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Geospatial Technology in Times of Global Challenges

Proceedings

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Preface

Applied Geoinformatics for Society and Environment (AGSE) series of conferences and summer workshops started in 2008 in Trivandrum, initiated by the initiatives of Dr. Pradeepkumar (University of Kerala) and of the Alumni Representative of Stuttgart University of Applied Sciences, Dr. Franz-Josef Behr. After the successful follow-up conferences in Stuttgart (Germany, 2009), Arequipa (Peru, 2010), Nairobi (Kenya, 2011), Johor Bahru (Malaysia 2012), Ahmedabad (India, 2013), again Stuttgart (2014), on Kish Island (Iran, 2017), Windhoek (Namibia 2018) and again Stuttgart (2019). The conference is closely related to the Master's Programme in Photogrammetry and Geoinformatics which started with the first batch 21 years ago, meanwhile there is a global network of about 500 alumni graduated from the program. Since its beginning, the course is supported by the German Academic Exchange Service (DAAD) in its program for Development-Related Postgraduate Courses (EPOS).

Also AGSE 2021 is incorporated into the DAAD supported alumni work of the University of Applied Sciences Stuttgart. Therefore, participants from many countries worldwide contribute with experiences from their home countries.

With the wide topic "Geospatial Technology in Times of Global Challenges" the summer school aims at contributions of Earth Observation and Volunteered Geographic Information (VGI) for data collection and information provision. The support of findable, accessible, interoperable and reusable (FAIR) data by Spatial Data Infrastructures (SDIs) and collaborative data custodianship is another focus.

The concept includes invited talks by international experts in combination with presentations by participants in the mornings and workshops in the afternoons on topics related to technological developments and recent data provision by Earth Observation Systems.

The objective of the conference is to 'take the benefits of geographic information technologies to a wide canvas of applicable areas'. Since 2008 we – scientists, practitioners, students and alumni – continue this path to empower one another in a participative way.

We wish this event a successful exchange of knowledge crossing borders and disciplines.

Prof. Dr. Dietrich Schröder　　　Prof. Dr. Franz-Josef Behr

Welcome

Dear national and international participants
Good afternoon and Namaste

I am honored and privileged to welcome all of you in this three days AGSE 2021 conference (Nov. 24- Nov. 26, 2021) at Katmandu University, Nepal organized by the Department of Geomatics Engineering, and the Geospatial Department of Stuttgart University of Applied Sciences, Stuttgart, Germany, co-organized by the Laboratory for interoperable, and open-source Geospatial Software, Data and Standards (HFT ICA-OSGeo-Lab). The theme of the AGSE 2021 conference is Geospatial Technology in Times of Global Challenges. The conference will be organized in hybrid mode. I would also share the information that AGSE 2019 conference was organized by Stuttgart University of Applied Sciences with the theme: Digital Landscapes: Chances for Development.
In this conference, we have opening ceremony followed by cultural program performed by Department of Music, Kathmandu University in a category of Newar Drum Ensemble, Nepali Folk Tunes and Classical Vocal Music and closing ceremony.
Similarly, there are six keynote sessions, two parallel technical sessions with thirty six presentations in a category of National mapping and infrastructure, Sustainability and natural resources, UAV, photogrammetry and Remote sensing, Sustainability, Environment and disaster management, open source, land use and management, four different workshops, young scientists session, and alumni session and professional development. In the Alumni Session(s) international alumni will share their experiences after leaving their German University.
I take this opportunity to express my heartfelt thanks to the organizing committee, officials from Kathmandu University and Land Management Training center (LMTC), faculties and officials from Stuttgart University of Applied Sciences, international advisory board, all national and international participants and funding agency German Academic Exchange Service (DAAD) for bringing the conference at this level.
I believe that the conference will be very successful in bringing the enthusiastic Geospatial communities together for sharing their skills, knowledge and experiences in the theme of the conference: Geospatial Technology in Times of Global Challenges and also open the doors for further collaborations in academic and research activities of Geoinformation domain.

Once again, welcome to all of you in the AGSE 2021 conference.

Thank you!

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Environment, Health, and Disaster Management

Addressing Climate Change through Participatory Mapping in Rural Tajikistan

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Keywords: *Participatory mapping, Open data, Climate change, Community empowerment*

ABSTRACT

How technology and community-based approaches support climate change adaptation efforts in rural Tajikistan? Effective climate change adaptation involves taking into account the views and local expertise of local communities, who usually have a long-term experience of disaster risks mitigation and resilience strategies. Therefore, this session will discuss building a strong national OSM community and engagement of rural communities in the process of collecting climate change related specific objects, creating maps and sharing ideas around subjective mapping, in order to help designing, implementing and guaranteeing successful climate change adaptation measures.

Digital Participatory Method for Environmental Justice Research: Lessons Learned from Adapting and Piloting DASEIN Concept in the Context of the Global South- Nepal

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Keywords: *Environmental justice, Smartphone, GPS, digital participatory, EMA*

ABSTRACT

1. Introduction

Environmental risk factors pose a huge public health challenge in cities. According to WHO, 24% of the global disease burden and 23% of all deaths are attributable to environmental factors (Pruss-Üstün & Corvalán, 2006). These risk factors include for example, exposures to pollution and chemicals (air, water, soil, products), physical exposures (noise, radiation), the built environment (buildings, land use, infrastructure) that may result in adverse effects on public health (Pruss-Üstün et al., 2017). Viewed from the environmental justice perspective, it is now commonly understood that much of the burden of environmental ill health falls disproportionately on socioeconomically disadvantaged people (Alvarez & Evans, 2020). Moreover, increasing evidence suggests that socioeconomically disadvantaged people from poorer nations are often exposed to higher levels of environmental stress (Hajat et al., 2015). Some of the reasons suggested are rapid, haphazard urbanization and motorization happening in the cities of the Global South paired with a lack of environmental management, which in turn is strengthening the gap among the social groups with regards to environmental exposures and thus contributing to global health inequalities.

Environmental justice is generally analysed by assessing social inequalities in exposure to environmental burdens and resources and whether this is the result of unequal participation in the decision-making process. By analysing objective data from a stationary station or mobile sensor or via a questionnaire survey (Ma et al., 2017; Xie et al., 2017) researchers decide whether or not the identified inequalities present cases of injustice. Accumulating evidence now indicates that individuals' perceived fairness or justice beliefs are related to health in numerous ways such as stress reactivity, coping and may affect in numerous measures of well-being such as life satisfaction, positive mood, anxiety, depression and general distress (Lucas et al., 2008). However, environment justice research to date has given little attention to perceived fairness of environmental exposures as experienced by the individuals.

Increasing use of a smartphone is now providing new avenue in environmental justice research. The use of mobile apps is enriching the assessment of individuals' exposures to various environmental factors in their living environment. By embedding sensors in individuals' mobile phones researchers are able to measure environmental exposure at the individual level. Global Positioning System (GPS) technology integrated in most of the smartphones has given further possibility to assess exposure at higher temporal, spatial and geographical scale (Caplin et al., 2019). In addition to this passive participatory sensing approach where individuals carry sensors that automatically collect location and data of exposures where they go, mobile phones are also creating opportunities for individuals' active participation—individuals can decide on their own to report their exposure. Nonetheless, to the best of our knowledge the existing approaches have not considered explicit recording of the subjective evaluation regarding the fairness of their exposures. Moreover, scholarly discourse in social inequalities in environmental exposure has generally focussed on cities in the Global North, and there is relatively less research assessing environmental exposure within cities in the Global South context (Hajat et al., 2015; Shao et al., 2021). Intrapersonal and interpersonal factors such as individuals' ability to cope and sensitivity may further influence how one perceives environment and its subjective evaluation across time and space (Liu et al., 2021; Ma et al., 2017). This suggests the need to account for both within- and between- person variation in the rating of environmental exposures and judgement of fairness.

To address this gap, the project Digital Assessment of Subjective Environmental Exposure and Environmental Injustice (DASEIN) was piloted in Bremen city, Germany. This study extends it to the context of Nepal, in the Global South context and reports on the feasibility of digital methods in order to participatorily record subjective environmental exposure of individuals and their perceived fairness of such exposures. In doing so, the study reports on adherence and compliance of participants in the study, captures perceived environmental exposures and perceived fairness of justice among the participants, assesses between- and within participants variation and eventually presents lessons learned in developing and implementing digitally enabled participatory approach for environmental justice research in the context of the Global South.

2. Method

We adopted smartphone-based Ecological Momentary Assessment (EMA) with GPS functionality as a method in our digitally enabled participatory approach which was operationalized through MovisensXS app. The app consisted of questions addressing type and sources of environmental exposures and their locations, subjective concerns and subjective perceptions towards fairness of exposures, momentary mood, life satisfaction and perceived health status. These questions were also asked at the beginning and end of the study as pre and post questionnaire. Participants for the study were recruited from the Kathmandu University in Nepal. A one-to-one online meeting for approximately 1 hour was set up with each individual who signed the consent form. During the meeting participants were provided with the link to install the MovisensXS app programmed with the study specific questionnaires in their own smartphone. Each individual participated in the study for 28 days. Descriptive analysis was used to assess the adherence and compliance of the study and their perceived exposures and perceived effectiveness of justice. We used linear mixed models to assess the within and between person variation.

3. Results

The study enrolled 23 participants and had a 95.6% (22/23) retention rate at 28 days. High adherence was observed to submitting locations of their exposures as compared to submitting images of such exposures. There was considerable variability among participants across various aspects of adherence. While participants felt exposed on an average of 19 days of participation, they did not report being exposed every day except for one participant who indicated exposure every day. Moreover, one participant indicated not being aware of environmental exposure most of the time and therefore reported exposures only twice over 28 days. Variability among the participants was found high with regards to number of self-reported events of exposures and in number of images submitted. Although air pollution and environmental pollutants were perceived by all the participants in their municipality, relatively higher frequency of exposures was reported for noise pollution especially caused by road traffic noise. Out of various sources of exposures, litter or rubbish on the streets were reported by all in their respective municipality and was also reported frequently over 28 days.

Most of the reported noise pollution and environmental pollutants were perceived to have bearable effects on more than 50% of participants whereas strong adverse effects were perceived towards most of the air pollution, odour and built environmental factors related exposures by more than 50% of participants. On the other hand, most of these exposures were perceived to affecting oneself equally as others. Yet, in few events of exposures almost half of the participants perceived that the exposures were affecting oneself more than others except for built environmental related factors. When compared to others, more than half of the participants judged their exposures to all environmental types to be either fair or they perceived them neutrally. Nonetheless, unfairness in exposures was perceived by the majority of participants in considerable events of air pollution. On the contrary, all types of environmental factors were perceived to be distributed either unfairly or rated neutrally. Moreover, slightly higher events of noise and air pollution were perceived to be unfairly distributed. These subjective ratings are found to differ within and between individuals as assessed by the intraclass correlation coefficient.

4. Conclusion

We explored the feasibility of employing a digitally enabled participatory method to record perceived exposures of individuals and their subjective perception of fairness of those exposures. We obtained high rates of study retention and adherence response, nonetheless adherence response found to vary among individuals. Our results suggest that the digitally enabled participatory method is feasible for identifying multiple types and sources of environmental burdens that individuals are exposed to in their daily lives. We found that individuals' justice perception varies within and between individuals, but also substantially depending on the types of environmental exposures.

Several opportunities and challenges were encountered while conducting the one-month long study from which lessons can be learned regarding 1) technology related challenges and needs, 2) participants involvement, retention, study duration and coping with uncertainties, and 3) digitally enabled participatory method for environmental justice. Enabling participants to use their own smartphone, which was indicated to be essential, was found feasible. Nonetheless, it is necessary to recognize early on the challenges pertaining to use of variety of mobile phone models as well as non-study related use of personal smartphones, thereby devise ways to circumvent such challenges. Our experience suggests that uncertainties are inevitable for such a longitudinal study as study design and timing may conflict participants' daily lives and priorities, indicating the study design to be flexible enough to accommodate such uncertainties. Regarding the implication of the method to environmental justice study, our learning suggests that the method allows to consider multiple geographic contexts of individuals' everyday lives beyond residential environment. However, this means that the individuals' daily life is not limited within an administrative boundary of the municipality, which may contradict the municipal planning operating within a fixed jurisdiction. Nonetheless, this study informed us of the necessary steps to using digital participatory method and the elements to ensure participant involvement.

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Extreme Weather Events in Kerala, India: a Scientometric Analysis of Disaster Response

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Keywords: *Extreme weather events, Disaster response, Kerala, India, Scientometrics*

ABSTRACT

Extreme weather events are on the rise, and nations often functioning at a sedate pace are overwhelmed, especially those which have little experience with such events. Examples are Germany and Belgium recently, and Kerala in India in 2018 to 2021. The responses to such events need to be documented and the research that culls from such events could be pointers to the lessons learnt from the events, and the way forward. Scientometric assessment often gives a holistic picture of the progress in the science of extreme events and responses. The paper will examine the key areas of research, the key papers, the most influential scientists and the most productive research organizations in this area of research viz-a-viz the floods in Kerala, India. A spatial analysis of the research will reveal the correlation between disasters and the geographic location of these. Extreme weather events have multiplied in recent years, and the phenomenon has been experienced all over the Earth. No place is exempt from this. Kerala, in India experienced devastating rains in 2018, and the subsequent years also experienced severe rain fall, flooding and deaths. Germany, which does not have a recent record of extreme rain events, was overwhelmed by flash floods across the country. The question of how these events are reflected in research literature is examined in this paper, mostly based on data retrieved from the SCOPUS database by the search 'ALL (TITLE-ABS-KEY (extreme AND weather AND events AND kerala) OR TITLE-ABS-KEY (flood AND kerala) OR TITLE-ABS-KEY (disaster AND kerala and weather)) There has been a spurt in publications post-2018 floods in Kerala (Figure. 1A). The key organizations that have spearheaded research in the area of extreme weather events and disaster responses are the IIT Bombay, Amrita University and University of Kerala (Figure 1B), keyword map makes it clear that over the years there has been a shift in thrust areas from pollution-related topics to disaster-related ones, with DST sponsoring many studies (Figure 1C, D).

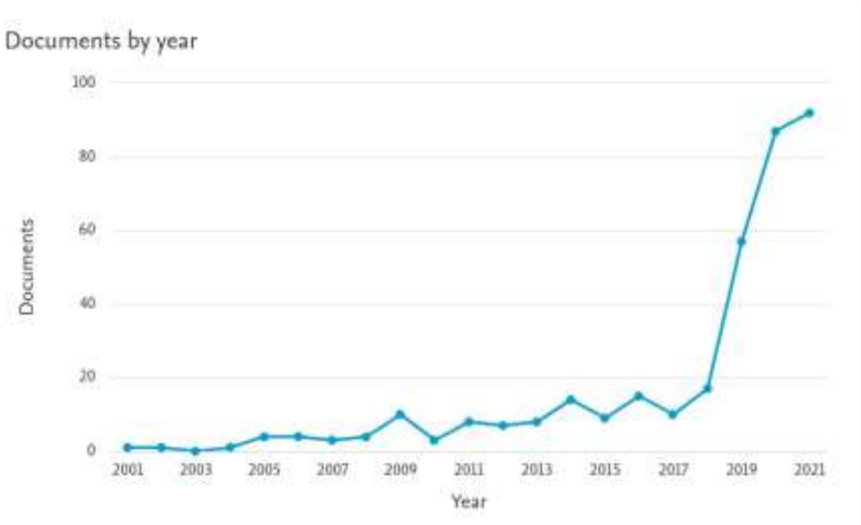

Figure A. Spurt in publications post-2018 floods in Kerala, India

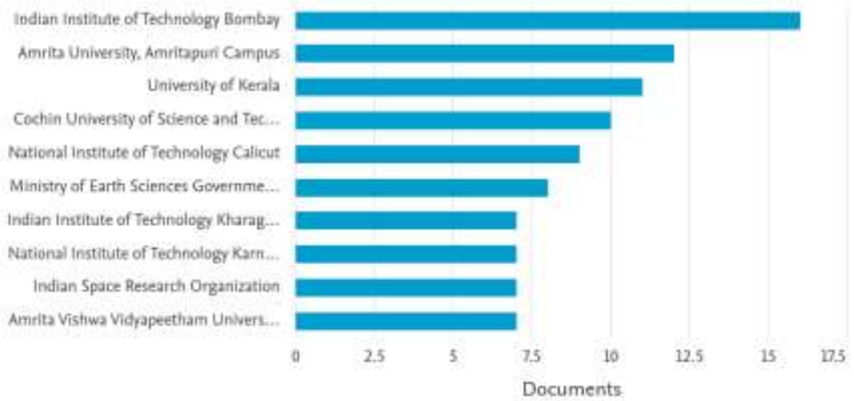

Figure B. Organizations which focused of disasters and extreme events

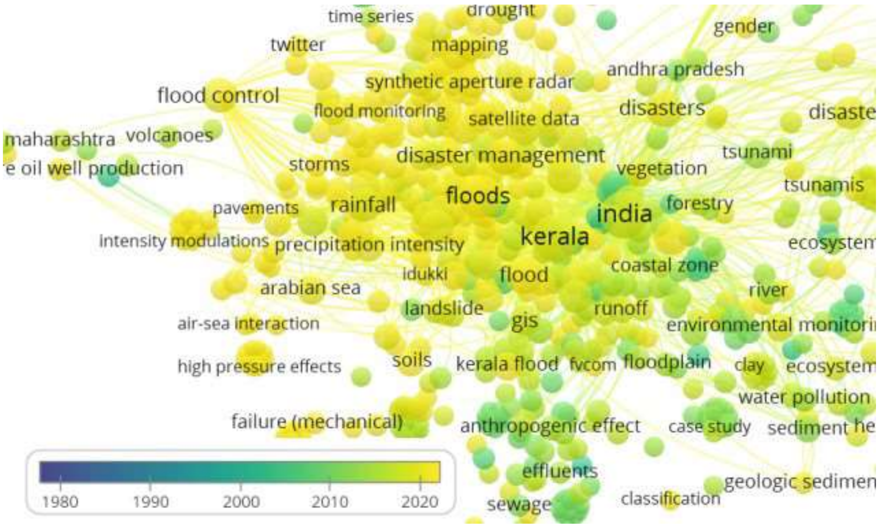

Figure C. Keyword map, darker shades older thrust areas, lighter ones, newer. It is evident that a shift from pollution related topics to disaster related ones (generated with VOS Viewer)

