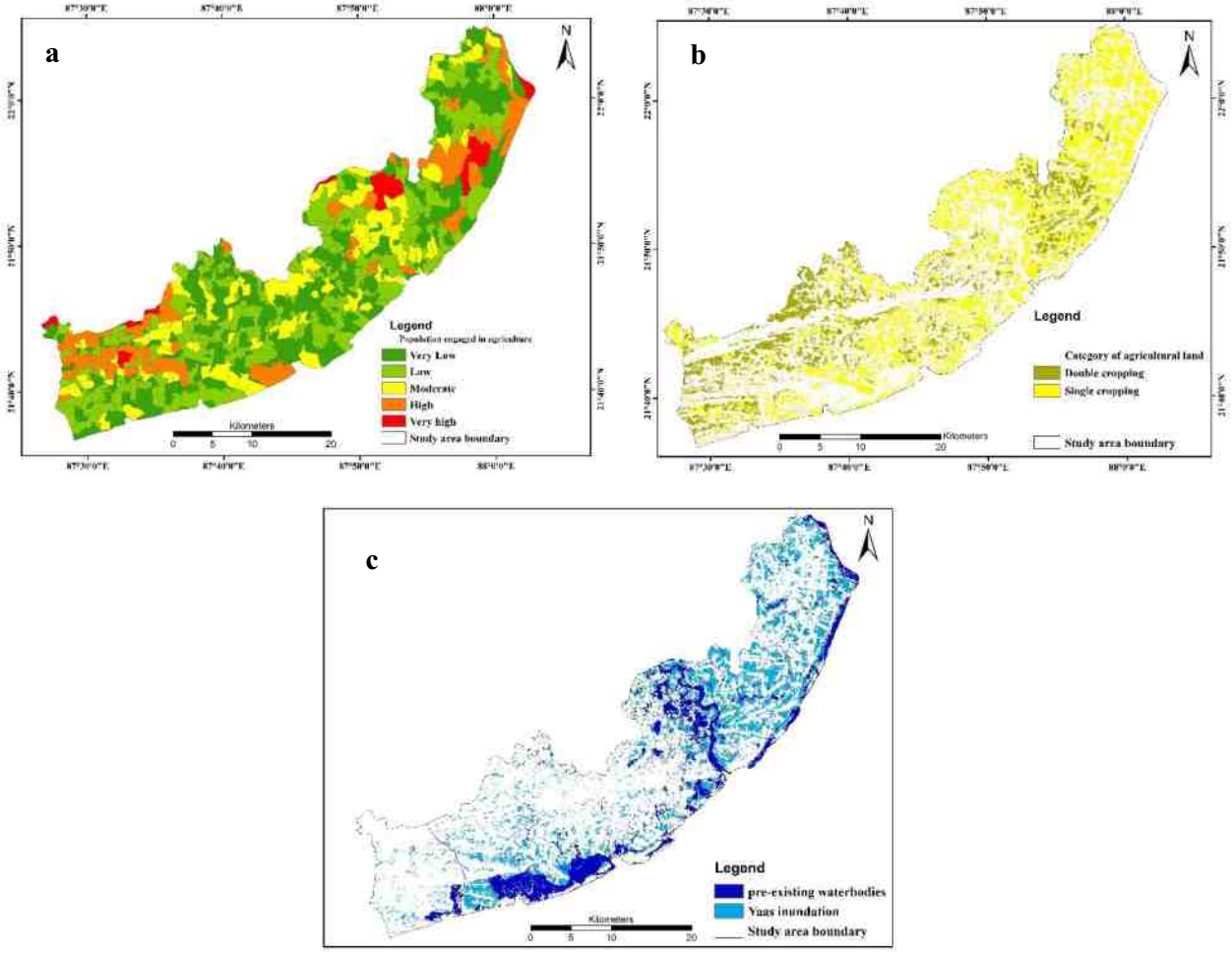

Fig.5: Parameters for calculating sensitivity index; a: Population engaged in agriculture; b: Agricultural land; c: Inundation due to cyclone Yaas