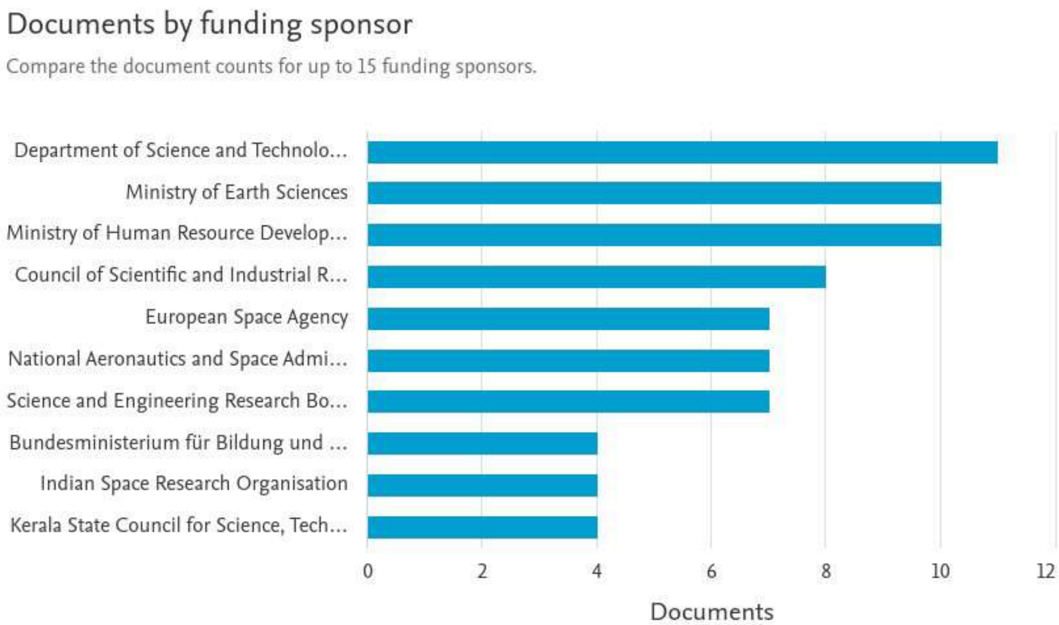

Figure D. Funding agencies of disaster-related studies in Kerala

Topographic Mapping with Unmanned Aerial Vehicles for Flood Hazard Modelling

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Keywords: *DEM, Orthomosaic, RMSE, UAV mapping*

ABSTRACT

Topographic information is widely used in the field of water resources management. In flood risk modeling, for example, topographic data is used for both hydrological process understanding and scenario analysis. Errors in the representation of topography affect the accuracy of topographic features such as stream networks and subsequently their use in regulatory applications. Lower quality topographic information also affects simulation results such as exaggerating the flood extents during flood hazard mapping. The state-of-the-art for obtaining topographic data at the required scales for detailed hydrologic and hydraulic modeling include LiDAR, remote sensing satellites, manned aircrafts and unmanned aerial vehicles (UAVs). These methods can be used in a complementary manner or individually with their suitability varying from one application to another. The aim of this research was to use a UAV to survey a small catchment and to generate quality topographic data that would be used in subsequent flood hazard and vulnerability mapping. To achieve this, a detailed flight plan was created to ensure that the sections of Narok town that are prone to flash floods, were fully surveyed. The UAV images were processed to derive a dense point cloud, a 10cm orthomosaic and 50cm Digital Elevation Model (DEM). Their absolute accuracy was tested using Root Mean Square Error. This was achieved by comparing reference ground control points and their corresponding image coordinates. The achieved horizontal accuracy was 2.9m at 95% confidence interval. The vertical accuracy of the DEM was tested by comparing the reference ground control points and their corresponding image elevation values derived from the DEM. The achieved vertical accuracy was 1.82m at 95% confidence interval. In addition, stream centerlines were modeled from the DEM and building footprints derived from the orthomosaic through a segmentation process. These datasets were used in subsequent hydraulic analysis of the flood prone Narok town.

Disaster Management

Geospatial Investigation into Landscape-level Changes in Invasibility

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Keywords: *Land use dynamics, Plant invasion, Geospatial analysis, Protected area*

ABSTRACT

Human-induced land alteration is one of the major drivers of global environmental change. Endless human demands owing to the demographic expansion intensify this land transformation that result in the replacement of natural vegetation and other inherent land uses. Consequently, many of the terrestrial ecosystems in the world are under the threat of land use change. In the wake of these unconstrained human interventions, the establishment of protected areas (PA) has been widely accepted conservation measure to reduce anthropogenic pressure and further environmental degradation. PAs are meant to protect biodiversity and natural ecosystems (Boucher et al., 2013). However, studies on the effectiveness of PAs revealed that many of them face various threats (Schulze et al., 2018) including fragmentation, habitat loss, isolation of natural ecosystems, invasion of alien species etc. Mostly the human pressure in a PA emnates from its adjoining areas - the anthropogenic matrix (Pauchard, 2013) -which is often composed of human-modified land uses.

The present study focused on the spatio temporal dynamics of the landscape within an anthropogenic matrix adjacent to a protected area in Southern Western Ghats, Kerala, India with specific reference to understand changes in landscape level invasiability. The biotic exchange with the protected area and the surrounding matrix enhances the vulnerability of invasion. Natural ecosystems surrounded by the human-altered landscape are more invaded than large continuous natural vegetation areas. (Lindenmayer and Mccarthy, 2001). Progress in spatial ecology with the emergence of geospatial technologies help to understand the land use dynamics. While land-use land-cover mapping quantifies area change in the landscape, spatial pattern analysis quantify the landscape composition and configuration and it is important in understanding the underlying mechanism of plant invasion (Vila and Ibanez 2011).

The study area was classified into three LULC Classes i.e., Woodland, Till Land and Built-up using Landsat imageries for 2001, 2011 and 2021. The latter two being human-induced land-use classes, may act as drivers of plant invasion. The landscape composition and configuration of the study area was quantified by computing relevant landscape metrics using Fragstat (Mcgarigal & Mark, 1995).). It includes Total Area (CA), Number of Patches (NP), Large Patch Index (LPI), Mean Patch Area (AREA_MN), TE (Total Edge) and Interspersion Juxtaposition Index (IJI).

The result showed that at the landscape level, the number of patches was varying with the highest value in 2011 (NP = 2499) and least in 2021 (NP=1752). The largest patch index (LPI) was almost invariant across the years, with a slight increase in 2021. The Total Edge (TE) decreased across the years, with the highest value of TE (791190 m) recorded in 2001 and least in 2021. The Mean Patch Area (AREA_MN) increased across the years. Interspersion and Juxtaposition Index (IJI) values increased from 2001 -2011 and dipped to 56.57% in 2021.Detailed analysis at the class level revealed the dynamics of compositional and configurational differences in the three land-use classes. Till-land was the dominant land use in the anthropogenic matrix during the study period, followed by woodland. Built-up showed a consistent increase across the years. The increasing trend of built up across the years shows the rapid urbanisation and human settlement in the area. The geospatial analysis provides a comprehensive understanding of the dynamics of land uses that facilitates plant invasion.

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Geospatial Analysis of Internal Displacement Impacts on Vegetation Cover in Jebel Marra, West Darfur, Sudan

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Keywords: Natural resources, Internal displacement, Jebel Marra, Sudan

ABSTRACT

Natural resources play a critical role in the livelihood of developing countries. This research aims to explore the impact of internal displacement on natural resources with emphasis on community forest using remote sensing and geographical information system (GIS) technologies in order to manage natural resources in Jebel Marra. Two Satellite images of the years 1995 and 2016 were used. Four LULC classes were determined namely: forest, agriculture, settlement and soil. The dynamic spatial changes of these classes were analyzed and status of community forest in Jebel Marra was assessed. The analysis showed that during 1995 and 2016, the forest cover has decreased by 26.3%. Agricultural area has increased by 4.5 %. Bareland has been increased dramatically by 22.8 % while settlement remains stable quantitatively; however, Nertaty town was heavily extended as the result of IDP movement from the surrounding settlements. Deforestation was resulted from felling down of valuable trees for fuel, building in addition to security reason related to conflict in the region. Deforestation also has caused by IDPs around and some kilometers away from camps. Bareland increased in Northern part of the study area due to felling of trees for sake of mechanized agriculture.
The study concluded that security instability and internal displacement was heavily affected the natural resources. The study recommended a local periodic assessment of natural resources particularly forestry sector. Capacity building of local people is highly recommended to manage forest and simple GIS techniques to enhance their ability to manage and monitor community forest. The study recommended resolution of conflicts to enable environment and community to manage their natural resources in sustainable manner.

Modelling Long Runout Landslides of the Western Ghats using RAMMS

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Keywords: *Landslides, RAMMS, Debris flows, The Western Ghats*

ABSTRACT:

The Western Ghats mountain-chain is prone to landslides. The typical tropical climate of the Western Ghats causes intense weathering and, thereby, landslides. Landslides in the Western Ghats have caused severe destruction to life and properties for the last three years. Around 4,700 landslides occurred in the Western Ghats in August 2018, in which around 2,800 were debris flows. These landslides are induced by heavy rainfall and possess long runouts. These long run-outs cause hazardous effects on the population through its path. Landslide inventory was created for the windward side of the Western Ghats by mapping using high-resolution Google earth imageries, Planet scope imageries and Sentinel-2 imageries. The landslides in the inventory are debris flows with long runouts, and that caused severe damages. The effect and the runout characteristics of these landslides are studied by numerical modelling, the Rapid Mass Movement Simulation (RAMMS). ALOS PALSAR DEM is used as the topographical data for simulating landslides in RAMMS. The runout lengths, lateral spreads, flow height and flow velocity, were obtained from the runout modelling. With the help of these parameters, the damage caused by such long-runout landslides is assessed. Landslide runouts were simulated for the long-runout landslides in the Western Ghats and found that most of them follow the flow path.

The Assessment of the Impact of Floods in Budalangi, Kenya

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Keywords: *Sentinel 2A, Open Street Map, NDWI, NDVI, QGIS*

ABSTRACT:

The world is witnessing the effects of the long-predicted climate change. This is in the form of extreme weather conditions such as severe droughts, heatwaves and more than average rainfall. With these ever increasing and erratic natural disasters, there is a need to develop efficient and effective ways of responding to and managing the situation.

Currently, there is a lot of focus on artificial intelligence in many data processing tasks. Even though this is commendable, the strength of many of these models lies in the availability of training samples. A mismatch between training samples and the locally sourced data leads to wrong data inferencing and by extension incorrect decision making.

This exercise on the other hand intends to utilise previously tried and tested remote sensing techniques to assess the impact of floods in a region in Kenya, heavily susceptible to flooding. It intends to showcase the strengths of spectral indices, open data and spatial analysis in the correct assessment of features affected by flooding.

Flood water and Vegetation are calculated using NDWI and NDVI respectively from freely available Sentinel 2 imagery while building and road datasets are provided by Open Street Map. The number of buildings, length of roads and acreage of vegetated land affected by the flooding is then determined.

This approach provides a straightforward way of utilising opensource software and data to aid first responders better cope with flooding events.

Sustainability

The Role of Geomatics in the Energy Transition

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Keywords: *Geomatics, Renewable, Energy, Commission, Decommission, Carbon, Transition*

ABSTRACT:

The global push to reduce our environmental footprint has required new set of applications of Geomatics in energy exploration. The power to know where what is, has become one of the defining factors to conserve or restore our planet to a sustainably habitable home. From commissioning to the decommissioning of projects in new and renewable energies, Geomatics play important roles. Some of these accountabilities include project setup, site selection, geodetic controls, boundary definitions, orientation of sensors, connection of natural features, mapping carbon credits, change detection, satellite and UAV remote sensing, hydrography and sea floor mapping.

In this presentation, from the author's experience working across countries, disciplines and private and government organizations, we will explore the life cycles of energy projects and show where Geomatics expertise are pivotal to the success of the project. Intentionally, we drive down to the role Geomatics play to mitigate against environmental degradation, which contributes negatively to climate change. Key to this is restoring the environment to its state before the energy exploration. Keeping track of the spatial intelligence of the environment, and sharing them within connecting spatial, temporal and related attribute databases, have helped to quantify our climate change progress.

1. Introduction

Geomatics continue to act as the bridge in energy exploration between project concepts and their realizations on ground. Whether it is a new Wind Farm, Hydroelectric dam construction or installation of Solar or Hydrogen stations, Geomatics expertise is required at the start to finish. We are typically involved in reconnaissance, construction, and final picks for project maturation and operation. Geomatics provide spatial information (GIS) and employ Remote Sensing technologies such as unmanned Aerial or Underwater vehicles to monitor facilities.

Another key role is provision of spatial data to support the Licence to operate and obtain other regulatory permits to explore for energy. This will usually involve the mapping and collection of attributes of environmental and community concerns, required to be completed by governing agencies around the areas of interest.

The following figure shows some examples of Geomatics technologies used in this era of the Energy transition.

Figure 1. Geomatics technologies Renewable Energy (Source: Google Images, multiple authors)

Traditional Oil and Gas production is set to decline in line with society's demands for more cleaner and sustainable energy. Giant Oil and Gas organizations are transitioning aggressively from fossil fuels as an energy source, to alternative sources of energy, in step with climate and environmental demands to reduce the global carbon footprint. Strictly speaking, fossil fuels are "renewable" in that they can be created in thousands to millions of years when organisms decompose under heat and pressure. However, since the rate of consumption (depletion rate) of these energy resources are acutely faster than their ability to replenish, they are classified as non-renewable. The other effect of energy from fossil fuels is their pollution effect on the environment, affecting the lives and health of organisms on land and the marine. The pollution also offsets the balance of the planet's eco-system.

Coal, Oil and Natural Gas are the three main fossil fuel energy sources. These energy sources are estimated to be depleted on earth by the year 2060, if we continue to burn them at the current rate (Energy, 2021). However, millions of earth's populations depend on energy from these sources for daily survival. In Alberta Canada, over 90 of energy required to heat and survive the cold winters are from fossil fuels (Canada Energy Regulator, 2021).

Figure 2. Coal dumper trucks. Photo Credit: (conserve-energy-future, n.d.)

There are several by-products and use of non-renewable energies globally. As of today, we will be unable to completely shut off energy from fossil fuels without destroying lives, and the ways of lives of millions of populations on earth. This is where it is important to quickly transition to cleaner and renewable energy sources like solar, wind, biomass, hydroelectricity, hydrogen, and geothermal energy. These energy sources are called renewable, because they can be replenished by natural or artificial processes before their depletion. Also, they are considered to have a lower carbon/greenhouse gas pollution footprint on our environment.

It is important to note that renewable energies also have effects on climate change, although this is significantly lower than non-renewable energy sources. Solar and Wind have high initial costs for commissioning, and unfortunately contribute to the demise of birds.

Nonetheless, the energy transition is important to sustainably call earth our home. It is about the least destruction to the environment, in our quest to provide the energy our civilization needs to survive, to be comfortable and grow, while protecting the earth for the next generations.

Society, Governments, and Industries as a whole, need to act to collectively limit our global rise in temperature to no more than 1.5 deg Celsius above preindustrial levels. One of the companies in the frontlines to reduce emissions is Shell. Shell sorts emissions (based on the industry recognized global greenhouse gas protocol) into three scopes. The first scope are the direct emissions from all of Shell's operations, which includes Oil and Gas exploration, production, and processing, refining and chemicals production. The second scope refer to energy Shell buys from third parties to power its production. The third scope are customer emissions from energy produced by Shell, and the emissions from energies Shell buys and resells to customers.

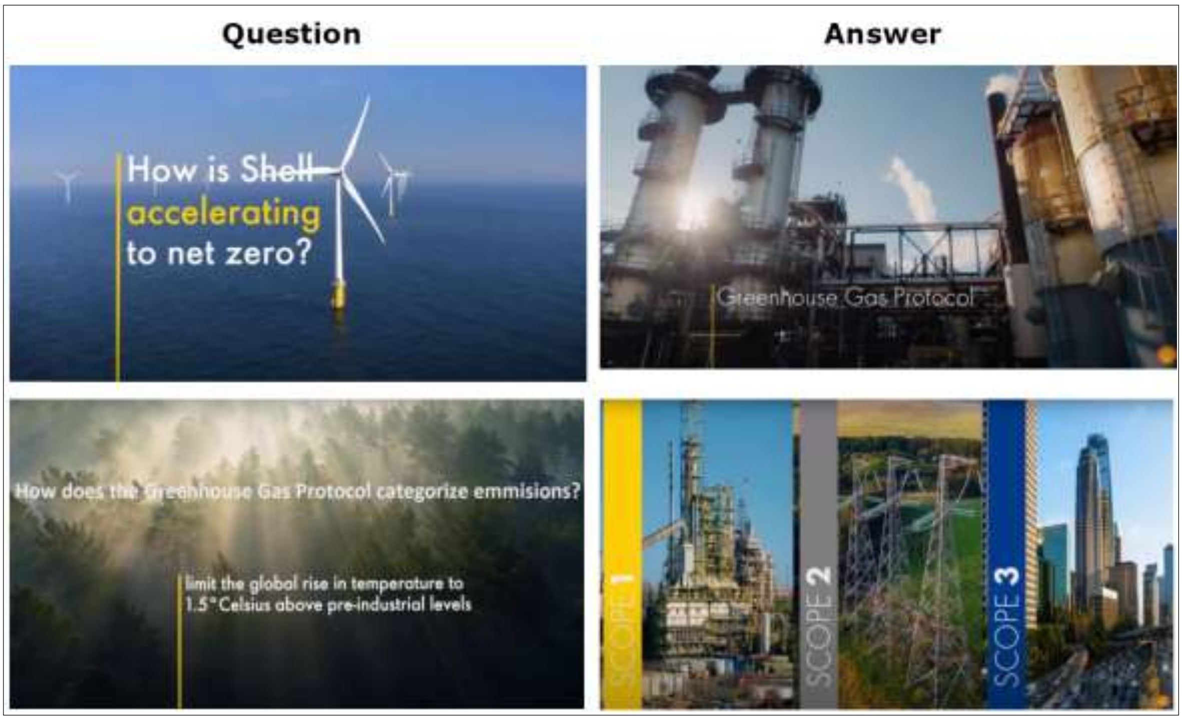


Figure 3. How Shell is accelerating to net zero (Shell, 2021)

Geomatics technologies play important roles in the energy exploration lifecycles and the energy transition. In each of these scopes, spatially tracking the emissions and mapping them with projects that provide offsets (for carbon credits) is one great value add Geomatics brings to the table.

In other major decarbonization projects like CCUS (Carbon Capture Usage and Storage), Geomatic technology help define the surface and subsurface location integrity and spatial mapping reports, required to explore, construct, and operate the capture of carbon, and place it safely below the earth.

Geomatics technologies monitor the capture process through deformation monitoring, seismicity and Wells location engineering, to ensure the captured carbon stays underground and not re-emitted into the atmosphere or to water bodies.

The Figure below is a summary of a typical example of the lifecycle of energy explorations.

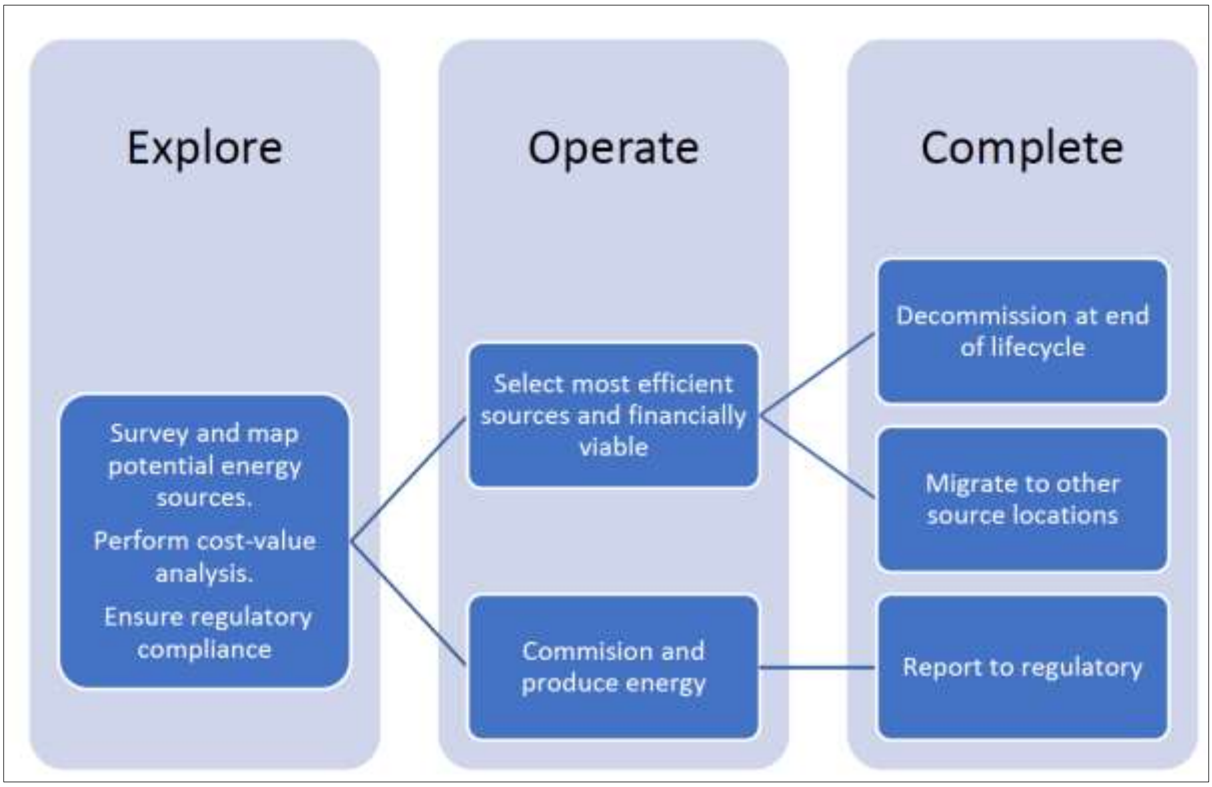


Figure 4. Overall lifecycle of energy exploration

We will quickly explore the workflow of common energy productions in the next sections.

1.1. Solar Energy

The harness of the sun for power has been done many generations before us. The sun has been the main source for giving energy to natural and man-made developments.

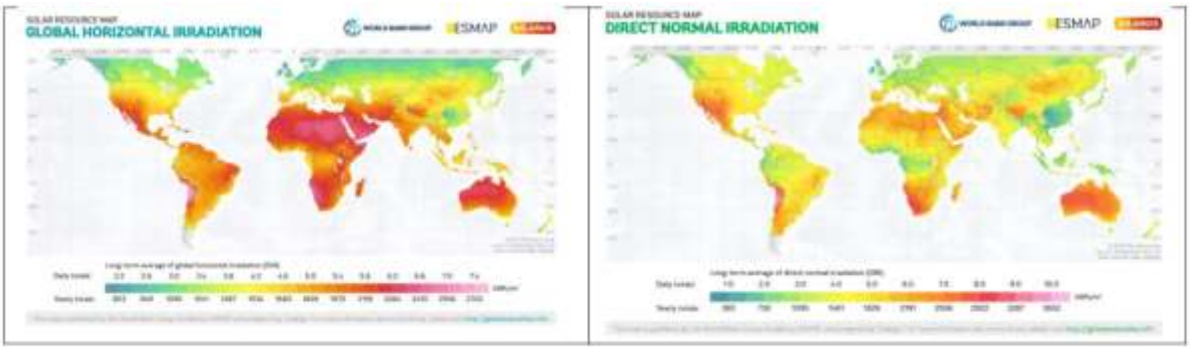


Figure 5. Global horizontal solar irradiation (Solargis, 2020).

Beseničara et. provide context for determining the azimuth for ground based and mounted solar panels as shown below. The Authors determined that the total solar energy in KW/day (SE) is dependent on the amount of radiation energy in KW/m3/day (RE), the surface area in m2 (SA), the angle of incidence (I) and the Azimuth.

Figure 6. Ground-mounted and building-integrated photovoltaic arrays (J. Beseničara et al, 2008).

In mathematical terms, SE = RE x SA x I.A

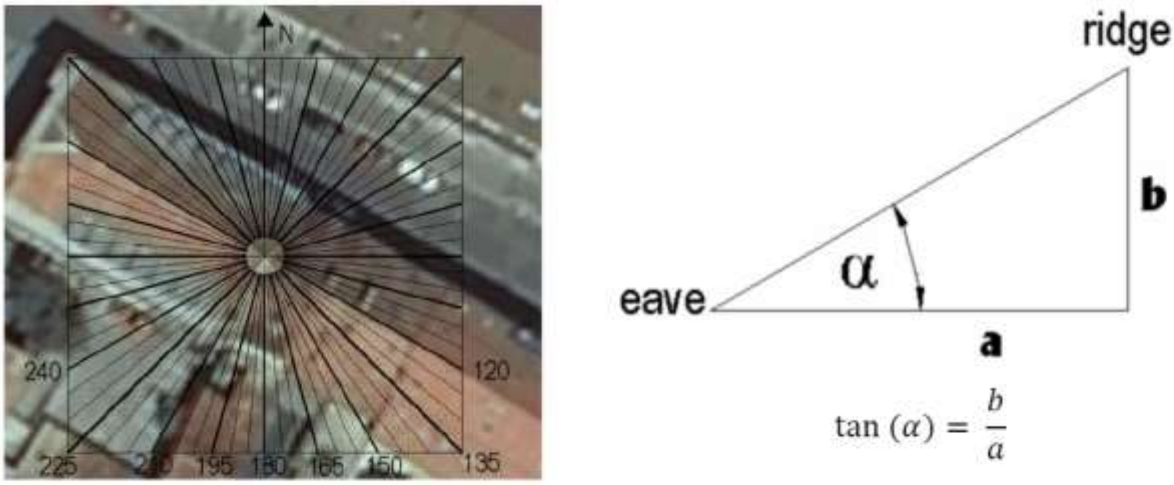


Figure 7. Azimuth determination for object (J. Beseničara et al, 2008)

The azimuth can be determined by orienting the object in line with a given North. Typically, the Magnetic North and its related Magnetic Azimuth is used, or the True Azimuths based on True North is used. Geomatics expertise and tools can be used to convert between the Grid north and True North (using Grid Convergence). Similarly, the difference between the Magnetic north and the True North, Magnetic Declination, can be used. In both cases, the East is reckoned as the positive direction. The Authors provided the formular for Inclination as the tangent of the roof height (b), which is the horizontal component of the steep (a).

Aside the azimuth angle, the tilt is also important for the best light incidence on the photovoltaic panels. It depends on the location and time. Noon at the equator will produce the highest sunlight. Placing the panels to face the equator improve outcomes. In the Northern hemisphere, the panels are placed to face south. And similarly, in the southern hemisphere the panels should face North. (McCloy, 2019) There are currently sun trackers which automatically tilt the solar panels to maximize the incidence of sunlight. Generally, without these trackers, knowing the latitude angle at the location of the solar panel, you can calculate the optimum tilt of the solar panels by adding and offset (e.g., 15 degrees) to the known latitude at winter and subtracting an offset angle (e.g., 15 degrees) from the latitude during summer (Rooij, 2021). The optimal azimuth and tilt can be determined by Sun Azimuth Surveys by Geomatics (Geodesy).

The measurement of mapping of ground and rooftop objects to determine suitability for solar energy is a key contribution of Geomatics. Shell has partnered with Silicon Ranch (a big independent solar power producer in US) and Cleantech Solar to growth it's solar business. Geomatics have been involved in the site location of solar panel sites. In Shell, projects relating to harnessing energy from the sun, are in several locations around the world.

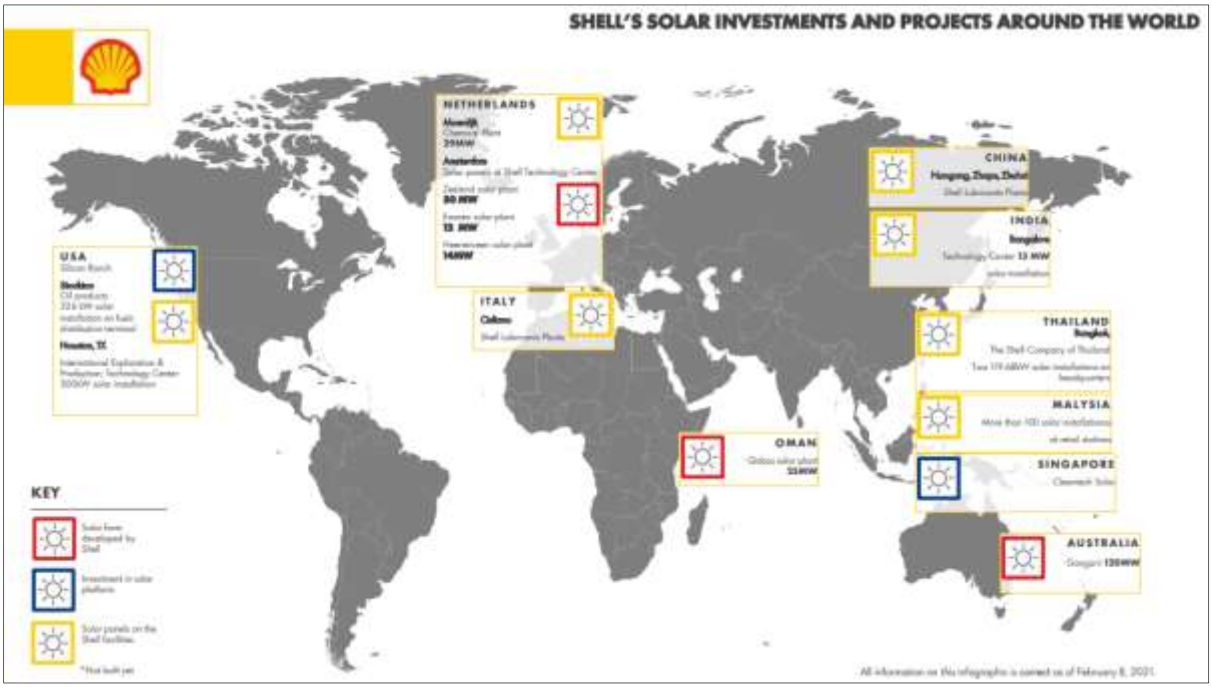


Figure 8. Shell Solar investments globally. (Shell, 2021)

Other ways of storing solar sourced energy beyond the availability of sunlight, and using the banked energy later, have been developed. However, there are many other supplementary energy sources that are considered renewable.

1.2. Other renewable energy source

The Figure below lists some energy sources from multiple sources and give some examples of the role of Geomatics in their exploration.

Energy source	Description	Examples of Geomatics Roles
hydroelectricity 	Globally, one of the cheapest and most affordable renewal sources of power is electricity generated from hydro-electric dams. Moving water spin a generator to produce electricity.	• Site selection • Land surveying/Levelling • Water ways and Displacement Maps • Reservoir Construction Survey support • Deformation Monitoring • GIS – spatial attribute data
Biogas 	Methane and CO_2 gases from the anaerobic decomposition or heat induced chemical conversion of organic waste from household, farming, sewage, and restaurants create renewable energy.	• Site selection • Site Mapping • Tank and piping construction • GIS / Online mapping • Facility inspection via drones
Wind 	Wind turns generators to produce electricity. Although it requires several other products to design, build and operate, Wind Energy, once operational provides a renewable source of energy between 20 to 30 years.	• Site selection • Land surveying/Levelling • Deformation Monitoring • GIS – spatial attribute data • seabed surveys • Construction • Subsea cable piping • Deformation monitoring • UAV (drone) inspections
Hydrogen 	The biproduct of this energy is water. This makes this a clean energy if it is sourced from non-fossil fuel sources like water. Over 95% is currently produced from fossil fuels.	• Site selection • Site Mapping • Tank and piping construction • GIS / Online mapping • Facility inspection via drones

Geothermal Energy 	This is a clean renewable energy produced from the earth's core. Heat is constantly generated in the earth's core and will continue to be for billions of years to come.	• Site selection • Land surveying/Levelling • Displacement Maps • Construction Survey support • Deformation Monitoring • GIS – spatial attribute data • Drilling location support • Surface and subsurface geodetic integrity
Marine Energy 	Converts kinetic energy generated from the fast movement of waves from the sea and ocean/river currents into electricity. Includes energy generated from temperature differences ocean salinity.	• Site selection • Land surveying/Levelling • GIS – spatial attribute data • Seabed surveys • Construction • Subsea cable piping • Deformation monitoring • UAV (drone) inspections

Figure 9. (Shell, 2021), (Renewable-Energy-Magazine, 2021); (Sonal, 2021) (Shell, 2021) (Tranter, 2021) (WaveStar, 2011)

In addition to the above roles, other efforts to provide the storage for CO2, harnessed energy and service stations are supported by Geomatics. Below are a few of them.

1.2.1. Electricity and EV Charge stations

Electricity is harnessed from multiple sources including solar, Wind, hydro-electric and biogas degenerations processes. During the selection of sites for recharge stations, Geomatics play an important role. The answer to where (in terms if distance) can a fully charged electric car reach before requiring a recharge is a typical Geomatics questions.

1.2.2. CCS

Carbon Capture and Storage (CSS) has advanced as the technology to offset large tons of carbon emissions contributing to climate change. In this technology, Geomatics is involved in collaborating with Geophysics, Geologists, and other Scientists to lock down CO2 down the earth, and keep it there.

Geomatics plays an important role in surface and subsurface monitoring when CO2 is ingested underground. Monitoring through seismic and deformation measurements has led to avoiding the release of the ingested gas back to the atmosphere or the environment.

1.2.3. Nature Based Solutions and Carbon Trading

This allows matching areas of carbonization with areas providing the carbon credits to offset the carbonization. Geomatics support accounting of quantities and answer key questions like "where is the source of the carbon located, and where is the target for carbon credits"? Included in the accountabilities is the carbon quantitates, stored as attributes.

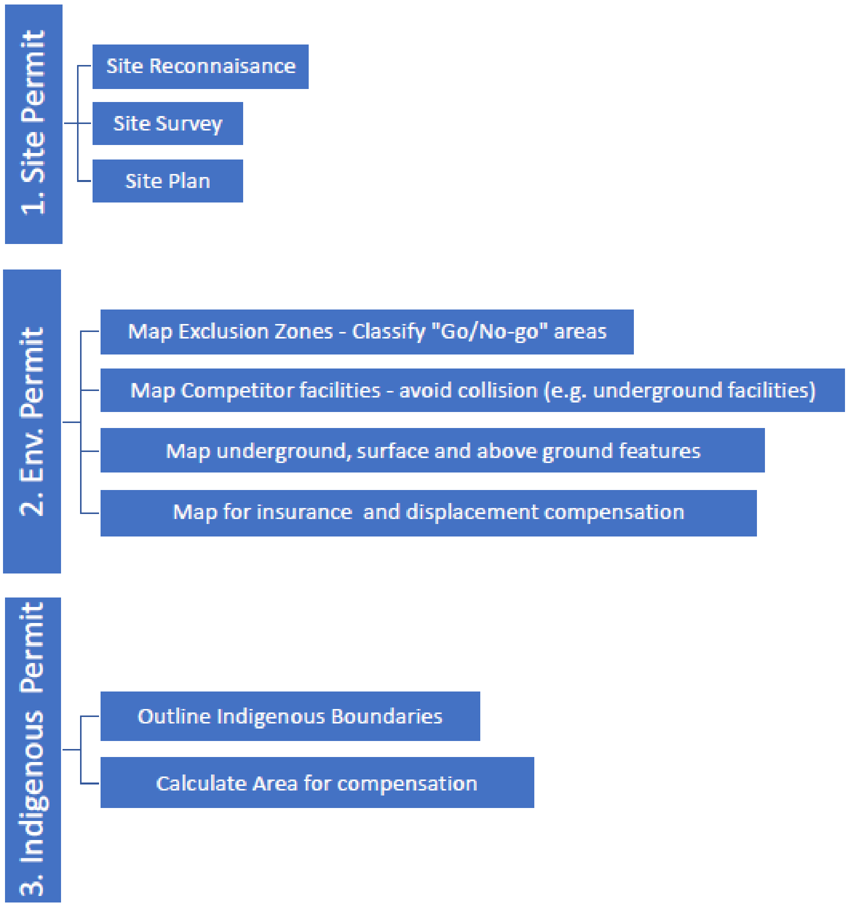
2. Common Workflow and Geomatics' Role

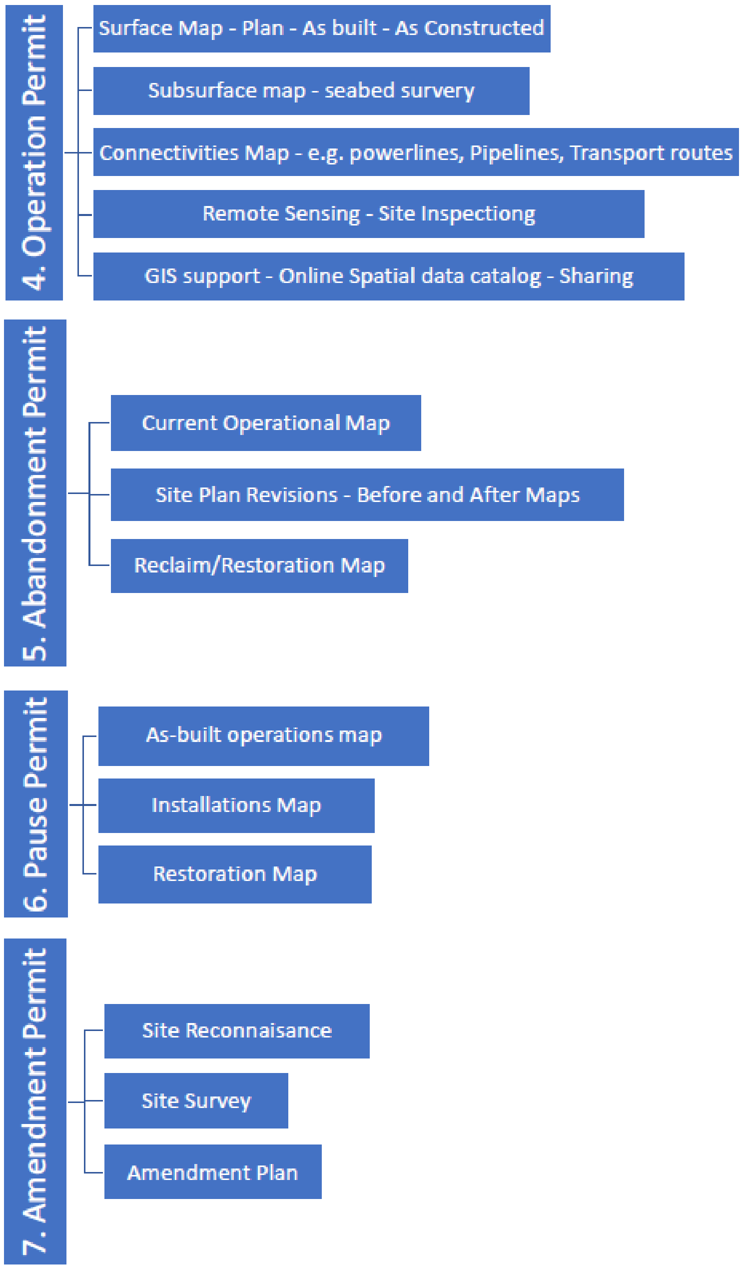
One of the early calls to Geomatics during energy exploration are requests for legal plans to apply for the Licence to operate. Geomatics is fully engaged in these Licence requests. Our input is required for:

• Regulatory Approval to operate at a location, which includes government, environmental and construction permits, within the land or sea boundaries, in accordance with the law governing the onshore or offshore location of interest.