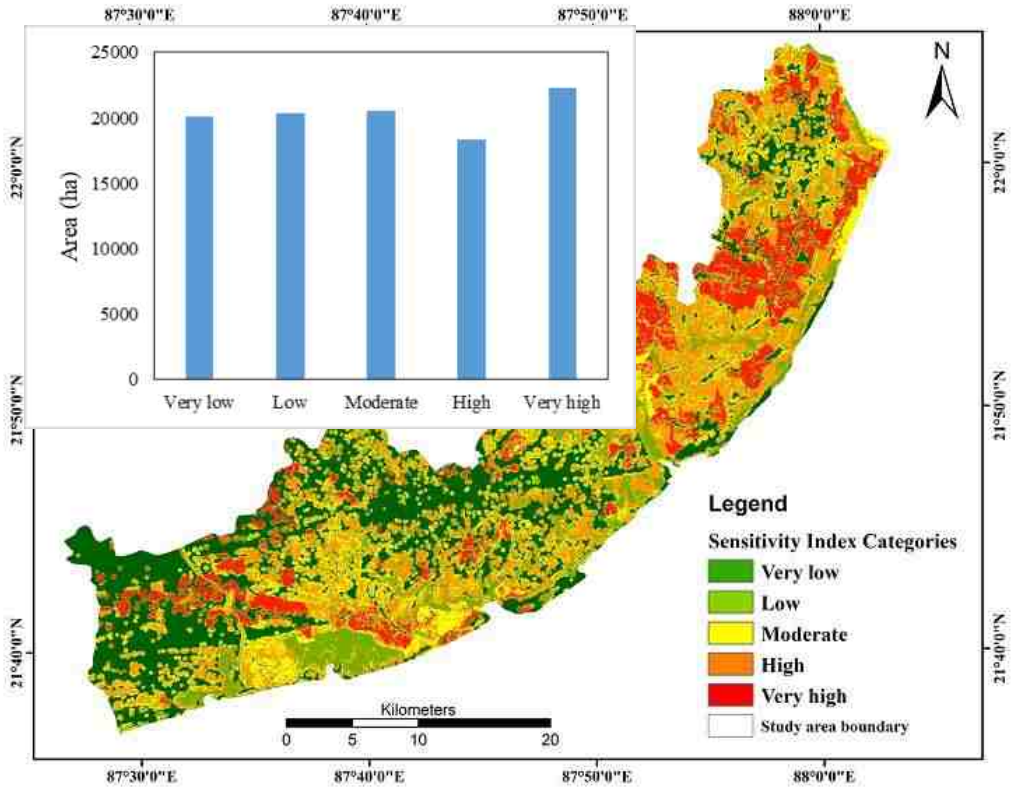

Figure6: Sensitivity Index

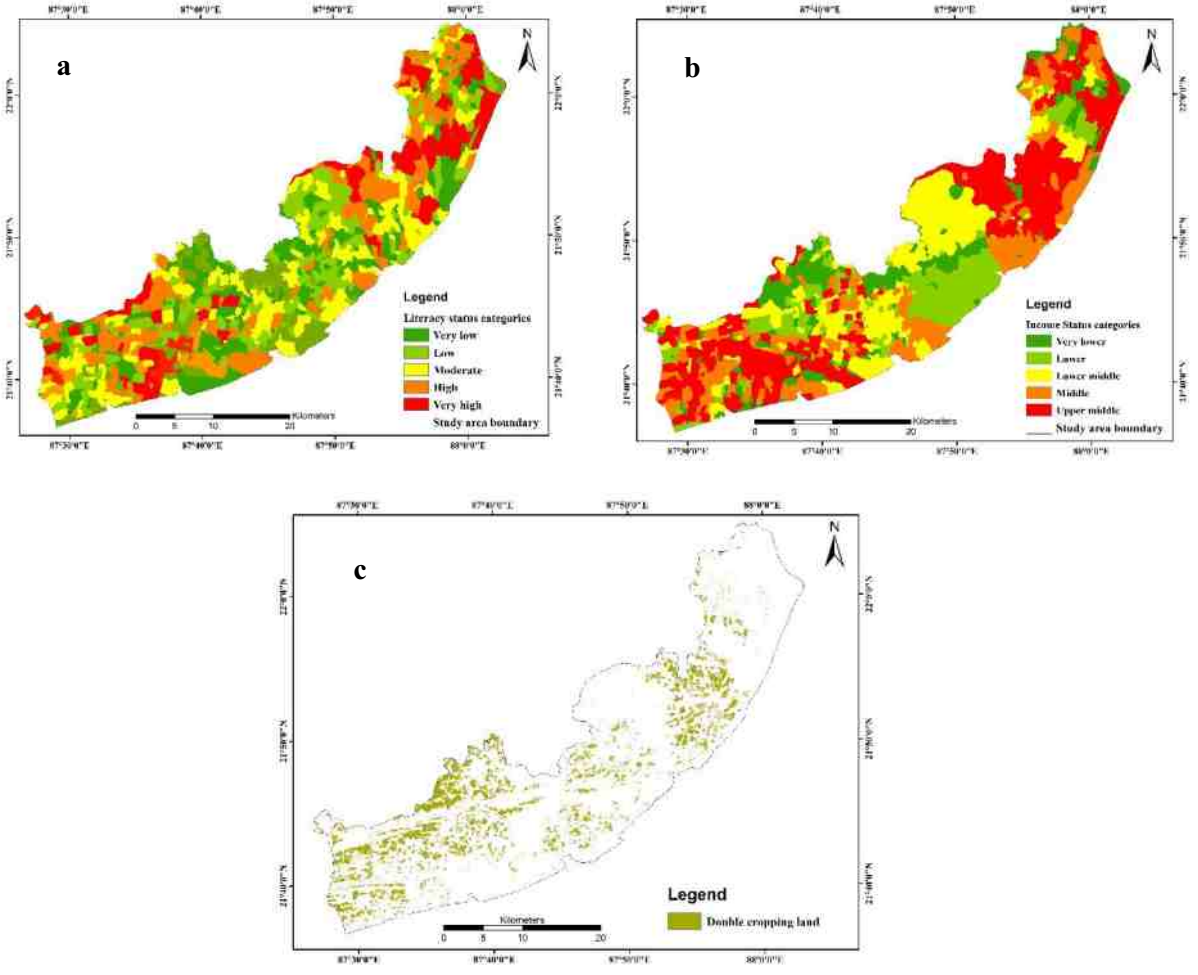

Fig.7: Parameters for calculating adaptive capacity index; a: Literacy; b: Income; c: Double cropping land