• Community acceptance to proceed with energy explorations in their territories. This is important when dealing with local landowners and indigenous settlers. The mapping of the location of cultural, religious, and historical sites, and determining acknowledgements and compensations based on area, is within the accountability of Geomatics.

The flowchart below provides a typical engagement:





Typically, several licensing processes are involved. Some of these include:

• Site Permits (Survey plans for surface and sub-surface exploration)

• Environmental Clearance Permit

• Indigenous (local landowners) permit

• Licence to operate (also known as Commissioning Licence)

• Licence to Abandon at end of Lifecycle (also known as Decommissioning Licence)

• Licence to Amend or Extend a previous permit

• Licence to Abandon (Pause operations) before the end of Life (for operating projects projected not to be commercially viable in the long term, due to high operation cost or low demand)

2.1. Exploration, Budgeting and Project Selection Phases:

Geomatics is typically part of the first team on ground to perform reconnaissance of the area of interest. Basic sketches are mapped for tabletop discussions of where the Organizations and Energy experts identify as places to consider for construction and operations.

Geomatics is the discipline accountable for capturing the location of surface and subsurface objects and their related legacy data (old data in the same area) with key attributes like the geology, soil type, zoning, and exclusions (reserved areas).

In this phase, one key expectation of Geomatics is for the group to provide the spatial intelligence that will rank explored sites, to help narrow down options at the Project Selection Phase.

2.2. Project Commission Phase

Once the business decides on the sites to construct the new energy facility, they will require Licenses to Operate. Geomatics provides all maps and related attribute data to satisfy compliance of the land and energy exploration Regulators. This could also include paper logs of all findings during the exploration stage like the location and quantities of deposits in the areas of interest, exclusion zones and other locations of public interests to protect.

Another key Geomatics contribution at this stage is to help get the approval from the local community to allow operations. Indigenous landowners are consulted with maps from Geomatics showing the areas required for the project. Compensations and other interests are calculated based on size of area of interest. Geomatics also help record these landowners and the area or areas they control in case they need to be contacted in the future.

2.3. Project Operational Phase

Geomatics is involved in the constructional phases providing the layouts translating plans on maps to the ground. We are also involved in the continual monitoring of the facility during operations – providing key spatial intelligence of visible changes around the facility that could create a hazard. For instance, on a solar farm, site inspection flights and image reduction help determine panels that are defective and require replacement or repairs. An inclining Wind Farm can also be spotting during deformation monitoring to avoid collapse. Windmills are heavy and huge constructions. A collapsing Windmill could cause harm and death to birds and humans. It is also the accountability of Geomatics to help spot sinking establishment on the seabed or on land. Early warning mapping systems help avoid fatal catastrophes, injury, or loss of property.

Continual regulatory compliance requiring Geomatics data expertise like health of facilities, deformation reports and expansions (to the as-constructed facility), continues with the lifespan of the project. For instance, with technologies utilizing subsurface installations, Regulatory organizations will require to know from Geomatics how stable the subsurface activities are. Seismic data and satellite data (InSAR) can be used to achieve deformation monitoring of surface stress relating to subsurface activities.

2.4. Project Decommissioning Phase

Finally, Geomatics is involved in the closing stages of the project. Restoring the site back to as close as possible to its original state, pre-exploration, is important for the balance or earths ecosystem. Now and then maps from Geomatics help in this restoration stage. Questions like what was where? How big was the plantation? How large was the swamp? Are all answered with the spatial intelligence Geomatics provide.

All regulatory closures on what was done and what was decommissions are dependent on the maps Geomatics provide. It is therefore safe to say Geomatics are part of the first team to arrive at energy exploration projects, and the last to leave.

3. Summary

It is clear Geomatics is a transferable skill and technology as the World seek more renewable sources of energy. From Commissioning to the decommissioning of projects in new and renewable energies. Geomatics expertise utilized in this transition include:

• Surface Location Integrity

• Subsurface location integrity – hydro and seismic

• Geographic Information Systems

• Project setup,

• site selection,

• geodetic controls,

• boundary definitions,

• orientation of sensors,

• connection of natural features,

• mapping carbon credits,

• change detection,

• satellite and UAV remote sensing,

• hydrography and sea floor mapping - Seabed Surveys and subsea construction

These expertise have helped to de-risk and mitigate against hazards in the selection, construction, operations, and closure of projects in the new energy sector.

We have discussed our specific roles in ensuring we provide the documentations required to allow for the safe and profitable exploration of energy (Licence to operate). Geomatics also play important roles in documenting constructions and operation data using maps with related attributes (GIS). Another key Geomatics role is using technologies like remote sensing (UAV, Underwater vehicles), Seismic and old-time levelling to monitor the stability of energy projects.

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Sustainable Energy Project Management: A Review on Success Factors

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Keywords: *Renewable energy, Project success factors, Project management*

ABSTRACT:

Chances of successfully completing a Renewable Energy (RE) project is always in question. Many scholars have tried to identify the critical success factors and barriers to overcome such that projects can be successful. A thorough review has been done here to compile the factors that need to be considered to make RE projects successful. Based on this theme, over fifty literatures were reviewed to identify fifty-six success factors. Those factors were further grouped into nine major categories, namely Project Strategy, Policies & Politics, Project Attributes, Stakeholder Interactions, Project Parameters, Culture & Leadership, Resources, Managing Risks and Project Governance. Further, weightage of each category is assigned based on number of factors belonging to that category. Finally, score to Project Success is calculated based on weighted average value of each category. We believe that this tool is very simple to use whereby stakeholders related to an RE project will be asked to rate their view on scale of 1-5 (where 1 stands for least likely, least satisfied or least agreed and 5 stands for most likely, most satisfied or most agreed) for all the fifty-six factors. Then average score of each factor is placed in the tool to automatically calculate the probability of Project Success. This tool can be modified as per the factors and/or weightage required in given project situation. The probability of Project Success is only tentative. Project team is suggested to regularly review the score of each factor and endeavor must be taken to increase the scores to 5 as much as practically possible.

Spatial Variation Analysis of Iron, Manganese, Zinc and Copper Existence at Anaimalai, Coimbatore

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Keywords: *Spatial variability, Geostatistical, Semivariogram, Interpolation, Soil micronutrient*

ABSTRACT:

Spatial variability models for Iron (Fe), Manganese (Mn), Zinc (Zn) and Copper (cu) available in agricultural soils of Anaimalai block, Coimbatore, India were derived in this study. The Study was investigated through geostatistical and geographical tools for producing soil micronutrient maps, which finds ample applications in agro-decision making. 106 soil samples were collected in regular grid (50cm × 50cm) at the agricultural farmlands of Anaimalai block. Soil iron, Manganese, Zinc and Copper existence founds to be spatially heterogeneous in nature, ranging from 0.5 to 28 ppm, 0.8 to 24 ppm, 0.1 to 11 ppm and 0.1 to 1.6 ppm respectively. Normality in distribution of soil micronutrients was accomplished by using logarithmic and box-cox transformation. Spatial autocorrelation was described by using directional exponential model for Fe, Mn, Zn and Cu. More precise spatial variation was pictured from Semivariogram methods. Spherical, exponential, Gaussian and linear models of Semivariogram experiments were conducted for each soil micronutrients. Randomized Mean Square (RMSE) was derived from each experimental model. Derived RMSE was compared and accuracy of various interpolation models is assessed. Reliable interpolation model is recognized as better assessment tool for spatial variable investigation of soil micronutrients. Scale of soil Fe, Mn, Zn and Cu is need to be monitored periodically and spatially since deficiency leads to stunted crop productivity where excess leads to soil contamination. Revealing precise spatial variability of micronutrients of Anaimalai block at large scale using geostatistical tools brings out the novelty of the study.

Alpha Diversity Mapping in Tropical Deciduous Forests Using High-Fidelity Imaging Spectroscopy

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Keywords: *Sentinel-2; AVIRIS-NG; Alpha diversity; Tropical deciduous forests*

ABSTRACT:

Plant species diversity is influenced by spatial heterogeneity while ecosystem and biodiversity assessments in real-time and accurate manner in changing global biodiversity are becoming increasingly essential. However, the biodiversity estimation over a large area using ecological field data is very challenging. Some of these limitations can be overcome using the use of satellite remote sensing and advanced approaches including Spectral Variation Hypothesis (SVH) that indicates higher chances of more organisms to coexist in a community under higher spectral heterogeneity over the different pixel units. The present study evaluates the potential of SVH in tropical deciduous forests (TDFs) using floristic composition and very high resolution AVIRIS-NG hyperspectral images (acquired on Jan. 2016 and Mar. 2018), and Sentinel-2 multispectral images (acquired on Jan. 2018, Mar. 2018, Oct. 2018 and Dec. 2018) to map the alpha (α) diversity of Mudumalai Tiger Reserve over different seasons. Field based observation, including the on-site description of a set of 42 plots (size: 20 m × 20 m) was performed to record the species diversity in the region. Spectral data was extracted by associating each plot with corresponding pixels from the satellite images. Relationships between field-based Shannon-Wiener diversity index (H') and satellite imagery derived alpha diversity was analyzed using linear regression technique. The study exhibited a positive relationship of H' with satellite imagery derived α-diversity and AVIRIS-NG derived α-diversity reporting the higher R2 score. Field-based H' had high correlation with AVIRIS-NG based α-diversity (R2: 0.83 and 0.82), compared to Sentinel-2 based α-diversity (R2: 0.50–0.63). The availability of Sentinel 2A satellite data supplements the seasonal variability between spectral variability and species diversity with high correlation during post monsoon (R2: 0.63), and non-monsoon (R2: 0.60) while least during monsoon seasons (R2: 0.57). The results highlighted the use of high spatial resolution hyperspectral and multispectral satellite datasets to complement field-based observation for fine-scale species diversity mapping at spatial and temporal scales.

Land Use and Land Management

Land Conflict Inventory: A tool to strengthen Land Conflict Resolution Mechanism - A case study of Chautara Sangachwokgadi Municipality, Nepal

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Keywords: *Land conflict, Land conflict inventory, Cadastral-based land conflict map, Land conflict patterns, Land conflict resolution mechanism*

ABSTRACT:

Land conflict is one of the most sensitive social phenomena in which at least two parties are involved, and whose origins are differences in interests regarding a given piece of land. The land conflict resolution systems need to be impartial, timely, affordable and shall provide alternative means to resolve the conflict.

In Nepalese context, the number of land conflicts is increasing every day, as the conflict resolution mechanism is inefficient. The analog resolution mechanism does not reasonably categorize the conflicts that would have aided the better resolution. Conclusively, the land conflict resolution mechanism opted by Nepal needs significant improvements. This research finds how, and to what extent – the recordation of land conflict supports the conflict resolution mechanism to deliver equitable and efficient land conflict resolution. Land conflict inventory is a comprehensive digital database of land conflicts and provides the references to previous conflicts and their non-spatial features. The initial step towards generating land conflict inventory is to collect the land conflict information from the district court, survey office, and land revenue office and record them in a standard format to create land conflict inventory. The analysis of elements of the conflict inventory suggests the significance of land conflict inventory to strengthen the current land conflict resolution mechanism.

1. Background

International Federation of Surveyors (1995) defines land as “a portion of the earth to which rights of ownership, stewardship, or use are exercised.” According to Nepali Land (Survey and Measurement) Act 1963, land refers to - all categories of land, including those with buildings, gardens, trees, factories, ponds, etc. Land as a symbol of wealth in Nepali community defines the social, political and economic status of an individual. Thus, due to its economic, social and emotional importance, land is also an important source of power in a community (Kaye and Yahya 2012).

The social definition of land varies from community to community. Even though legal definition limits land to a physical object, communities perceive it as an intangible asset. For instance, a family in a Newar community shall have at least one piece of land inside the community territory to be a part of the community (Guthi). Similarly, Raute tribes, one of the marginalized tribe of Nepal, do not accept legal ownership over a piece of land but believe that the whole forest is their home and no one can pull them away from his or her property.

According to the Nepalese national agriculture census of 2001, out of total 3,364,100 farmer families, landless farmer families (less than 0-0.1hector) are 227,100 (8 %) in number and marginalized farmer families (up to 0.1-0.3 hector) is 670,000 (20 %) in number (CBS Nepal 2003).

Adequate distribution of land and other natural resources among the population is challenging due to limited but high demand for land. In Nepal, many attempts to manage land related discrimination and avoid landlessness failed to achieve the target. For example, even though land reform of 1960’s in Nepal, limits ownership by defining the maximum landholding ceiling, a large portion of the population still lack land ownership.

According to annual report 2015/16 of the Supreme Court of Nepal, 21.5% of total court cases in different courts of Nepal are land-related cases. The total registered cases in 2015was 38,741 among which only 17,886 cases were solved, and 20860 cases are pending. Conflicting Acts and policies, inefficient and unprofessional land agencies, corruption & unaccountability in land administration, political and social dominance, traditional organizational system and technology, and so forth contribute to land conflict in Nepal. As consequences of these problems, conflict in land is escalating. Transparency International finds land sector as one of the most corrupted public sectors in Nepal (TI Nepal 2016).

Land for generations in Nepal are being recognized and recorded in various form. Before 1964, when land records were not based on cadastral maps, lands were recorded by local heads like Jimindars, Talukdars, Mukhyas and Patawaris (Acharya 2008). The government of Nepal has created legislation for land management and land reform repeatedly but with the little actual result. Fixing land ceiling, protection of tenancy rights, farmer-oriented land reform, land right to landless slum dwellers, preparation of land use policies, and strengthening are good attempts towards increasing land tenure security. However, traditional LIS, unaccountable and corrupt bureaucratic system and less participation of the public in policy formulation are challenges to tenure security (Rawal et al. 2016). In the countries like Nepal where diverse ethnic groups reside, the diversity of land tenure patterns enormously contributes to conflict (Upreti 2009).

Land conflict information registered in the formal system (court, land revenue office, survey office, and municipality) with a huge effort can be used as a valuable source to develop a land conflict inventory. However, assembling information of conflicts resolved by informal mechanism will be challenging because conflicts are not registered/recorded. Since many land-related cases are solved out of formal system, inclusive land conflict inventory is ideally incomplete. Very often, the tools used for conflict resolution as defined by the existing law such as mediation, trust land management, land redistribution, rapid assessments, and so on seems outdated. This habitually raises questions over truthful justice. Hence, categorizing different types of conflicts and analyzing them in a spatial manner can be a better way out to define authentic tools for resolving them in bulk.

2. Components of Land conflict inventory

As an initial step of the research, data required for the study were collected from multiple platforms. Both spatial and non-spatial data, required for the research were assembled from the concerned authorities. The challenging part of this data collection was to reach concerned person and inventory because of the complex legal and bureaucratic procedures.

Spatial (locational) and non-spatial (attribute) data are two major types of data used in this research. Besides, data assembled via questionnaire and semi-structured interviews aid this study. Primary data for this study are the data collected through questionnaire and semi-structured interviews. Conflict data from different government inventories and cadastral map in digital form from survey office are secondary data used in this research. Along with, types of conflicts, causes of conflict, actors involved in conflict, and so on are the components of land conflict inventory.

2.1. Types of land conflict

The typology of types of land conflict as in different literature is used to categorize different land conflicts that exist in Chautara Sangachwokgadi municipality. Land conflict Inventory of Chautara Sangachwokgadi municipality reveals the existence of 15 types of conflict. These conflicts along with the consequent number of the conflicting parcel are as in table 1.

According to the respondent of the questionnaire, boundary conflict, and inheritance conflict are the most occurring types of land conflict. However, encroachment in public and unused land, provision of trust land, the dispute in ownership, conflict due to transfer, conflict due to land use, and so on are other types of conflict common in Chautara Sangachwokgadi Municipality.

The major types of land conflicts as per respondent’s opinion are analyzed in a bar graph by relating them to the types of land conflict in land conflict inventory. The weight of the graph refers to (i) the percentage weight of the respective type as defined by the respondents, and (ii) the percentage of conflicting parcels according to type categorization as in land conflict inventory. Figure 1 demonstrates how familiar the respondents are with the existing land conflicts.