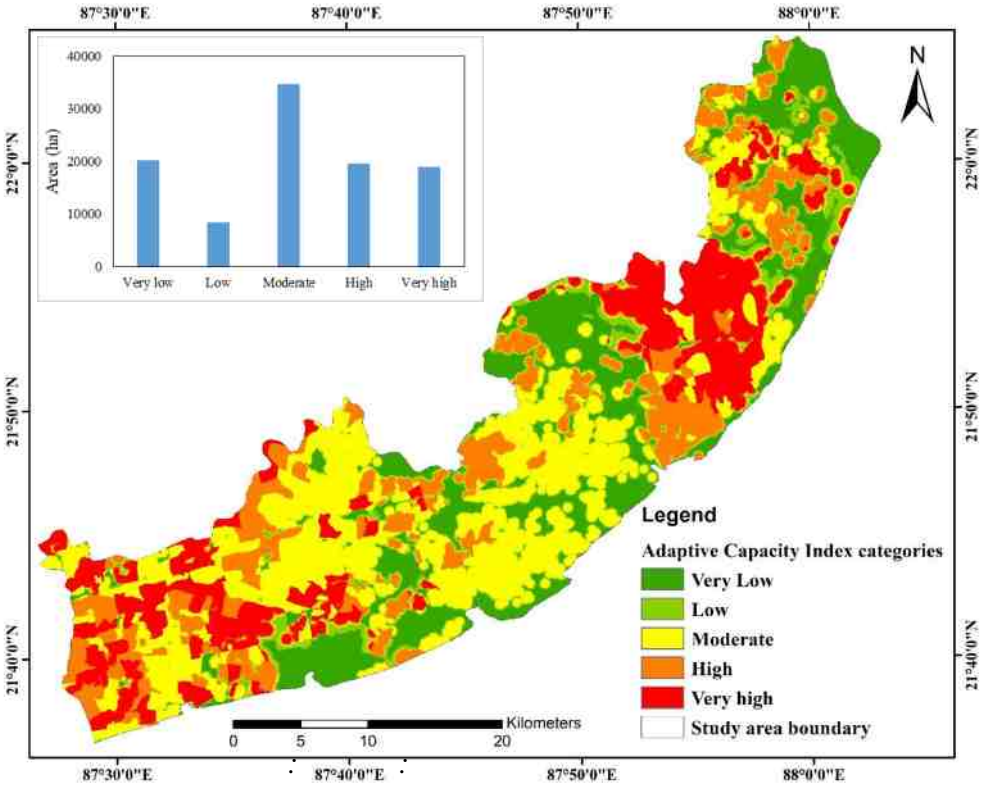

Figure 8 : Adaptive Capacity Index

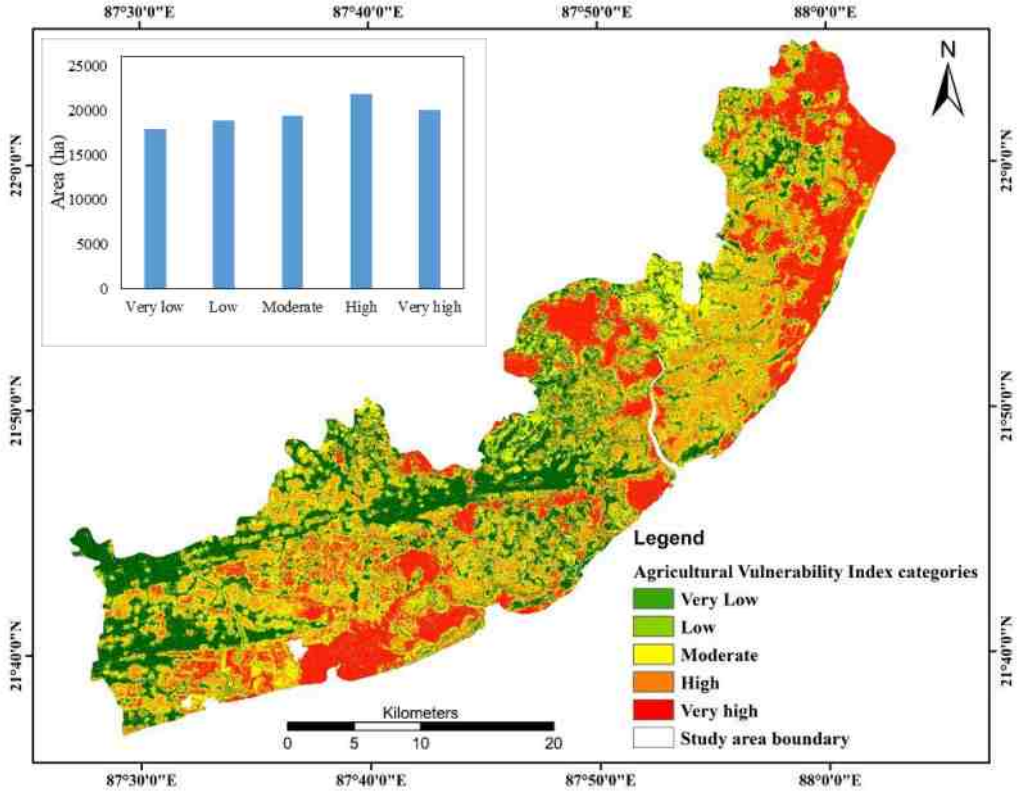

Fig.9 : Agricultural Vulnerability Index

Trending Cartography - Past Present Future

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Abstract

Trending Cartography indicates transformation of maps from Past time to Present time and gradually would be future time. According to the cartographic association, Cartography is the discipline dealing with the conception, production, dissemination and study of maps. Four components of cartography are environment, map maker, map and map user. The evolution of Cartography is a long term process. Cavemen were remarkable cartographers. They depicted their surroundings and everyday life in the form of cave paintings, for example Ajanta and Ellora caves in Maharashtra, India. Next cartographic successors are stone tablets, religious maps, printed maps, and digital maps (multi-layered) of modern times utilizing Geospatial Technology (GIS ,GPS and Remote sensing). In Cartography, Modern Technology (GIS) is very much useful for depicting any development processes i. e. Tribal development, Infrastructure development, tourism development etc. This paper tries to illustrate cartographic trends using modern technology (GIS) as a tool of analysis (Tribal development Process). Tribal development is a basic socio economic issue. These developments are mainly significant due to their survival issues, productivity enhancement, occupational diversity, back to the mainstream of social structure, preservation of cultural heritage and reduced migration. The motto of development is economic prosperity. Important schemes for tribal development in respect of Socio-economic development are namely Van Dhan Yojona, National Scheduled Tribes Finance andDevelopment Corporation (NSTFDC). In the field of Educational development such as Eklavya model School, Govt. Scholarship, Ashram School. Cultural development is concern, Tribal Museum, TRI have been set up.

Keywords: GIS, Geospatial Technology, Cultural development, Eklavya model school, TRI, Van Dhan Yojona

Introduction

Modern cartographic tools (GIS, Satellite Imagery, GPS, Aerial photos with different software etc.) can evaluate any socio economic process and problem flawlessly. This tool can solve the problem quickly and act as a principal source of societal welfare.

Case study: Tribal Development in India

It is a burning socioeconomic issue all over the world including developing country like India.

Objectives of the Study:

I) To examine the present demographic pattern of ST and compare with past scenario.

II) To explore important tribal development programmes for betterment of social and economic status.

Methodology

The study mainly based on Secondary data and using GIs software. The prime sources of secondary data are the Ministry of Tribal Affairs, Census of India, National Sample Survey Report, Report of Tribal Development Department, News Papers, Working Papers, journals, Books, Govt. Website etc.

India is an overpopulated country. Indian population statistics are quite astonishing, as per 2011 census, notified tribal population are 10.43 corers, constituting 8.6% of the total population. Among them about 80 percent live in the 'central belt', extending from Gujarat and Rajasthan in the West, and across the state of Maharashtra, Madhya Pradesh, Chattisgarh, Bihar, Jharkhand, and Orissa, to West Bengal and Tripura in the East. Most of the remaining 20 percent live in the North-eastern states of Meghalaya, Mizoram, Nagaland, Arunachal Pradesh, and Sikkim and in the union territories of Dadra and Nagar Haveli Andaman and Nicobar, and Lakshadweep. A small percentage of them (tribal) are live in the Southern states of Kerala, Tamil Nadu, and Karnataka. Andhra Pradesh has the largest tribal population among the Southern states of India. The Ministry of tribal affairs was set up in 1999. The main motto of the ministry is the socio-economic development of the Scheduled Tribes (STs).