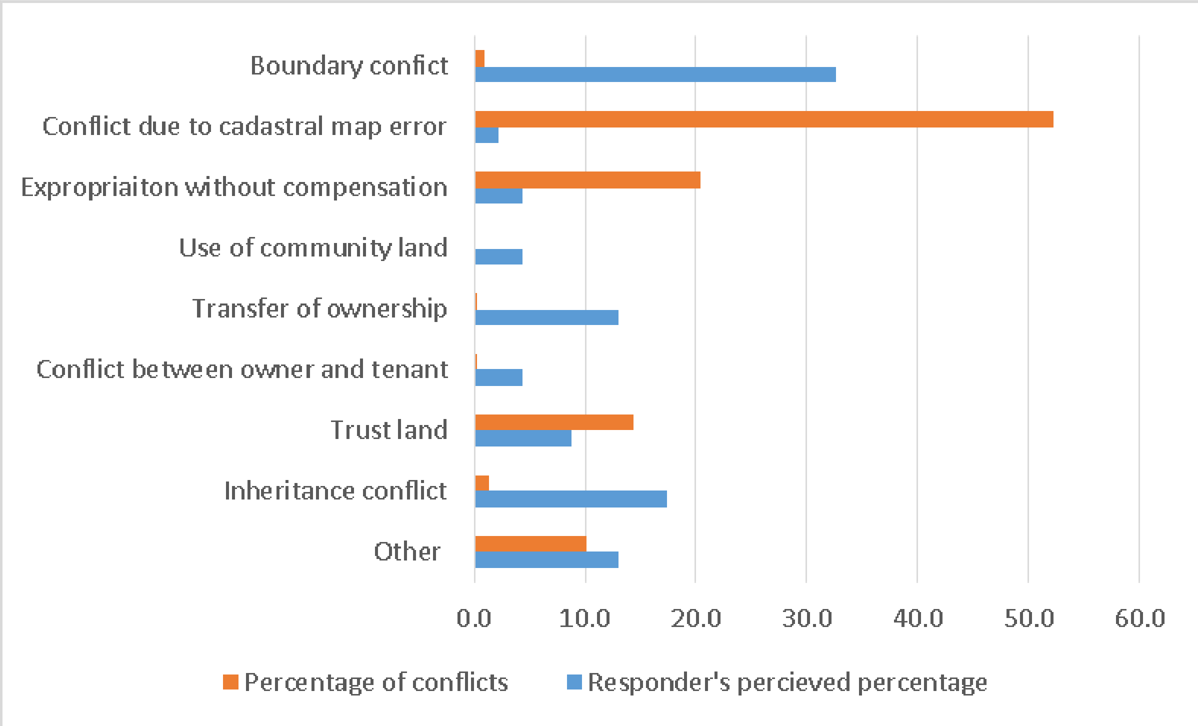

Figure 1: Bar graph of respondent understanding over the types of conflict in land conflict inventory

(Source: Author)

The analysis of information in questionnaire shows that the respondents, who directly involved in policymaking and implementation, lack information about the dominant type of land conflict in this particular area. Expropriation without compensation, and land conflict due to an error in cadastral maps, as in table 1, are the major land conflict types in Chautara Sangachwokgadi municipality. However, the respondents seem lacking proper information on existence and frequency of dominant land conflicts. Thus, this situation enhances the significance of land conflict inventory.

TYPES OF CONFLICT	NUMBER OF CONFLICTING PARCELS
1. Conflict due to lack of registration	2
2. Conflict due to wrong naming of owner during land recordation	5
3. Illegitimate expropriations by bank	8
4. Boundary Conflict	25
5. Conflict over Use of community land	4
6. Conflict due to trust land	363
7. Conflict due to divorce	12
8. Inheritance Conflict	35
9. Conflict of ownership between owner and tenant	5
10. Conflict due to Tenancy right	221
11. Encroachment on public land	2
12. Conflict due to duplication of parcel number in cadastral map	5
13. Conflict due to error in cadastral map/data	1321
14. Expropriation without compensation	515
15. Transfer of ownership	6

Table 1: Numbers of conflicting parcels corresponding to different land conflict types (Source: Author)

According to the annual report 2016 of district court Sindhupalchwok, legally defined conflict types are boundary disputes, registration revokes, decision revoke, tenancy removal, right assignment, deeds revoke, right clearance, transfer, harvest/product violation, leased crops and others. Since 15 different conflicts exist in our study, it is significant to reclassify under the domain of 11 different types of legal land conflicts and analyze the inter-relation.

2.2. Causes of land conflict

Land and land conflicts always occur with multiple phenomena and hence cannot be subjected to a single cause. However, the primary cause of the conflict can be witnessed by studying them precisely. The causes of land conflict can follow different typologies. In this study we reference to Wehrmann (2017) typology of causes of land conflicts. The causes of these conflicts in Chautara Sangachwokgadi municipality are found to be either political or socioeconomic or financial or socio-cultural or legal or administrative or and technical. Table 2 shows the classification of types of land conflicts under the domain of causes of land conflicts.

PRIMARY CAUSES	TYPES
ADMINISTRATIVE	Conflict due to lack of registration
	Conflict due to wrong naming of owner during land recordation
ECONOMIC AND FINANCIAL	Illegitimate expropriations by bank
	Boundary Conflict
POLITICAL	Conflict over Use of community land
SOCIO-CULTURAL	Conflict due to trust land
	Conflict due to divorce
	Inheritance Conflict
	Conflict of ownership between owner and tenant
SOCIO-ECONOMIC	Conflict due to Tenancy right
	Encroachment on public land
TECHNICAL	Conflict due to duplication of parcel number in cadastral map
	Conflict due to error in cadastral map/data
LEGAL AND JURIDICAL	Expropriation without compensation
	Transfer of ownership

Table 2: Reclassification of existing types of land conflicts as per their causes (Source: Author)

The assessment of causes of land conflict was conducted among the 22 respondents to questionnaire. The quantitative measure was taken to evaluate the role of different causes of land conflict. Respondents of the questionnaire were asked to value of the different causes in a land conflict. Assigning the values from zero to ten (0= no effect, 10= totally affected), the average value for individual cause was calculated.

The highest score was 6.492 for economic and financial cause whereas psychological causes scored the lowest value with the score 4.048. Along with economical and financial cause, legal and juridical cause, administrative cause, and technical causes contribute more than an average to land conflict.

Since the lowest value is 4.048, we consider 4.0 as a baseline to plot the score in a bar graph as in figure 2.

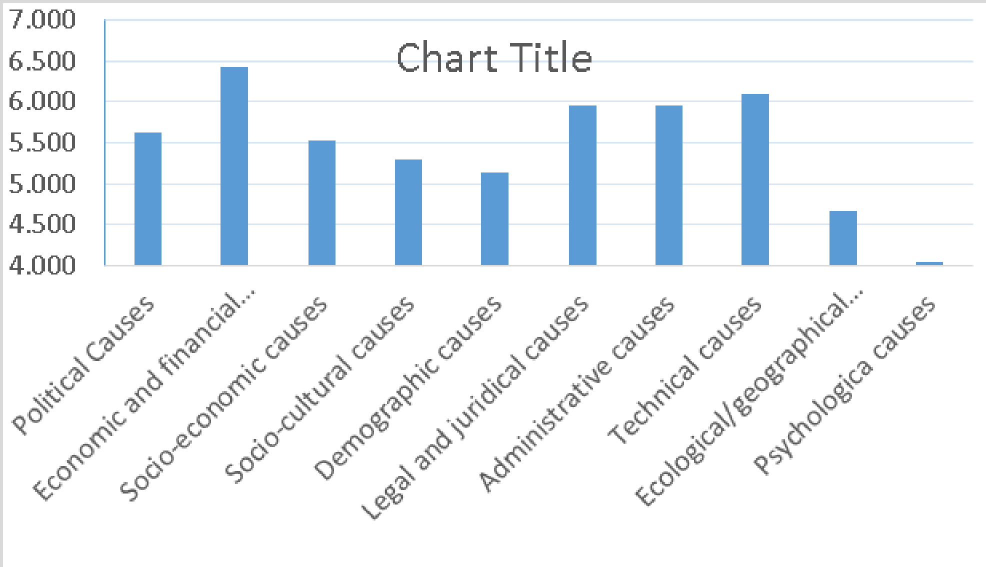

Figure 2: Bar graph of causes of land conflict as per respondent's opinion (Source: Author)

3. Land conflict inventory

The first task in mapping land conflict is to reconstruct the spatial database as per study requirement. Mapping land conflict in a spatial domain is a technical task. The use of advanced mapping software like ArcGIS, QGIS, AutoCAD, etc. makes the map dynamic and informative. In our research, the cadastral map of Chautara Sangachwokgadi municipality as provided by survey office of Sindhupalchwok district contributes as a spatial data. Since the municipality is formed by merging ten neighbouring VDCs , the data contains ten VDC boundaries as administrative boundaries. The digital cadastral data contained individual map sheet that seeks technical assistance to merge them. The hard copy maps of different scale were scanned and manually digitized to construct a digital database. One hundred and thirty-four individual map sheets were merged to form a single database of the municipality in shapefile format. This function was carried out with the use of ArcGIS 10.4 software and python programming skills.

The second task is to generate the land conflict inventory. Land conflict inventory as in conceptual model is an inclusive registry or database of land conflict. In this research, MS Excel sheet was used to record properties land conflicts assembled from different platforms. Different parameters of conflict as a type of conflict, the cause of conflict, actors involved, etc. were recorded in a specific format. Along with the spatial attributes like VDC code, map sheet number, ward number, and parcel number were recorded manually. Since these land conflicts are aimed to overlay in the cadastral map, spatial attributes of individual parcels that undergo land conflict are mandatory.

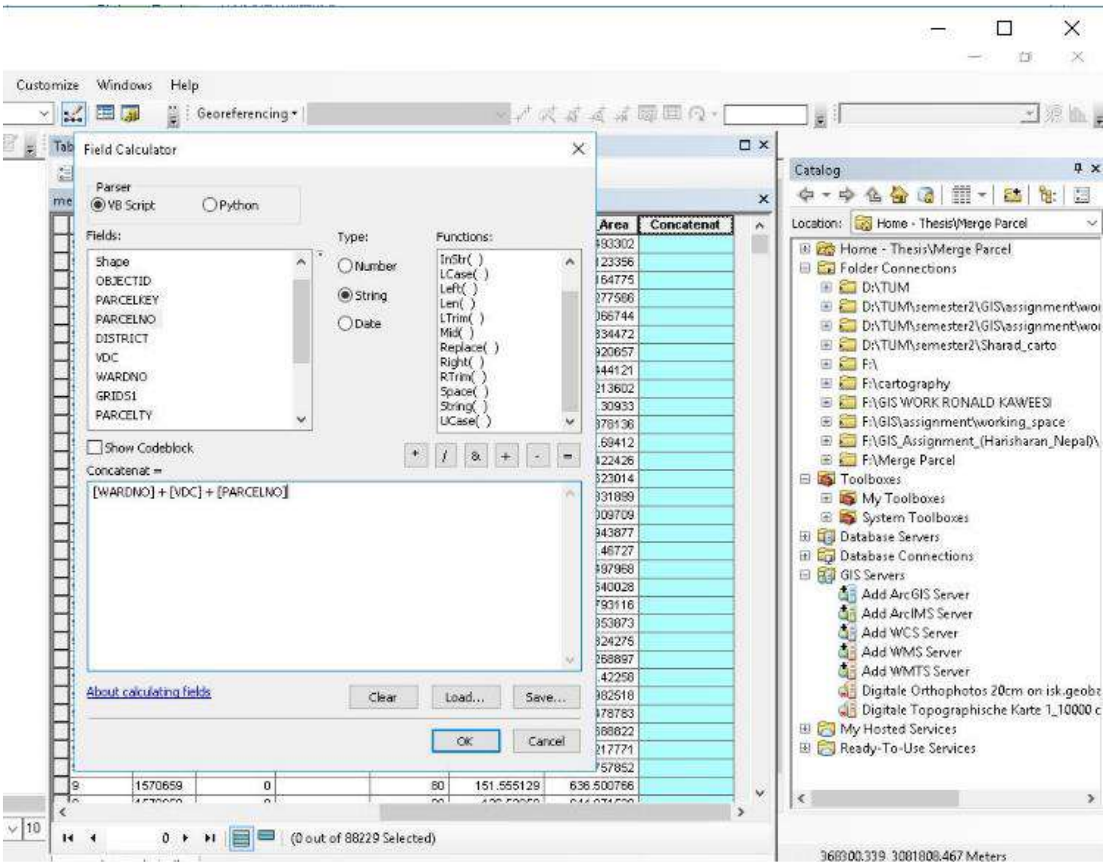

Figure 3: Concatenation function for generating unique field (Source: Author)

The third task is to link cadastral database with land conflict inventory. In order to join two databases, at least one column in each database needs to be common. This common column serves as a primary key to join the database. To generate such common parameters among spatial and on spatial data is challenging. Therefore, relevant information necessary for this technical task were identified before data collection and were assembled during the data collection. In our study, concatenation function was used to generate a primary key as in figure 3. Concatenate function, in this study, was assigned to form a concatenated value using VDC code, ward number and parcel number. The combination of these three attributes is unique and hence provide with a feature of primary key. "Join and relate" function of ArcGIS software provides with the tool to join cadastral database (shapefile) and the land conflict inventory in excel sheet.

Land conflict inventory notices that 2,529 parcels undergo land conflicts in Chautara Sangachwokgadi Municipality. These conflicting parcels are categorized in fifteen different types as in table 1. Similarly, seven different causes are analyzed influencing these conflicts and are discussed in table 2.

4. Significance of Land conflict inventory in resolving land conflicts

Land conflict information provide with to the information regarding the conflicting land. Land conflict inventory contributes to the source of land conflict information. Non-spatial attributes of the conflict such as the type of conflict, causes of conflict, actors involved in conflict, date or period of conflict and so on help the analyst and decision makers with fruitful information about the land conflict. Along with, spatial attributes like the location of the conflict, area, spatial pattern, administrative boundaries, etc. aids in quick visualization of information.

Failure of different rules, regulations, policies, and programs regarding land management and land conflict management demonstrate that they lack proper planning tools. Without understanding the basics of conflict, the projected conflicts in these programs may differ from the real-world conflicts. As discussed in chapter two, resolution of land conflicts without understanding their components degrades the situation. Thus, the implementation phase followed by less participation of the target group, often fails. The difference in understanding major land conflicts among the respondents of the questionnaire and existing conflicts as in land conflict inventory, as in bar graph of figure 1, is the best example to demonstrate that land conflict inventory provides with the relevant information. Along with, to meet the sustainable dreams of hunger less and rich society, land distribution system, if needed, shall be reviewed. Land conflict inventory can be a better tool to have a quick overview of existing land conflict chart of any territory.

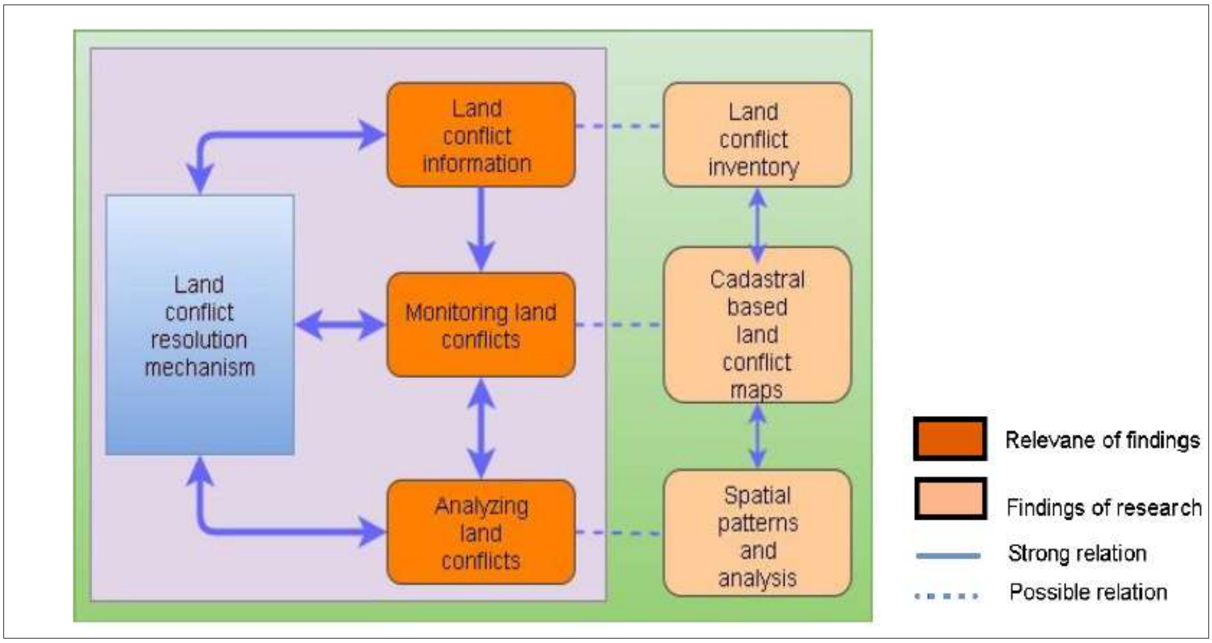

Figure 4: Relevance of CLCM and spatial analysis in land conflict resolution (Source: Author)

Even though a piece of land is physically static, the conflict it may change over time. Influence of different causes of conflict can make a single parcel of land follow multiple conflicts in a different period. Therefore, the decision-making institution and individuals for better resolution of the conflict need to understand the history, present status, and future factor of land conflict. Hence, updated land conflict inventory is the framework that strengthens the existing conflict resolution mechanism via providing necessary information regarding land conflicts.

Along with, the cadastral-based land conflict maps and their spatial pattern is a better and quick tool to visualize land conflict. If the state plans for minimizing the existing land conflicts, the first information necessary is the location of land conflicts. Along with, the pattern analysis helps in clustering the conflicts and hence aids policymakers with a suitable land conflict information.

5. Conclusion

Land conflict inventory is a database of land conflicts. Collection of data from different registries and platforms, and integrate them using a specific format are important steps in building a land conflict inventory. Individual parcels those undergo land conflict are components of land conflict inventory. Characteristics of land conflict like the type of conflict, the cause of conflict, actors involved in conflict, period of conflict, location of conflict, area of conflicting land and so forth are the elements of land conflict inventory. Land conflict inventory systematically collects conflict information and supports analyst to understand the position of land conflicts.

The conflicting parcels in land conflict inventory can be mapped using the spatial referenced coordinate system to generate cadastral-based land conflict maps (CLCM). Features of land conflict inventory and parcels in cadastral map are source to cadastral based land conflict maps.

The existing land conflicts via their spatial occurrence in this cadastral based land conflict maps significantly aid in identifying spatial patterns of the conflicts in land and analyze them.

Hence, land conflict inventory by providing relevant information about land conflict, cadastral based land conflict maps- by assisting in the monitoring of land conflicts, and spatial pattern analysis of land conflicts by supporting to analyze the land conflict - aids current land conflict resolution mechanism for better resolution to land conflicts.

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Spatial GIS-based Multi-Criteria Evaluation Approach to Assess Walkability Conditions Around Identified TOD Station Areas: A Case Study of two Neighbouring Indian Transit cities

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Keywords: *GIS, TOD, Delhi, Noida, SMCA, Walkability*

ABSTRACT

Designing transit systems in developing countries requires enhancing local accessibility to the transit station and nearby places. Further, it will strengthen non-motorized (NMT) and public transport, keep public transit fares reasonably priced and protect walkability of pedestrians from the motorized travel. The overarching aim of this research study is to have an integrated methodology using GIS-based spatial analyses and group multi-criteria approach to measure and evaluate walkability of areas within walkable distance from the identified TOD stations across 2 adjoining Indian transit cities Delhi and its satellite town Noida. The objective of this study is to evaluate GIS-based walkability conditions of TOD station areas using a Spatial Multiple Criteria Analysis (SMCA) walkability index based on six criteria namely 1) walkability and cyclability, 2) capacity utilization of transit, 3) parking supply at the station, 4) urban design, 5) open spaces and 6) points of public interest. For this study, a five-minute walking distance, encircling 5-15 minutes walking radius of maximum 800 meters surrounding transit station as the 'transit core' will be considered. The station locations, the surrounding road network and land use data including were available in the vector format as separate spatial layers through OSM plugin used in QGIS. Thereafter, the establishes relationship between Pedestrian needs (PNs) and alternative design code requirements (ADRs) using analytic network process (ANP) to aid future TOD policy preparation considering pedestrian—friendly environment to a large extent. The results reveal that small block sizes ranging between 100-150 meters on the streets with vibrant commercial and job activities promote walkability around the area. There should be minimum 20% of the total TOD area allocated as open spaces in the form of neighbourhood parks, green belts and recreational areas.

Figure 1. GIS-based analysis of Identified TOD stations across Delhi and Noida

Detection and Prediction of Land Cover and Land-use Change in Kathmandu, Using Geospatial Technologies.

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Keywords: *QGIS, PostgreSQL, PostGIS, EAI, ALKIS data, SQL, Python, Lizmap*

ABSTRACT:

Rapid urbanization significantly impacts land use, climate, and rainfall. By unbalancing energy demand, random land cover change has a detrimental effect on Kathmandu's land surface temperature and precipitation. Higher land surface temperature (LST) in urban areas increases energy consumption, which the impoverished are unable to meet with their meager income. Detection and prediction of the influence of land changes on land surface temperature and precipitation. The results revealed that land cover change was a significant driver of LST increase during 2000 and 2018. The study shows how the land cover has changed over time, increasing built-up areas while decreasing forest, open space, and riverine and lake regions. The removal of trees resulted in an increase in maximum and lowest temperature and a considerable decrease in precipitation. By 2025, land use and land cover change trends are likely to deteriorate, with forest, farmland, and water bodies all expected to decline by 15%, 18%, and 25%, respectively. Urbanized areas are expected to rise the most in 2025, with a 20% increase. The fundamental cause of these changes is rapid urbanization, which is accompanied by a lack of solid planning and increasing rural-urban mobility. These changes are associated with the soar in temperature, rainfall, energy use, which positively influence poor people. It recommends that city planners consider their urban design plan and policy.

1. Introduction

Land cover in metropolitan areas is constantly changing, posing a direct threat to the natural resources required to sustain life and the environment. Human activities, which transform landscapes and have a negative impact on ecosystem services and human well-being, are primarily responsible for these changes [1–4]. Rapid urbanization [5,6], population growth [7], and other socioeconomic development activities that result in deforestation [8], biodiversity loss [9], encroachment on arable agricultural land [10], and water resource depletion [11] are all key drivers of environmental change contribute by land-use change. Furthermore, a number of studies have revealed that changes in land cover affect energy use, socioeconomic and hydrological processes, resulting in local climatic changes. Such changes might make populations, ecosystems, and localities vulnerable to climatic pressure and create a more unpredictable environment [13,18]. To discover how land cover changes, such analysis and mapping of land use and land cover are essential aspects in monitoring studies, resource management, and planning activities (Aspinalls & Hill, 2008; Foody & Atkinson, 2002). Land cover patterns on the Earth are regularly being changed by different human activities, thereby influencing biophysical processes (Li & Shao, 2014). Thus, detailed land-use and land-cover mapping is an important research topic nowadays.

Temperature and precipitation patterns will be altered as a result of climate change (Thapa, 2019). It has resulted in rising temperatures, erratic and extreme rainfall patterns, and an increase in the frequency of floods, landslides, and droughts, all of which cause huge loss of life and property each year (FAO, 2014; Karki et al., 2011; NAPA, 2010; Dixit et al., 2008). Climate change and land-use changes are two major worldwide ecological changes that are expected to occur in the future. Until now, the causes and implications of human-caused climate change and land-use activities have been studied separately (but see Turner et al. 1993). Markov chain analysis is a discrete stochastic modelling approach that is random in both time and state. It forecasts future land-use change probability by calculating land-use changes over two time periods. Then, future changes are predicted using the possibilities derived from previous changes. The Markov model is ideal for land use modeling because land use data is spatially sensitive. When compared to other approaches, the Markov model has the ability to predict all multi-directional land-use changes.

The present study has attempted to show the status of the land use and land cover change impact on temperature and precipitation in Kathmandu. It gathers information about how land use and land cover change impact heat and rain in the years 2000 and 2018 through Landsat images, which would be the framework for further study, useful for different stakeholders for decision-making and formulating plans and policies. It could provide helpful information for implementing an urbanization project for the benefit of these urban communities. Similarly develops a well-defined strategy for environmental protection and climate change issues.

2. Study area, data, and methodologies

2.1 Study area and data

The study area, the city of Kathmandu, is located to the north of Bagmati River and extends from 7°38’22” to 27°45’70” North (latitudes) and 85°16’50” to 85°22’32” East (longitudes). In recent years, it has densely populated urban cities, extends over 65 square kilometers of area, and has an approximate total population of 1376000 in 2019. Kathmandu is densely populated, with 12,664 persons per square kilometer compared to other country cities (Sharma, 2003). An increase in population plays a significant role in increasing the trend of temperature and precipitation. The present increasing trend of the temperature of Kathmandu valley is 0.8°C per decade and 0.08°C per year (Wagle et al. 2007). For a few decades, there have been several unusual weather events in Kathmandu valley (Kattel, 2008). Changes in the use and occupation of land caused by human actions have been shown to significantly affect climate (Pielke et al., 2002, 2011). The rapid growth of population and increasing temperature and precipitation trend provides a situation of its study, and proper analysis, in terms of LULC, is worthwhile. Landsat images have been utilized for LULC study (Ding, H., & Shi, W. 2013; Erener, A., Düzgün, S., & Yalciner, A. C. 2012; Gao, Y., & Zhang, W. 2009; Kaul, H. A., & Sopan, I. 2012; Xiao, H., & Weng, Q. 2007). Landsat 8 acquires eleven bands from two separate sensors: Operational Land Imager (OLI) and Thermal Infrared sensors with 30 m spatial resolution. One thermal group 10 and 11 help provide more accurate surface temperatures and are collected at 100 meters. Landsat 7 provides eight bands, i.e., six in the visible and near-infrared regions with 30 m spatial resolution, one panchromatic group with 15 m spatial resolution. Due to these benefits, Landsat images were chosen as a suitable medium for assessing LULC and LST change, dated 1 January 2000 and 30 December 2018.

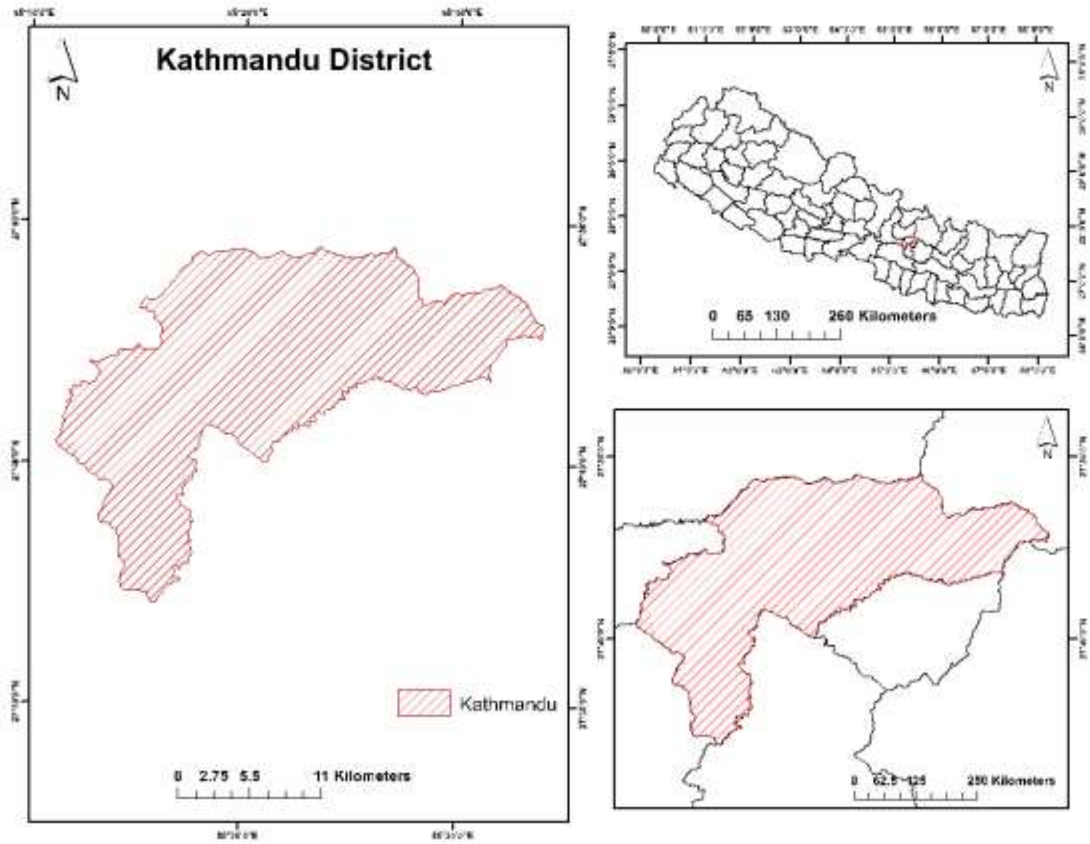

Figure 1: The study area, the city of Kathmandu

2.2 Methodologies

During image acquisition, no cloud cover was selected, atmospheric corrections non-included. Spatial registration was performed on the multispectral bands of both images acquired over two days: 1 January 2000 and 30 December 2018. LULC is classified using maximum likelihood supervised classification in ArcGIS 10.5 software.

2.2.1. Image classification

In the past 18 years, LULC changes provided through image classification and segmentation. A total of 31,154 random sample points were selected from 1 January 2000, and 28,796 point samples were randomly selected from 30 December 2010. Using Google Earth was used in the extraction of ground truth samples. Seven land-use types were classified from both images for the study area-specific LULC type in Table 1.

Land use types	Description
Built-up Area	Residential houses, Apartment
Forest	Farmland trees, Mountain Forest, Roadside trees, trees around water bodies
Riverine and Lake Area	River, lake, pond, reservoir, wetland
Open Area	Stadium, Ground, Gardens, Vacant spaces
Agriculture	Cultivated land
Religious Area	Palace, Cloister, Temples, Shrines, Mosque, and monastery area, archaeological area
Commercial Area	Hotel, Shop, Business center, Exhibition hall, Market, entertaining sites, petrol pump

Table 1. Land-use/land cover types for classification

2.2.2. Accuracy assessment

For both images, data confusion matrices were created using the test samples to check the accuracy of the classification results, as shown in Tables 2 and 3. Then, it is predicted along with the kappa coefficient using the confusion matrix defined below (Lillesand et al., 2004).

$$Overall\ Accuracy \sum_{i=1}^{r} \frac{Kii}{x} \qquad (1)$$

Where Xii is the diagonal elements in the error matrix, x is the total number of samples in the error matrix.

$$Kappa\ coefficient\ (K\hat{}) \frac{n\sum_{1=1}^{r} X_{ii} - \sum_{i=1}^{r} X_i + X + i}{n2 - \sum_{i=1}^{r} X_i + X + i} \qquad (2)$$

Where r is the number of rows in the matrix, Xii is the number of observations in row i, and column i, Xi+, and X+i are marginal total for row i and column i, respectively, and n is several observations (pixels).

2.2.3. Retrieval of land surface temperature

The LST was retrieved for both the images, for Landsat 8 band 10 and 11 used, and their mean is used as the LST final result of 2018. Similarly, Landsat 7 band 6 has two images which average is for the final result of LST of 2000. For conversion from satellite temperature to land surface temperature, the following equation is used:

$$LST = \frac{TB}{[1 + \left(\lambda * \frac{TB}{c2}\right) * \ln ln(\varepsilon)]} \qquad (3)$$

Where λ is the wavelength of emitted radiance, whose value is 11.45 for Landsat 7 and 10.8 for Landsat 8 and c2 is equal to 14.388 µmK. First, the DN values were converted to the top-of-atmosphere (TOA) radiance measured by an instrument using the following equation (4):

$$L\lambda = \frac{L_{\max} - L_{min}}{(QCAL)_{max} - (QCAL)_{min}} \left((DN) - (QCAL)_{min}\right) - L_{min} \qquad (4)$$

where λ is wavelength; Lλ is the TOA radiance at the sensor's aperture in W m-2 sr −1 µm −1 and QCALmax and QCALmin are the highest and the lowest points of the range of rescaled radiance in DN, with values 255 and 1, respectively for both images of band 6 on Landsat 7 and Landsat 8 band 10 and 11. Lmin and Lmax are the TOA radiances that are scaled to QCALmin and QCALmax in W m −2 sr −1 µm −1 and can be found in the Landsat 8 and Landsat 7 Science Data Users Handbook (http://landsathandbook.gsfc.nasa.gov/pdfs/Landsat8_Handbook.pdf) (http://landsathandbook.gsfc.nasa.gov/pdfs/ Landsat7_Handbook.pdf). The spectral radiance Lλ should be further converted to the at-sensor brightness temperature TB in kelvin and the conversion equation can be written as

$$TB = \frac{K2}{\ln ln(\frac{k1}{l\lambda} + 1)} \qquad (5)$$

$$(kelvin\ into\ degree\ Celcius) TB = \frac{K2}{\ln ln(\frac{k1}{l\lambda} + 1)} - 273.15 \qquad (6)$$

where TB is the at-sensor atmosphere brightness temperature in kelvin; K1 (1282.71 K) and K2 (666.09 Wm−2 sr−1 μm−1) are calibration constants for band 6 and images of Landsat 7 and K1 (774.8853 K) and K2 (1321.0789 Wm−2 sr−1 μm−1) for band 10 and K1 (480.8883 K) and K2 (1201.1442 Wm−2 sr−1 μm−1) for band 11 of Landsat 8. Brightness temperature is that obtained by a blackbody to produce the same radiance at the same wavelength. Emissivity is calculated according to the following equation:

$$\varepsilon = 0.004 \cdot * Pv + 0.986 \quad (7)$$

where ε is surface emissivity and Pv is the vegetation proportion obtained according to Sobrino, Jimenez-Munoz, and Paolini (2004) and Landsat 8 handbook:

$$Pv = \left[\frac{(NDVI)-(NDVI)_{min}}{(NDVI)_{max}-(NDVI)_{min}}\right]^2 \quad (8)$$

Here NDVImax = 0.5 is the threshold to separate the bare soil pixel and the mixed pixels, and NDVImin = 0.2 is the threshold to separate the full vegetation pixel and the mixed pixels (Ding et al., 2013). Thus, NDVI can be expressed using the following equation:

$$NDVI = \frac{\rho(band5)-\rho(band4)}{\rho(band5)+\rho(band4)} \quad (9)$$

Where ρ(band5) and ρ(band4) are the spectral reflectance of bands 5 and 4, respectively, for Landsat images, the parameters used to convert DN to spectral reflectance can be found in the metadata file associated with Landsat images.

2.2.4. The CA-Markov Model

The Markov model is ideally suited for land-use modeling since land-use data is spatially sensitive. However, because its analysis is not spatially explicit and does not account for spatial information allocation within each class and the fact that the probabilities of change among landscape states are not constant, the Markov model is best suited for short-term predictions. As a result, it can deliver the proper magnitude but not the right direction of change. The CA compensates for this flaw–the Markov model combines the Markov model with a more dynamic and empirical cellular automata model. A cellular automaton is a bottom-up dynamic model that incorporates the spatial dimension to add modeling direction. CA's ability to describe spatial and dynamic processes in simulations is crucial in land use studies. For example, for 2025, the CA–Markov model was used to forecast land use and land cover change in the Kathmandu district.

3. Result and Discussion

The study is a pie chart of LULC for 2000 and 2018 shown in Figures 2 and 3. In 2000, forest, agriculture, and built-up were the dominant land-use types, with percentages of 34%, 30%, and 10%, respectively, whereas in the year 2018, forest, agriculture, and built-up areas were still the dominant land-use type in the study area with a percentage of 32% followed by 33% and 11%, respectively.

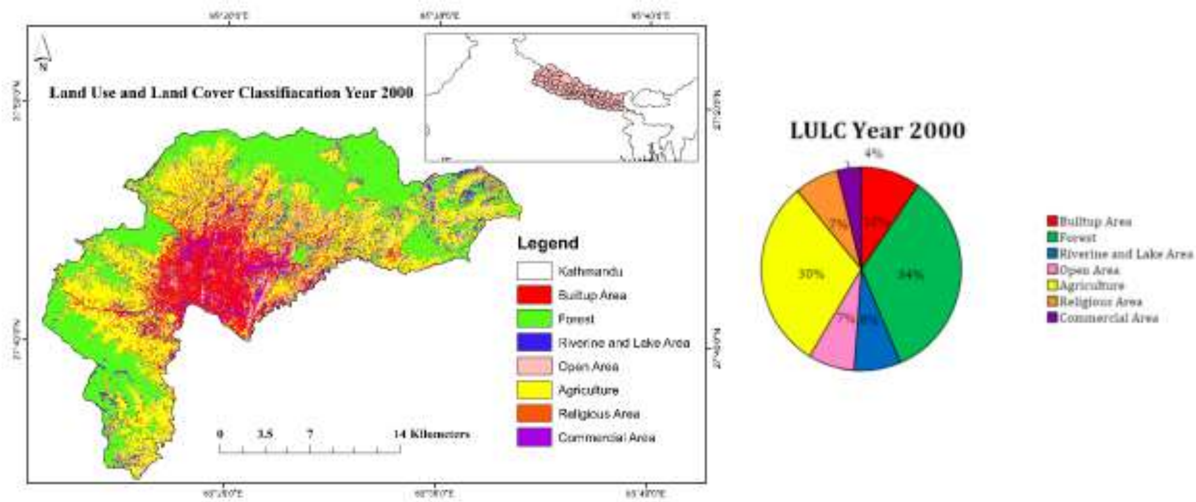

Figure 2: LULC map and a pie chart of the study area (2000)

In the tables, the overall accuracy for 2000 and 2018 was 73.87% and 73.74%, respectively, and the Kappa coefficients for corresponding maps were 0.7325 and 0.7345, respectively. LULC change data deduced from these data, which were qualified by further analysis.