Percentage of tribal population in India is more than 8.6% approx in the total population. So without adequate tribal development, proper development can't be possible. But general trend of tribal development is not very significant. PT. Neheru's PANCHASHEEL (1961), PESA Act (1996, The Panchayats Extension to Scheduled Areas), the Forest Rights Act (2006, FRA) and other initiatives have all been

made an effort to enhance their way of life.

Three approaches of Tribal Development from pre independence to post independence: The approaches were Isolationis (leave them untouched), Assimilationist (the tribal people to mingle with the neighboring non-tribal's) and) **Integrationist** (Protective and Promotional measures introduced by Pundit Nehru).

Scenario of ST Population (1951 to 2011)

The growth rate of tribal population from 1951 to 2011 according to census of India (Table 1) are varies from 5.2 percent to total population In 1951, in !961 it is 6.87 percent, in 2001 it is 8.2 percent and in 2011 it is 8.6 percent. It indicates increasing growth rate.

Globalization and industrialization have uprooted villages, disrupted ancient cultures and forced Tribals to give up their traditional occupations. Many have become migrant wage workers in unorganized-sector units, living one meal at a time. Unbridled interaction between tribes and the general population has resulted in indigenous cultures being suppressed.

Important measures have been taken for Socio-economic development for tribes:

TSP (Tribal Sub Plan) : It was introduced in 5th five year plan period (1972) for rapid socioeconomic development of the tribes by Prof. S.C.Dube. It is very useful strategy in nowadays. Salient features are :

a) To identify the problems and need of tribal people and critical gaps in their development.

b) To Identity all available resources for TSP

c) To Prepare a broad policy framework for development,

d) To Prepare a detailed department wise plan

e) To define a suitable administrative strategy for its implementation.

f) To specify the mechanism for monitoring and evaluation

Budget allocation for ST Development from 2016 -23 shows healthy progress (Table 2) ; In the year 2016-17 it was Rs. 4826.5 in Crore ,and year 21-22 it is Rs. 7524.87 Rs. in Crore. It will be increased in Rs.8451.92 Crore in coming year (2022-23),

Van Dhan Yajona: Van Dhan (VDVK) Yojana for economic development of tribes: “Mera Van Mera Dhan Mera Udyam”

Objective of VDVK is to create a tribal enterprise comprising of tribal gatherers/ entrepreneurs, who would collectively undertake all related activities starting from collection, value-addition, packaging, branding and marketing of value added products. These Kendras would also have arrangement of space for value addition work and storage of products, arranging transportation, packaging of value added products, branding and retail marketing (Map 1).

NSTFDC (National Scheduled Tribes Finance Development Corporation): National ST Finance and Development Corporation (NSTFD C) under Ministry of Tribal Affairs , Govt. of India provides financial assistance by way of soft loans for income generating activities for economic development of the Tribes. The NSTFDC loan schemes are implemented through state channelizing agencies, select PSU Banks , RRBs and other institutions . Scheme for income Generations viz. i)Term Loan Scheme ii) Adivasi Mahila Sashaktikaran Yojna(AMSY), iii) Marketing support assistance iv) Advasi Shiksha Rinn Yojna etc.

It provides Term Loans for viable business units costing up to Rs 50.00 Lakhs . Soft loans under the scheme are extended up to 90 % of the unit cost and the balance is met by way of promoter's contribution, subsidy and margin money loans (Table 3).

Eklavya Model School for Educational development:

The Ministry of Tribal Affairs provide grants to 22 Tribal Sub-Plan and 4 tribal majority States under the First Proviso to article 275(1) of the Constitution. Since 1997-98, it has been decided to utilize a part of the funds under Article 275(1) of the Constitution for setting up 100 Model Residential Schools (named as Eklavya Vidyalaya) from class 6th to1 The objective of setting up of the Eklavya Vidyalayas is to provide quality eeducation to the tribal students. 164 Eklavya Model were sanctioned to 22 States upto 31/03/2014 since the beginning and 120 Schools are reported to be functional (Map2). Other educational schemes are Ashram Schools, Girls/Boys Hostel, Vocational Training centre etc.

TRI (Tribal Research Institute): The Ministry of Tribal Affairs committed to overall development of the people belonging to Scheduled Tribes and to project the rights of such people and preserve and to promote tribal culture and heritage has recently taken up a number of new initiatives towards their development i.e. tribal research institute.

The main objective of the Tribal Research Institute is to 'do research, survey, and analysis of tribal culture & issues'. It is a 'nodal' centre in support of tribal culture.

Tribal Museum: In order to acknowledge the heroic & patriotic deeds of tribal people, the govt. has decided to establish the tribal Museum. Tribal Museum act as a store house of tribal art & culture also. These Institutes have organized number of exhibitions inside and outside the State. Recognizing the need to preserve, document and promote these cultural histories of various unique tribes of India, the Ministry of Tribal Affairs has taken several proactive initiatives. Remarkable initiative is state wise fund released on freedom fighter Museum.
State wise Fund released with Mota's Commitment on Freedom Fighter Museum (table 4).

In conclusion it can be said that tribal development process is not very remarkable in all states but slow and steady changes occur in states like Odisha,Bihar, Rajasthan, Gujrat, West Bengal, North Eastern Hilly States etc.

Development scenario: Nowadays some of them (tribal communities) are enjoying prestigious post like IAS, IPS, and Doctor, Engineer, Officials of central and state Govt. etc. It indicates steady development. But wide awakening are needed in both way, tribal people as well as non tribal authorities.