	Reference Data						
	Built-up Area	Forest	Riverine and Lake Area	Open Area	Agriculture	Religious Area	Commercial Area
Built-up Area	28	0	3	0	0	3	6
Forest	0	34	0	0	0	0	0
Riverine and Lake Area	2	2	12	1	1	1	0
Open Area	0	0	0	9	3	0	0
Agriculture	0	2	1	5	51	0	0
Religious Area	0	1	1	4	3	6	3
Commercial Area	3	2	1	0	2	2	7
Producer's Accuracy	84.85%	82.93%	66.67%	47.37%	85.00%	50.00%	43.75%

Table 2. Confusion matrices of LULC classification, 1 January 2000

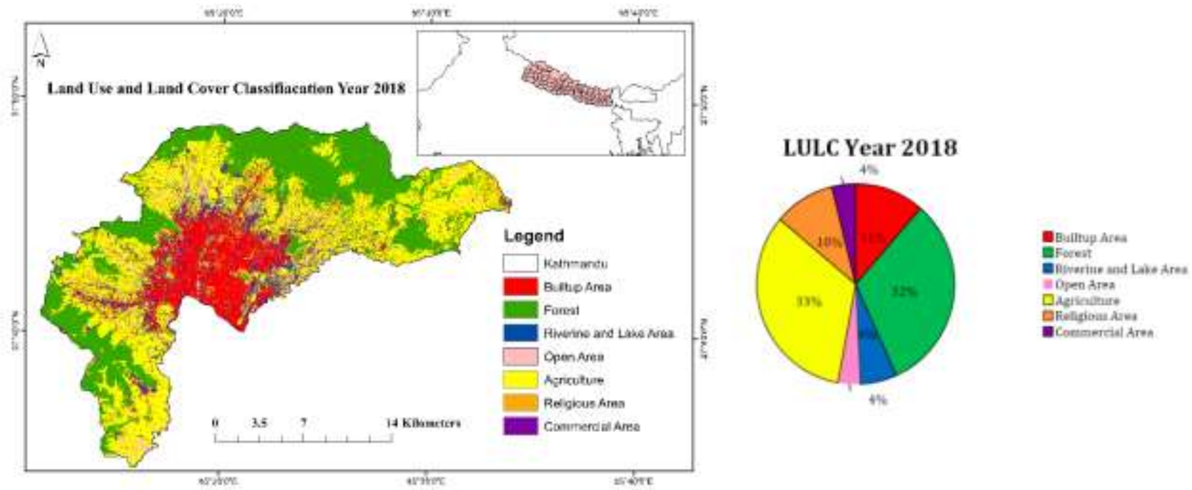

Figure 3: LULC map and a pie chart of the study area (2018)

The comparison between 2000 and 2018 demonstrates the significant decrease in the study area's forest, open area, riverine, and lake area. There is an increase in a built-up area, agriculture and religious area; for example, about 7% of open space and 34% of forest and 8% riverine and lake area in 2000 have been converted to the built-up area, agriculture and religious places. In summary, over the past 18 years, a significant decrease in an open space and riverine and lake area has taken place. These dramatic land-use changes will raise the low availability of water. According to a report by the Asian Development Bank, inadequate access to water has led to increased disease incidence, health risks, and associated economic burdens, disproportionately impacting the poor and vulnerable (ADB, 2013). Kathmandu Valley is the world's most at-risk seismic urban area (DRM, 2015). Open area reduction will increase the risk of finding safer places during a natural disaster. Also, deforestation will lead to unknown water sources, precipitation, and a significant increase in temperature.

	Reference Data						
	Built-up Area	Forest	Riverine and Lake Area	Open Area	Agriculture	Religious Area	Commercial Area
Built-up Area	28	0	3	0	0	3	6
Forest	0	33	0	0	0	0	0
Riverine and Lake Area	2	2	12	1	1	1	0
Open Area	0	0	0	9	3	0	0
Agriculture	0	2	1	5	51	0	0
Religious Area	0	1	1	4	3	6	3
Commercial Area	3	2	1	0	2	2	7
Producer's Accuracy	84.85%	82.50%	66.67%	47.37%	85.00%	50.00%	43.75%

Table 3. Confusion matrices of LULC classification, 30 December 2018

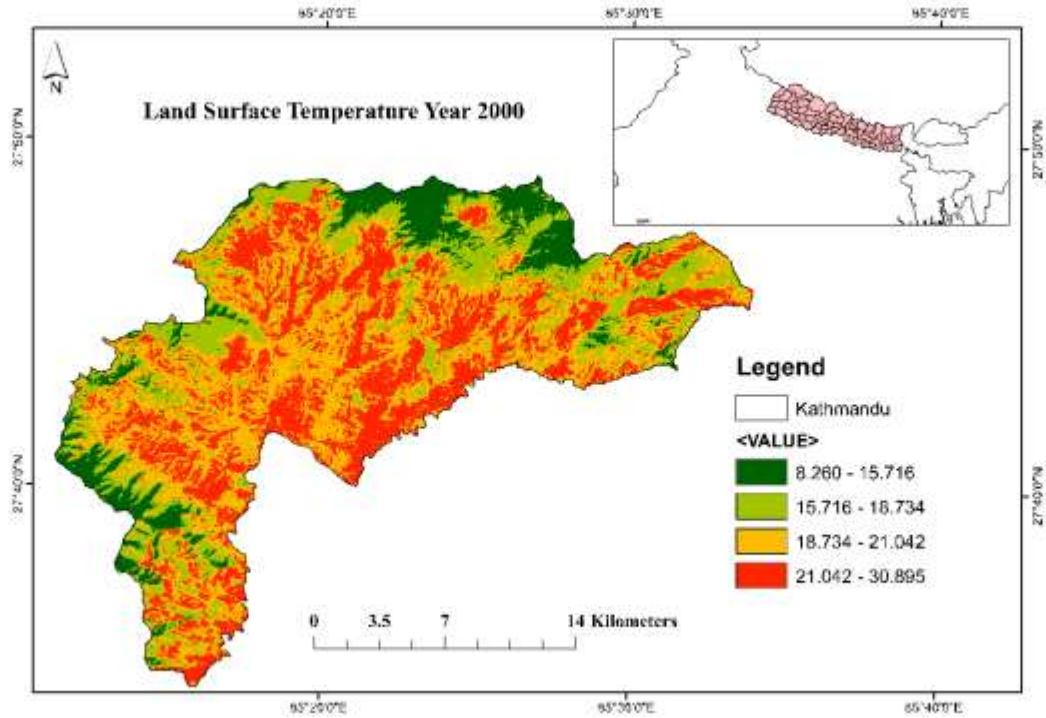

Figure 4: LST map of the study area (2000)

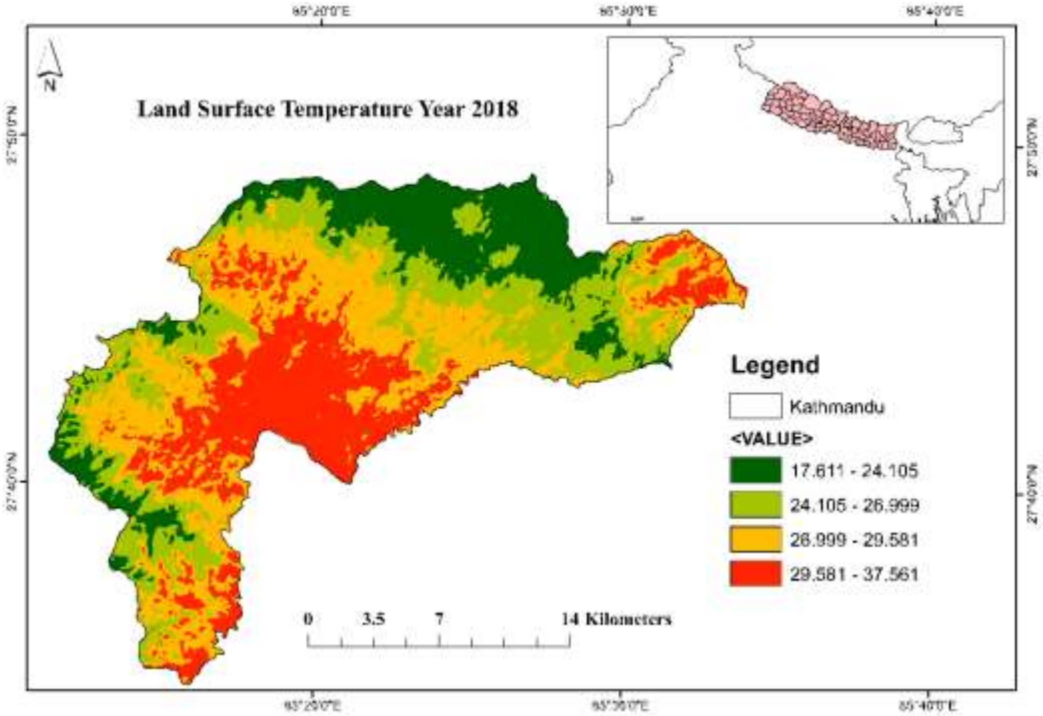

Figure 5: LST map of the study area (2018)

The map of LST in the study area for 2000 and 2018 is shown above in Figure 4 and Figure 5. In 2000, the study was land surface temperature with a minimum of 8 degrees Celsius and a maximum of 30 degrees Celsius, which has significantly more than double the minimum temperature of 17 degrees Celsius and a maximum of 37 degrees Celsius in 2018. Hence, the increase in a built-up area and decrease in a forest, open space, and riverine and lake area compared to 2000 and 2018 LULC classification.

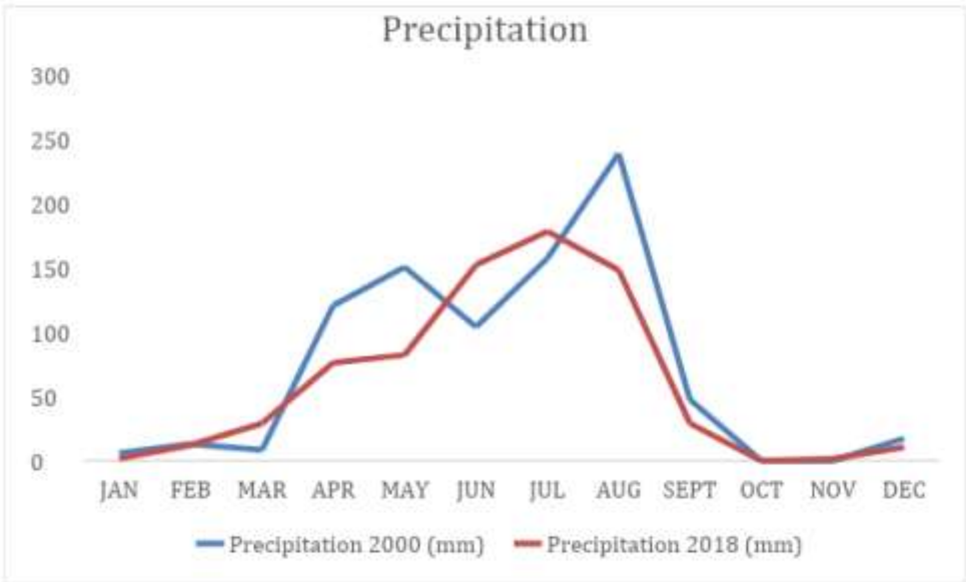

Figure 6: Precipitation line graph of the study area (2000 and 2018)

The overall rainfall of 2000 and 2018 had a significant decrease due to this population being more dependent on groundwater and highly vulnerable to water. Therefore, this decrease might play a vital role in the livelihood strategies and water. Thus, this study concludes that the land surface temperature of the study area significantly increases and sharpens a decrease in precipitation (Figure 6). Such a situation plays a significant role in people's livelihood vulnerability index and increases water scarcity.

4. Conclusion

The study area LULC change analysis in 2000 and 2018 reports a significant impact on temperature and precipitation. Recently, water has been decreasing in such a way; now, people face shortages and rely on other sources such as tankers and water jars. This research study using remote sensing images for LULC changes indicated that remotely sensed images could demonstrate changes in land use and variation in surface temperature. They were able to provide the status of land use and land cover change effect on temperature and precipitation, which will be valuable for a decision-maker to formulate and implement plans on this study area. However, the remote-sensing method has limitations such as cloud cover, which negatively affects imaging quality, and restricted revisiting cycle of the satellite for the individual location. These limitations, there should be research under the process of integrating application with multi-sensor satellite data and meteorological data from ground-based stations; this will provide highly accurate land-cover change information.

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Application of Geospatial Data in Land Use Planning for Food Security in Nepal

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Keywords: *Land use planning, Food Security, Spatial Analysis*

ABSTRACT:

More than 820 million people in the world were still hungry in 2018, underscoring the immense challenge of achieving the Zero Hunger target by 2030(FAO, 2018). 2030 agenda for sustainable development focused on the eradication of poverty and hunger. Food security deals with the people's access to sufficient food based on physical and economic perspective for healthy life of them. Protection of agricultural land for production of food in Nepal is very important so government is mainly focused on protection of that land. Cultivation land was decreased from 0.173 hectares in 1971 to 0.133 hectares in 1981.Similarly the amount was decreased to 0.126 in 1991. This indicates that decline has adversely affect the food security of country due to decrease in productivity. Thus, planning of land is important for protection of agricultural land such that it contributes in combating food insecurity.

Land use planning is the process of allocation of land for different uses across the various landscapes. Proper allocation land for use is major challenging part in developing countries. GTZ 1995 defined land use planning in the context of development cooperation is an iterative process based on the inputs form the stakeholders for sustainable land uses in rural area including initiation and monitoring measures for agreed land uses. Land use planning plays vital role to stop the decreasing trend of agricultural land ultimate contributes for food production. Land use planning also reduce the risk of natural hazard.

Use of geospatial data is very important for land use planning. Concept of spatial analysis is base for land use zoning and knowledge of geoinformation technology plays vital role in land use planning. Recently government endorsed the land use act 2019 based on land use policy 2015. The process of land use zoning classes based on geospatial data using spatial analysis up to local level has been completed in mid of 2021. The handover of those data to local level is going on.

Hence, this paper mainly focuses on the spatial analysis and challenges for implementation of land use zoning data for local level land use planning. The case study of on implementation of land use planning will be explored by applying the Institutional and Legislative Systems (ILS) approach on three aspects: i) legal and regulatory frameworks, ii) policies and programs, and iii) organizational/institutional set-up. methods. In addition, this study reflects on the suitable methodology for implementation of land use planning based the spatial analysis. Finally, the outcome of this study contributes as a guide line for local government in using land zoning maps for local level planning in order to obtain sustainable use of land resources.

UAV, Photogrammetry, Remote Sensing

Using Remote Sensing in the Assessment of Desert Locust Breeding Areas in Northern Kenya

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Keywords: *Desert locusts, Control, Environmental variables, Predictive model, Remote sensing*

ABSTRACT:

Desert locusts (Schistocerca gregaria, Forskål) have been a regular threat to crop production as well as pastoralist activities. The invasion has been rampant in the horn of Africa and has extended to the Eastern Africa region, especially the northern part of Kenya. Current survey and control methods rely greatly on field exercises which are inefficient, time-consuming, and cumbersome. In order to mitigate their effect on agriculture and pastoral land, there is a need to have a better approach in the control of the desert locusts before they are large enough to fly. It is important therefore to locate their breeding sites early enough in order to destroy the eggs or when the desert locusts are hoppers or fledglings which cannot fly. If breeding is not controlled on time, waves of desert locust populations will eventually lead to multiplied breeding thus outbreaks will turn into upsurges and even plagues.

In this project, the location of locust breeding sites has been studied by finding its relationship with environmental variables: soil moisture, soil type, vegetation greenness, temperature, and wind speed. Current desert locust control methodologies have been using rainfall estimates and vegetation cover data to locate suitable breeding locations. However, this approach has faced challenges as vegetation and rainfall do not translate directly to soil moisture, which is one of the most important factors in the development of the desert locusts' eggs.

Remotely sensed soil moisture estimates products, soil type data, greenness estimates data, temperature estimates, and wind data have been utilized to predict the occurrence of desert locust breeding sites. A predictive model is developed to show the potential desert locust breeding sites. These parameters of the prediction can then be used in future desert locust control management operations. Knowledge on the potential desert locusts breeding sites will assist in the location of desert locusts to specific extents where field control measures and necessary surveys can be directed and achieved in a timely and efficient manner.

Monitoring In-SAR Coherence in Sepulchered Aoronga Impact Crater, Chad, Using Sentinel-01 Time Series Data

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Keywords: *In-Sar coherence, Sentinel-01 time series data, Aoronga impact crater, Chad*

ABSTRACT:

The impact craters are among the important geomorphic features that are studied in planetary science as they play a significant role in deciphering several geological phenomena including the evolution of the planets. Hence, any study in meteorite impact craters is significantly important. In the present study an attempt to monitor the behaviour of InSAR coherence in sepulchered Aoronga impact crater, Chad was attempted using Sentinel-01 time series data. The results obtained from the analyses of InSAR coherence reveals that coherence values are lower to moderate in disparate regions encompassed by dunes with rocks, and higher in monotonous areas like dunes and rock exposures.

Quantifying Erosion Rates of Simple Meteorite Impact Craters

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Keywords: *Erosion, Simple meteorite impact craters, Paleoclimate*

ABSTRACT:

The various geological agents active on the surface of earth are continuously modifying its surface. Different morphological features are constantly sculptured by the erosional activities. Thus, the rate of erosion has been estimated for various geomorphological features using several different methods. The long-term erosion rate on the surface of earth is estimated by Hergarten and Kenkmann (2019) as a function of present-day topography and climate using the impact-crater inventory. Most often the influence of erosion is manifested in positive relief features. The relationship between topographic relief and erosional efficacy is expressed as $r = \Delta s$, where r is the erosion rate of excessive erosive regimes such as shield, orogeny and igneous province (Indu et al. 2022). Simple impact craters are simple, bowl-shaped depressions formed by hypervelocity meteorite impact events. The study aims to quantify the rate of erosion in thirteen terrestrial simple impact craters considering the influence of various climatic zones traversed by the crater and the geological province in which the crater is located. In most cases simple impact craters preserve the original morphology hence it is chosen for the study. The influence of climate on erosion is better constrained by deriving the temporal range of each crater in distinct paleoclimatic zones (Indu et al. 2022). The rate of erosion of the region hosting the impact craters and the rate of erosion of the individual crater are estimated separately using two methods. The first method considers the relief of the geological province where the crater is located and the second method calculated the initial relief of the transient impact crater using a set of crater morphological parameters. The relief calculated is then applied to the equation $r = \Delta s$ to identify the rate of long-term erosion. The estimated values of long-term erosion rates of craters are correlated with existing data. The difference in actual and estimated erosion rates of some impact craters are attributed to dynamic evolutionary trends of terrestrial simple impact craters.