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Table. 1 Growth of Scheduled Tribes in India: (1951 to 2011)

Census Year	Total Population of Scheduled Tribes (in millions)	Percentage of Scheduled Tribes to Total Population
1951	19.1	5.2
1961	30.1	6.87
1971	38	6.94
1981	51.6	7.58
1991	67.8	8.08
2001	84.3	8.2
2011	104.3	8.6

Source: Ministry of Tribal Affairs

Table. 3 Term Loan Scheme

Table . 2 Budget Allocation for ST Development from 2016 - 23	
Year	Budget (Rs. In Crore)
2016-17	4826.5
2017-18	5329.32
2018-19	6000
2019-20	6894.96
2020-21	7411
2021-22	7524.87
2022-23	8451.92

Name of Scheme	Quantum of Loan per person	Repayment Period
Term Loan	Upto Rs. 5.00 Lakhs	5-10 years
Term Loan	Above Rs. 5.00 Lakh to Rs. 10.00 Lakhs	5-10 years
Term Loan	Above Rs. 10.00 Lakhs to Rs. 45.00Lakhs	5-10 years

Source: Ministry of Tribal Affairs

Map. 1 State wise status of VDVK for tribal development(Source : Ministry of Tribal Affairs)

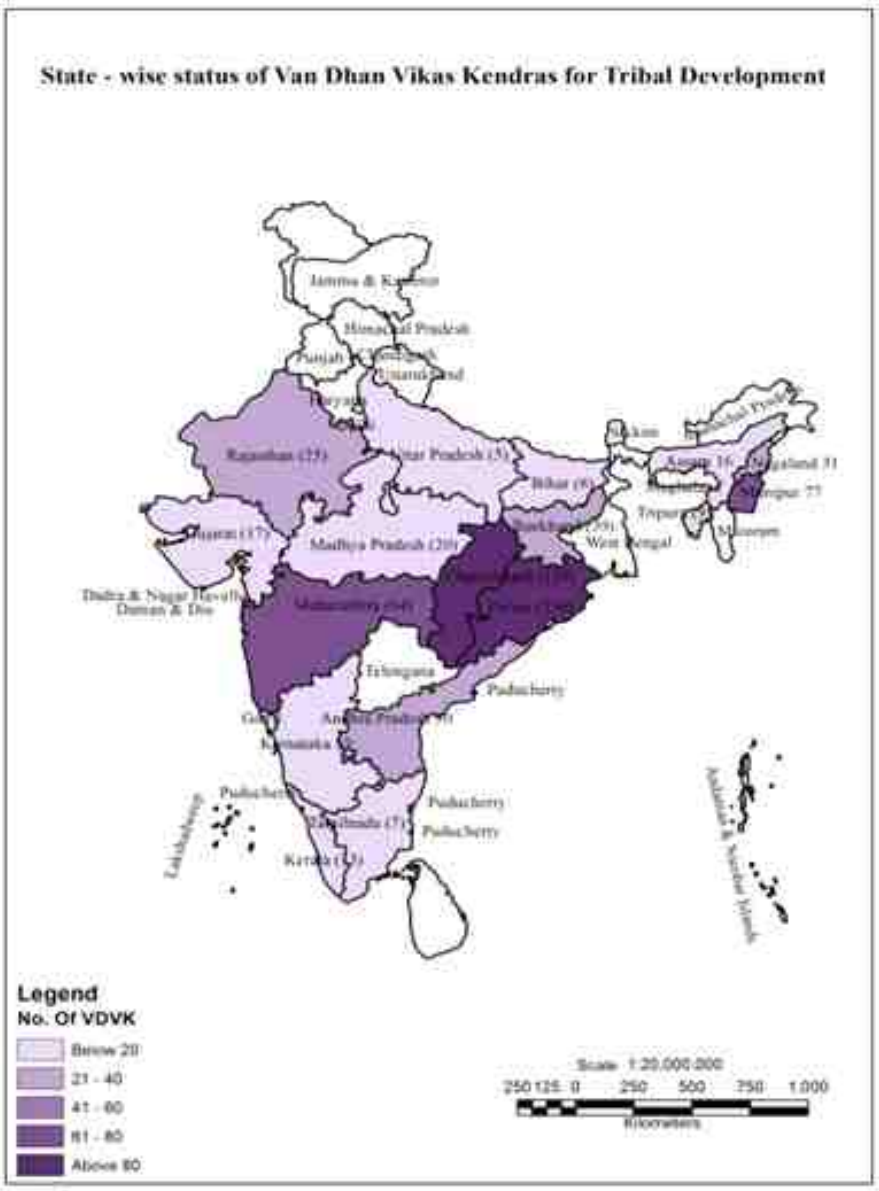

Table. 4 State wise Fund released with Mota's Commitment on Freedom Fighter Museum

State name	MoTA's Commitment for Tribal Museum	Fund released For Tribal Museum (Rs. In Crores)
Andhra Pradesh	15	7.5
Chhattisgarh	15	4.65
Gujarat	50	50
Jharkhand	25	25
Kerala	15	7.5
Modhya Pradesh	15	6.93
Mizoram	15	1
Telengana	15	1
Manipur	15	1
Total	180	104.58

Source: Ministry of Tribal Affairs

Hydrographic Services Essential Towards Advancing Blue Economy Goals of India

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Abstract

Blue Economy is defined by the World Bank as the "sustainable use of ocean resources for economic growth, improved livelihoods, and jobs while preserving the health of the ecosystem." For its ties to economic growth, environmental sustainability, and national security, the blue economy generally refers to the multitude of ocean resources accessible in the country that can be utilized to aid in the creation of goods and services. The blue economy offers coastal nations like India a huge socioeconomic opportunity to responsibly use ocean resources for societal benefit. However, the human activity has impacted the food cycle and the ecological balance which may bring a catastrophic impact to the generations to come. Sustenance to development is deemed necessary in order to harness the potential of Blue Economy. The SDG 14 (Sustainable Development Goal) Life below water is related to the ocean resources and its sustainable exploration.

Developed Hydrographic Services is considered essential towards maritime trade, protection of the marine environment, national infrastructure development, coastal zone management, marine exploration, marine resource exploitation (minerals, fishing, etc.), maritime boundary delimitation, maritime defence and security, and coastal disaster management. Hydrographic surveys carried out by INHD (Indian Naval Hydrographic Department) collects multiple data sets of the Indian Ocean Region. The processed data is primarily used for production of electronic navigational charts and paper charts which can be considered the primary tool towards achieving efficient Marine Spatial Planning (MSP) which underpins the development of blue economy.

Keywords: Coastal Marine Spatial Planning, Sustainable Development Goal, Indian Naval Hydrography Department, Traffic Separation Scheme, Coastal Regulation Zones

Introduction

Blue economy is a subset of the nation's economy tapping the potential of the oceans. India being a growing economy requires room to expand its growth potential. India has a vast coastline with a potential to tap enormous resources especially in the offshore areas. Currently the exploration costs are high, however it is envisaged that as the demand for resources rises and the availability of reserves diminishes on land, this high cost will be compensated. Data collection from the oceans is a time and capital intensive activity. Marine spatial data infrastructure (MSDI is the key enabler towards multilevel utilization of the marine data collected. A robust GIS (Geographic Information System)based MSDI is required to achieve a holistic sustainable economic, social and ecological objective. Marine Spatial Planning (MSP) is the core foundation upon which the Blue Economy Model is developed. The Government's Vision of New India by 2030 enunciated in February 2019 highlighted the Blue Economy as one of the ten core dimensions of growth. The Blue Economy was mentioned as the sixth dimension of this vision so as to improve the lives of the coastal communities and accelerate development and employment.

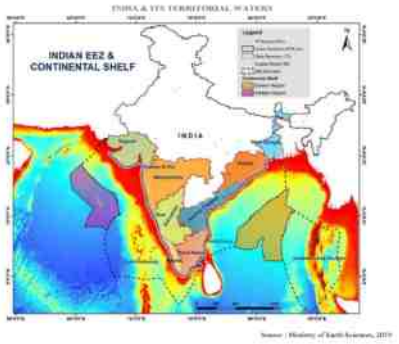

Fig. 1: Economic map of India

The hydrographic services for the nation are being provided by INHD. It is considered that Hydrography is a significant step to bolster the move towards blue economy. The varied and vast data repository at INHD has different layers of the big data cylinder. The vast ocean resources are available to the Nation needs to be spatially planned and demarcated for economic activities.

Hydrographic Services

The Indian Naval Hydrographic Department has been carrying out bathymetric surveys and charting depths for India and friendly foreign countries in IOR. Hydrographic

Survey Committee (HSC) meetings are held every year with relevant stakeholders from various Ministries and departments to ascertain the requirement of surveys in the maritime domain for different applications. The data collected during a hydrographic survey is manifold and can be utilized by different stakeholders for their domain augmentation. The INHD is responsible for charting the coastal areas and the adjacent water bodies upto the EEZ.

The marine space accommodates numerous activities, some of which includes the CRZ (Coastal Regulatory Zones), Traffic Separation Schemes (TSS), military exercise areas, aqua culture sites, Marine Protected Areas (MPA), inter tidal zones, ports, anchorages, fishing stakes, offshore wind farms, offshore oil rigs etc. It is important that these activities are *spatially de-conflicted* in order to efficiently use the limited marine space available to a nation.

Typically, a paper/electronic Navigation Charts which is the primary product of INHD has most of these activities geographically depicted along with numerous other vital pieces of information. *Therefore, it would not be incorrect to say that a chart can be considered the basic and the most vital tool for undertaking MSP*.

A variety of technologies such as shipborne sonars, bathymetric, oceanography, data buoys, gliders, satellite-based observations using LiDAR, SAR, EO/IR, Blue Green lasers, hyperspectral sensors and terrestrial observation units are used to generate localised geo-spatial 'Big DATA Cylinders'. These 'cylinders' beginning from the sea bed, vertical column and the immediate sea surface are populated with data from different sensors. The INHD has seven ocean going survey vessels which are deployed to collect data every survey season. These ships are issued with hydrographic instructions to carry out surveys along with their priorities discussed during Hydrographic Survey Committee meeting. The data collected undergoes a QA/QC check onboard and is dispatched to National Hydrographic Office Dehradun for further checks and charting. All the data collected in different formats of tidal stream, bathymetry, coastline data, conspicuous objects and their height, levelling data, side scan sonar data of wrecks and shoals, MPA, buoys and aids to navigation, TSS, recommended routes, port data is collated and desired deliverable is published/updated.

Blue economy- sustainable development

Blue Economy has been defined as a subset of the national economy comprising of the entire system of ocean resources and man-made *economic infrastructure in marine, maritime and the onshore coastal zones within India's legal jurisdiction*, which aid in the production of goods and services and have clear linkages with economic growth, environmental sustainability and national security.

India has 13 major ports and 187 minor ports, handling about 1400 million tons of cargo every year with 95% of India's trade by volume transiting by sea. India's Exclusive Economic Zone of over two million square Km is rich in living and non-living resources and holds significant recoverable resources which need to be managed sustainably. The sustenance to development can only be achieved by spatial planning of the marine environment. Unlike the terrestrial area the marine environment is in three dimensions – surface, seabed and water column. Multiple resources co-exist in all these three dimensions and for its sustainable utilization demarcation of the marine realm is critical. In case the utilization of marine space is planned randomly with no central body monitoring there would surely be conflict of interests from various stakeholders. For example, if an area is considered rich in oil is falling within a MPA or an ecologically sensitive area, a central agency would require to take a decision on which activity is to be accorded priority based on various factors. However, in order to take this informed decision, what would primarily be required is the data from the Hydrographic office in the form of a chart.

The increasing demand for energy and the fast development is creating conflict of interest for economic reasons. The economic advisory committee had published a Blue economy policy with seven priority areas.

(a) Priority Area 1: National Accounting Framework for Blue Economy and Ocean Governance

(b) Priority Area 2: Coastal Marine Spatial Planning and Tourism

(c) Priority Area 3: Marine Fisheries, Aquaculture and Fish Processing.

(d) Priority Area 4: Manufacturing, Emerging Industries, Trade, Technology, Services and Skill Development

(e) Priority Area 5: Logistics, Infrastructure and Shipping (including transhipments)

(f) Priority Area 6: Coastal and Deep-Sea Mining and Offshore Energy

(g) Priority Area 7: Security, Strategic Dimensions and International Engagement

The United Nations adopted the 2030 agenda for sustainable development in 2015 describing 17 sustainable development goals (SDGs) which are an urgent call for action by all countries. The SDG 14 life below water is to – conserve and sustainably use the oceans, seas and marine resources for sustainable development. The blue economy, also known as the sustainable ocean-based economy, comprises a range of economic sectors and related policies that aims to foster economic and social progress while maintaining the health of our oceans and coasts.

Mumbai harbour- a case study

The deliverable shown below i.e an ENC (Electronic Navigational Chart) is an outcome of a hydrographic survey. As shown the area has TSS, buoyed channel, wrecks, fishing stakes, oil rigs, ports, coastal industries. A better spatial planning of the marine space can enhance the economic activity for the region.

Some of the activities in the marine space which one can see in the above chart are enumerated below: -

Traffic Separation Scheme: A traffic separation scheme is promulgated to avoid congestion of marine traffic at busy port or straits, such is the case here. The incoming traffic from south, north and west are conjoining at the junction and is entering a port within the bay.

Wrecks: The number of wrecks on the ENC is evident which is posing a great threat to surface navigation and limits the development of some other activities like aquaculture. A wreck in a traffic dense area like Mumbai will severely affect the smooth navigation by shipping as avoiding wrecks leads to wastage of marine spatial area.

Anchorage Areas: As depicted on the electronic navigation chart, anchorage areas for ships are designated towards the north and south of channel and inner side. It is evident that a sector wise planning has been carried out for cargo embarkation, disembarkation, waiting station etc. It is often observed that the marine pollution is profound in these areas as these anchored ships discharge untreated effluents causing damage to the marine ecosystem and marine lifecycle therefore the designated anchorage areas should be planned spatially well apart from any MPA/ESA.

Oil Rigs: The ENC depicts the offshore oil platforms, its temporary positions and its movements published through notice to mariners. The public sector and private players in oil and natural gas extraction industry would have mapped the sub bottom layers of the adjacent ocean space. The coast to extract these at higher depths may be considerably high, however as the demand goes high an equilibrium will be achieved by increased production. In order to increase the production, the offshore activity has to increase, a better planned marine space earmarked for exploration will deconflict the marine space.

Ports and Harbours: The port limits, harbour dangers, buoyed channels to these harbours are all available on an ENC. The present data set of all the harbours and ports are available with INHD, as matter of fact, INHD can be a key player in planning the MSP and its implementation.

Military Exercise Areas: Military exercise areas are marked on e- chart such as submarine exercise areas, firing areas, experimental flight test area, satellite launch areas, which are to be avoided by normal seamen. As part of defence surveys undertaken by INHD, data is collected and updated with the repository which is published for defence users only as additional military layer. The MSP will eliminate a conflict in those areas which are earmarked for defence purposes.

Submarine cables: Submarine cables carrying electricity, OFC, oil and gas are transported to ashore facilities. These cables play a pivotal role in establishment and sustenance of offshore infrastructure. Any rupture of cables or damage to these cables can have a catastrophic effect on the ecosystem and lead to pollution. All the areas having submarine cables are marked on chart with special precautionary note of not anchoring on top of them. Survey of submarine pipelines is an economically intensive activity requiring supplicated survey equipment. Any conflict in these areas can lead to damage of ecosystem.

Areas Covered with Mangrove: Marine Protected Area and ecologically sensitive areas are marked on charts. These areas are given special protection for natural or historic marine resources by local, state, territorial or national authorities. The spatial plan can include activities restricted in such areas to protect them.

Fishing zones: Fishing stakes are planned on the chart for earmarked fishing activity. These areas are marked

with the knowledge of availability of fishes and their movements. Any other activity in the area may be detrimental to the marine life cycle.

As we have seen that in a small area of 30 nm x 25 nm there are numerous activities taking place which all need their independent space and cannot have any overlap. For example, we cannot have recommended anchorage over an area where submarine cables are passing or oil rigs amidst a military exercise area. Each of these activities are vital components of blue economy and therefore space management through MSP is critical so as allow these activities to co-exist albeit in their own space. Once again to have an effective MSP the primary tool available for planners is obviously a navigation chart published by INHD.

MSP- Marine Spatial Planning

MSP is the optimal usage of marine space catering the temporal and spatial usage of human resource and the interaction between its users. It is important to understand that by implementing MSP we can only control the human activity and not the ecosystem. As per UNESCO MSP guide there are ten steps towards setting up MSP which requires multiple feedbacks at multiple levels. The MSP is not a one-time approach and single plan for years together, it's implement-monitor-evaluate-revise plan, MSP doesn't replace single sector planning. In today's world it may seem to have no conflict in marine space but it may not be the same after 10 years, as the shift towards renewable energies competition is set to increase and conflicts are set to happen. A laid down laws and regulations may ease out the issues. Different steps of MSP are: -

(a) Identifying need and establishing authority
(b) Obtaining financial support
(c) Organizing the process through pre-planning
(d) Organizing stakeholder participation
(e) Defining and analyzing existing conditions
(f) Defining and analyzing future conditions
(g) Preparing and approving the spatial management plan
(h) Implementing and enforcing the spatial management
(i) Monitoring and evaluating performance
(j) Adapting the marine spatial management process

In India the Ministry of Environment Forest and Climate Change (MoEF&CC) has constituted five working groups for implementing CMSP as enumerated: -

(k) Sub Group-1 CMSP Framework w.r.t IOC-UNESCO Document
(l) Sub Group -2 Sector-wise BE components
(m) Sub Group -3 Mapping, Zoning and Data Security
(n) Sub Group -4 Assessment – Investment – Implementation
(o) Sub Group -5 International Cooperation, Regulation, Policy and Governance

In realizing the full potential of Blue economy, Marine Spatial Planning (MSP) constitutes the core foundation, upon which the Blue economy model is built. MSP involved mapping the charactersing ocean spaces and land sea interfaces, to provide actionable data to Government and business, towards making informed decisions about sustainable use of oceans, deconflict competing requirements, synergies similar use-ace and optimal ocean use.

Generation of MSP: To generate MSP Hydrographic data, which is authoritative and up-to-date, would be needed towards evidence-based decision making and resource management. A wide spectrum of activities take place at sea apart from traditional activities, including extraction of hydrocarbons, energy production, aquaculture, tourism etc. The unregulated activities damage the marine biodiversity and ecosystem. Hydrographic data and information are acquired, managed, manipulated and disseminated primarily through hydrographic offices. Given that the Indian Navy has extensive domain expertise, resource and equipment to undertake comprehensive mapping and measurement of various metrices in the EEZ and land-ocean interface areas, the obvious institution of choice would be Chief Hydrographer to the Govt of India.

MSDI: Spatial data is data or information that identifies the geographic location of features and boundaries on earth. SDI is “the relevant base collections of technologies and institutional arrangements that facilitate the availability of and access to spatial data”. The marine element of SDI is MSDI. It is an infrastructure catering different data sets aimed at multiple users from different domains like environmental management, spatial planning and emergency response. The data collected during a hydrographic survey is enormous, the user receives only a

very small part of the data. The fine processed shoal biased sparse data designed for navigation is published. The data collected has a lot of information to the compiler and passed only a small amount to the recipient. These hydrographic data sets have potential for a wider range of audience. Citing the example of hydrographic data, it can be used for seabed mapping and modeling for engineering purposes, geodetic and tidal data for datum studies, sound velocity for oceanographic studies, back scatter data for sedimentary analysis.

The key components of MSDI are as follows:-

Fig. 4: The four pillars of MSDI

Policy and Governance: A policy needs to be created which defines the interoperability of the data. The policy can be at organisational, national or regional in nature. There should be a transparent decision making and governance for achieving common goal.

Technical Standards: The geographic information data standards are being developed. All the hydrographic data confirms with S44 data standards. IHO S 100 Universal Hydrographic Data Model provides a framework for next generation ENC and other related digital products.

Information systems: The information sharing between multiple stakeholders is very important for interoperability of communication on internet, satellite or digital wireless interfaces. This will allow interconnection of heterogenous software systems on different ships, offshore platforms.

Geographic content: A consistent coordinate reference system is important for a SDI. The reference information may be base and thematic reference information, base forms the fundamental topographic features whereas reference is used to support geo-referencing or analysis.

Leveraging the potential of Hydrography to attain blue economy: A hydrographer collects all the data sets to deliver an electronic navigational chart as depicted above. The Indian coast and the island territories are all mapped and updation of data is a continuous process. The "big data cylinder" i.e the seabed, water column and the surface are mapped by a hydrographer with the state-of-the-art technologies, with multiple sensors and data formats. Seabed exploration and renewable energy harnessing is a matter of utilization of the same data set. A Marine Spatial Data Infrastructure with all the data sets and the levels of data availability will enable utilization of the data at mu

MPA (Marine Protected Area) and ecological sensitive areas are mapped on the respective area charts, INHD has a repository of data sets for years together. The HO (Hydrographic offices) has a wealth of data including navigational marks, TSS, boundaries and limits. Hydrography in MSDI is a core reference data (bathymetry, maritime boundaries, coastline, geographic names). **"**Hydrography is the branch of applied science which deals with the measurement and description of the physical features of oceans, seas, coastal areas, lakes and rivers, as well as with the prediction of their change over time".

India being in the initial stages of developing blue economy needs to establish a MSDI and then on to plan the marine space to harness the full potential and deconflict the area for economic activity. India had supported the SDG 14 "Life below water" and the blue economy policy envisages the use of renewable sources of energy thereby conserving the marine ecosystem. It is recommended to migrate to S 100 standards for enhancing interoperability, the education system may include more emphasis on Geographic information systems and the industry can offer more open-sourceGIS technologies. Blue economy is a national goal involving multiple stakeholders and domain experts, synergy in planning and implementation of MSDI, MSP and the various priority areas can achieve this at the earliest.

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Fig. 2: Marine space

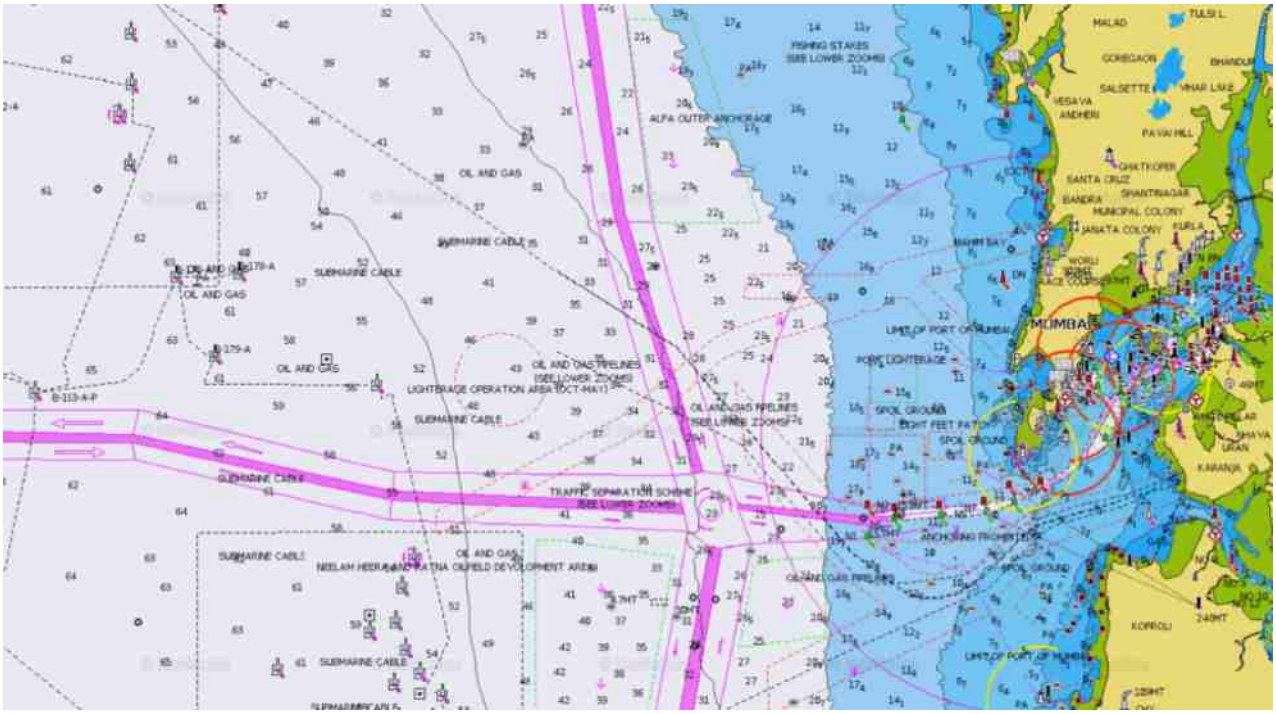

Fig. 3: Electronic navigational chart of Mumbai

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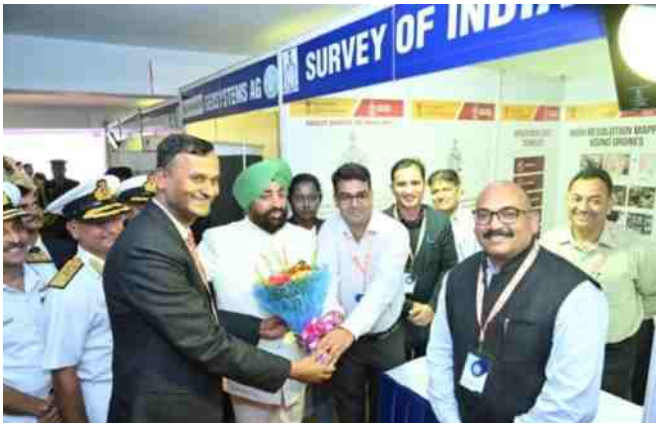

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