PSInSAR as a Tool to Monitor Hydroelectric Power Projects

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Keywords: *InSAR, Deformation, Dam, Hydroelectric power projects*

ABSTRACT:

Interferometric Synthetic Aperture Radar (InSAR), a radar-based remote sensing technique, provides a cost-effective approach for long-term deformation monitoring of dams. This technique can be used to supplement repeated field inspections of target structures at risk. Here, three dams from the southwestern India viz., Idamalayar Dam, Malankara Dam, and Upper Sholayar Dam were monitored. 23 Sentinel-1 radar images during 2016-2017 were processed using Persistent Scatterers Interferometry (PSI). Of these dams, the Idamalayar Dam is found to be relatively stable (-1mm/year), while Malankara Dam (-2 to -7mm/year) and Upper Sholayar Dam (-7 to -10mm/year) are experiencing various amounts of subsidence. Thus, this study demonstrates the capabilities of InSAR to indirectly monitor a dam's health in a cost-effective way.

Sustainability and Natural Resources

Trend Analysis of Agro-Meteorological Parameters Collected Using IoT-Based Ground Sensors

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***Keywords:** Soil Moisture Sensors, Soil Moisture Index, Temperature, Humidity, Trend Analysis, Iot, Agriculture, Water Use Efficiency*

ABSTRACT:

Soil moisture content is a key variable in many land surface processes, especially in the growth of plants in an efficient way. The temporal pattern of soil moisture is of great importance for the proper understanding of the water exchange between the topsoil and the atmosphere. Water is a critical input for agricultural production and plays an important role in food security. Normally, agriculture with the facility of managed irrigation represents approximately 20 percent of the total cultivated land and comes up with nearly 40 percent of the total food produced worldwide. So, irrigated agriculture is roughly twice as productive per unit of land which ultimately affects the size of productivity. The excess use or unmanaged use of water can cause the condition of lack of enough water for agricultural areas and also the deficiency of water may lead to drought. So, it clearly signifies that optimal use of water to the plant is the absolute necessity to get the optimal production. Water requirement for a crop can be estimated by measuring soil moisture by using many techniques including professional expensive soil moisture sensors. But, IoT based low-cost sensors can be cheaply deployed, and measurements can have very high temporal resolution. In this study, the amount of moisture contained in a soil was obtained in an agricultural field of Tomato (Solanum lycopersicum), where temporal data of soil moisture index was obtained along with temperature and humidity measurements. The sensors that were used are resistive soil moisture sensor, Capacitive soil moisture sensor and DHT22 sensor (for air temperature and humidity measurements). Ground data was collected by the use of IoT Analytics in the Thingspeak server remotely, where collected data of soil moisture, temperature and humidity using sensors were sent to the server with the help of GSM 900A module. The instrument setup was prepared and the code was installed in Arduino for the collection as well as transfer of data to the server. The stored data were downloaded in excel format and arranged according to the shift separation of morning, day and evening for understanding the variation of soil moisture on a daily and shift basis.

The trend of soil moisture variation time of the day, number of days after irrigation as well as relationship with air temperature and humidity changes were studied. The inter-relationship among the variables have been explored and the results have been presented. The change in temperature varied from 19 to 26 degree Celsius and humidity ranged between 93% and 99.9%. The SMI was studied in a concept that increase in temperature and decrease in humidity results in the decrement of SMI but it didn't show as we expected and this condition can be possible because of rainfall and high infiltration. Also, the comparison between soil moisture indices of resistive soil moisture sensor and capacitive soil moisture sensor was performed at the same point on the ground.

The resistive and capacitive sensors were showing different soil moisture indexes at the same point under similar conditions. The SMI from the capacitive soil moisture sensor was 20-26% higher than the resistive soil moisture sensor. The results of SMI's to temperature, the relation of capacitive soil moisture index showed better relationship with temperature than that of resistive soil moisture.

This study addresses the possibility of extracting the information of soil moisture using ground measurements. This can ultimately support the appropriate use of water for the efficient growth of agricultural production.

Mapping of Wheat Cultivation Area with PlanetScope Image

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Keywords: *Planet, Sentinel-2, Wheat mapping, Random forests (RF), Support-vector machine (SVM), Google Earth Engine (GEE)*

ABSTRACT:

With the rise of population, we can observe the growth in global food demand which can be only fulfilled with an increase of agricultural production. We can observe a similar pattern of food demand in Nepal as well. Wheat crops stand at 3rd place after rice and maize in Nepalese cereal production. The total area of wheat growing fields was 745,823 hectares with the production of 1,736,849 metric tons having the productivity of 2.33 tons per hectare (Bhatta et al., 2020). The productivity is too low as compared to the immediate neighbor India, where productivity is 3.53 metric tons per hectare in 2019 (India: Yield of Wheat 2020 | Statista, n.d.). Crop mapping must be kept accurate and up to date, it must be taken as first and the foremost step for the informed crop management, food security planning, and the development of agricultural policies.

In this study, PlanetScope image was used for delineation of wheat cultivated area. We collected field samples for wheat crops as per the crop calendar of November to April along with the samples of other crops which overlap with the wheat. With the help of Google Earth Engine (GEE) platform, time series NDVI values were studied using sentinel-2 images (Tiwari et al., 2020) over the crop calendar based upon the field samples to identify the crop phenology of wheat (de Castro et al., 2018). We selected the suitable date for crop mapping based upon the crop phenology, cloud coverage for image and wheat peak growth time along with coverage of wheat cultivation over our study area, then we used planet image (26th February 2021) for the image classification. Random Forest (RF) and Support-vector machine (SVM) were used as pixel-based image classifiers to delineate the wheat cultivation area. The delineated wheat cultivation from this study was found to be 19,000 hectares within the study area, Dhangadhi region (area of 64,895 hectares) of Kailali districts. The best overall accuracy (OA) achieved for the wheat classification was about 96% with Random Forest (RF) and 95% with Support-vector machine (SVM). The accuracy might be because of mixed crop practice in the context of Nepal i.e., mustard, wheat, and pulses in the same field. Further this study can be extended to the whole Terai area for the mapping of small wheat farms as well. Overall, we can say this study can be used for data driven policy formulation to increase productivity and achieve food security in the nation.

Monitoring the Relationship of LST, NDVI, NDSI, NDBI and NDMI using Pre-Winter Landsat Data in Beas Basin, Himachal Pradesh, India

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Keywords: *Land use land cover changes, Land surface temperature, Indian Himalayan Region, Single window algorithm, NDSI, NDVI*

ABSTRACT:

Present study is an attempt to assess the role of spatio-temporal Land Use Land Cover Changes (LULC) on the variations of Land Surface Temperature (LST) using Landsat 7 ETM+, Landsat 8 TIRS/OLI and Sentinel-2 data for Beas basin of Kullu district, Indian Himalayan Region (IHR). Also, the relationship of various remote sensing indices such as NDVI, NDSI, NDBI and NDMI with LST were established using coefficient of correlation to monitor the role of natural ecosystem alteration on LST. LST was calculated using Single Window algorithm (SW) for eight major land cover categories extracted from Landsat-7 ETM+ and Landsat-8 (Path-147 and Row-38) Thermal Infrared Sensor (TIRS) data for October, 2000 and October, 2020 respectively. LULC change detection revealed that there was a huge increase in agricultural land including orchard expansion of 123 % during the year 2020 than that of 2000. Also, there is a sharp increase of 40.63 % in settlement areas which includes the tourism activities. These are the significant factors for the changes in LST. Further, it shows that negative correlation with the strong correlation coefficients of R2 = 0.7072 and R2 = 0.5642 between NDSI and LST in Pre-winter season of 2000 and that of 2020 respectively. Whereas, the correlation between NDVI and LST showed positive correlation with the coefficient of R2 = 0.2577 in 2000, which increased to R2 = 0.5959 in 2020. This positive relationship highlighted the fact that an increase in LST provides favourable conditions for the vegetation growth in the valley during the pre-winter season 2000 and 2020 respectively. The main outcome of the paper, we believe, will be helpful in analysing the dynamics of land cover changes and sustainable environmental planning in the Beas Valley, which is crucial for livelihood sustainability of the people residing in the already fragile IHR.

Evidence Based Decision Making for Integrated Water Resource Management (IWRM) Using UAV Data

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Keywords: *Evidence-Based Decision, UAV, Illegal Encroachment, Sustainable River Management*

ABSTRACT:

Rivers are very essential part of the largest deltaic country like Bangladesh. Most of the major cities are blessed by the presence of rivers. There is no exception in the case of the capital city Dhaka. There are six important rivers around Dhaka City, but they are being polluted and illegally encroached over time. BIWTA (Bangladesh Inland Water Transport Authority) plans to develop four rivers (Buriganga, Turag, Balu & Sitalakhya) by correlating with BWDB, City corporation and RAJUK. The main objectives are to identify unauthorized structures along the banks, demarcating pillars of foreshore land, and making walkways (on high or low bank) on both banks of these river to safeguard them from erosion as well as illegal encroachment. Identification of the encroached part is a very difficult task from the available satellite images and ground surveys. This challenging job is made easy by the utilization of the UAV system. 150 km of riverbanks are surveyed with UAV with an average distance of 100 meter toward the country side. A topographic map is generated from the very high resolution (5cm GSD) UAV images. This map illustrates all features on the ground with high positional accuracy such as Buildings, Roads, water bodies, parks and play grounds in the study area. Orthophotos, DSM, DTM and point clouds from the UAV helped to find out the present scenario of the both banks of four rivers. The ultra-high-resolution data from UAV systems paved the way to make evidence-based decision for multi-disciplinary profession. The output of this study helped the planners and engineers a lot to take the right decision with a view to safeguarding the sustainable river management.

National Mapping and Infrastructure

Implementation of a New Geospatial Information (GI) Standard in DEM Generation to Support Disaster Management

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Keywords: *DEM, Interferometry, Topography, Radar, Standard, DM*

ABSTRACT:

Digital Elevation Model (DEM) is a mandatory dataset for reliable contribution in the geospatial based analysis for Disaster Management (DM). Many organizations put DEM as a data input to assemble their timely processing workflow. On the other and, the official body such as National Mapping Agency (NMA) requires a certain standard which can ensure the suitability of user requirements in conjunction with the advent of new technologies. DEM is an essential end product derived by the NMA from geospatial data acquisition that can be used as a mandatory input to develop the Decision Support System (DSS). The aforementioned important role only can be guaranteed if the quality of the DEM is sufficient for example in terms of resolution and accuracy.

Since there are a lot of DEMs available to be used in DM analysis, the evaluation and comparison both of commercial and open source DEM can be done in order to assess their usability as well as the quality of the derived results. Indeed, the certain standard shall be also evaluated in term of practical issues. A standard implementation plays an important role as a benchmark or reference especially in a situation where there are so many available technologies and methods on the market. The related implementation also can be used as a rule-based model in order to formulate the objectives and requirements of the DM stakeholders. Defining an up-to-date and reliable standard and method to derive the radar interferometric data product is a main issue for the provision of the uniform national DEM to be used as consistent input for DM by the stakeholders.

Generally speaking, TanDEM-X uses X-band for its acquisition, while Sentinel 1 uses C-band with their own characteristics. For DEM generation, TanDEM-X applies a more consistent approach to probe earth surface by simultaneous measurements using 2 satellites which is basically more accurate in the context of geometric accuracy. Obviously, many aspects determine the technology driven factors which can be best suited for radar interferometry technique. The tangible factor is related with the data availability. Since radar platforms used for measurements generally don't operate continuously, the acquiring data only available based on request by the control station. Nonetheless, for the nearest future it could be possible to request data measurement, since for many regions around the globe archived data may be inaccurate.

On the other hand, certification and accreditation in Geospatial Information (GI) are still mandatory especially in conjunction with technological improvements and the potential threat of natural disasters as the main constraints to be considered for the GI data acquisition in Indonesia. This process includes knowledges, skills and/or advancements as well as working behaviour relevant with the tasks and conditions in a so-called Competency Working Standards of Indonesia (SKKNI). In addition to the SKKNI, competency standards can also use relevant international standards or specific standards as a reference. Competency standards are the basic requirements for any activities related with the national GI provision especially in the context of DM. Based on analysis of the national interests, the qualification identifications can be performed by specific study in the context of business process and GI industry from the scope of above mentioned national/international view as well as particular (GI) industry.

Finally, this paper discusses dan formulates the competency standards and GI empowerments that can be used by corresponding stakeholders involved in the Indonesia’s DM from the actual regulation as well as technological/industrial perspectives. The standards of GI empowerments are fundamental especially in a

situation where there are various technology and method available in the society as well as GI industry. For this purpose, the proper professional certification must be essentially well regulated in order to incorporate excellent GI human resources as the primary source for the provision of reliable GI data and information in a favour of the acceleration program for Large Scale Topographic Mapping (LSTM) in Indonesia.

Toponymic Spatial Database as a Primordial Toponymic Activity-Design and Representation

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Keywords: *DEM, Interferometry, Topography, Radar, Standard, DM*

ABSTRACT:

Toponymy (geographical names) is an essential component of topographic maps, this information is updated as well as the topographic information.
The toponymic activity consists in the implementation of a set of technical tasks: collection of geographical names, validation and cartographic representation.
The extensive and increasing availability of collected toponymic data has made excessively difficult to manage this information even using traditional relational database.
As more users are interested in retrieving information related to the locations and geometric properties of spatial objects, relational database technology is inadequate for managing spatial data. That means it is quite tedious to build a spatial database.
The fundamental outlook and perspective required to achieve the objectives was the design of spatial toponymic database.

Developing a spatial database normally starts with developing a data model (which relates to the conceptual, logical and physical data modelling).

The main steps for the task are:

- Analyze user environment and existing data and systems : products and datasets
- Determine the purpose of toponymic database and new future system
- Database conception :structure and organization of the data
- Choose a DBMS and implementation
- Choose of adequate tools for developing GUI to access to the spatial toponymic database
- Representation and visualization the toponymic database in a GIS TOOLS

Integration of Urban Spatial Data Management and Visualization with Enterprise Applications Using Open-Source Software

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Keywords: *QGIS, PostgreSQL, PostGIS, EAI, ALKIS data, SQL, Python, Lizmap*

ABSTRACT:

In recent years, efficient management of urban spatial data has played a major role in improving urban planning projects both in terms of cost and time savings. Since urban planning projects involve various disciplines like city planning and architecture as well as working with different spatial data, one of the main challenges is how to integrate and manage these multimodal data for a proper workflow. Currently, the involved companies are using project management and accounting systems, so called Enterprise Resource Planning (ERP) systems, to handle these complex urban projects - that partly handle the same data objects as stored in urban spatial databases but without any spatial reference. Embedded in the application example of an urban redevelopment area, which according to the German Urban Development Promotion Act aims at financially promoting urban districts in need of renewal, project-related spatial and non-spatial data that were previously kept separate are linked and integrated. Therefore, our work presented here bridges the gap between these two types of application systems, the non-spatial accounting system called Finanz Management System (FMS) and the urban spatial databases. FMS manages information related to parcels, buildings, property owners, as well as the legally required payments connected to urban development, while an urban spatial database manages the geodata. We describe the prerequisites, procedures, and software development steps for coupling different types of applications by providing an example of the Enterprise Application Integration System (EAI). Our innovative integration process aims at making information from the spatial database available in FMS and vice versa and allows updating the corresponding databases. Our work shows the potential of open-source software for cadastral data processing and visualization as well as accounting procedures for urban planning projects.

1. Introduction

1.1. Technical Background

In 1971, the Urban Development Promotion Law (Städtebauförderungsgesetz StBauFG) was passed in Germany. Until now, more than five thousand urban redevelopment areas have been designated with the aim to maintain, modernize, and revitalize the urban structure and to improve the living conditions for their inhabitants (BauGB, 2017; Ostadabbas et al., 2020). The ongoing urban redevelopment process can take place more than a decade and need to be closely monitored, both financially and spatially, regarding the complex redevelopment measures ranging from building demolition and construction to new transportation infrastructure to be built. For the monetary aspects, accounting systems like the FMS were developed to fulfill the specific needs of statutory funding. For the surveying aspects, geo spatial databases handle the changes of the urban structure.

To combine and integrate these two mentioned aspects is, concerning the whole procedure of managing an urban redevelopment area, a unique German task and legal invention. Therefore, a specific case comparison is hard to be carried out and will not meet the application task to be aimed at. The following sections will explain the two systems, the content and the input data. . Further, in section 1.4, the need, the benefit and the innovation of such application integration will be pointed out.

1.2. Urban Spatial Database

The content of a spatial database consists of space information that is necessary for applications, where there is a need to monitor the dynamic spatial position of an object or event. Therefore, spatial databases describe the fundamental representation of objects derived from spatial or geographic entities. They support aspects of space and offer spatial data types in their data model and query language (Samson et al., 2017).

In the following work, a spatial database (PostgreSQL with the extension PostGIS) was set up especially for urban planning and development applications. PostGIS is a spatial database extender for the PostgreSQL object-relational database, containing spatial information and following the Simple Features for SQL Specifications of the Open Geospatial Consortium (OGC) (Obe et al., 2011, PostGIS, 2021). The spatial objects stored in the database represent all aspects of documenting and monitoring changes in the urban structure. Corresponding objects are mainly urban quarters, parcels, buildings and the infrastructure network. Additionally, many object-specific attributes like e.g. the usage of a building, are stored in the database.

To guarantee the complexity of urban structure changes, the database allows enhancing information towards each spatial object. Official land cadastral data (ALKIS) present the main input dataset for the urban spatial database. ALKIS®, established in all federal states of Germany in 2015, combines and integrates data of the former cadastral map as well as the former property registry. In ALKIS®, for the first time, spatial and non-spatial related data were kept together systematically redundancies-free. The consortium of the Surveying Authorities of the States of the Federal Republic of Germany (AdV) developed a functional design to manage all basic geo data of the official surveying and mapping. All federal states agreed upon a unique data model using the UML standard (AdV, 2009, Seifert 2005). The conceptual design of the ALKIS® data defines different kinds of relations between the object types encoded in GML format (Lake et al. 2004, Portele 2007) and has been re-modeled in this project for the needs of the accounting procedure (Ostadabbas et al.,2019).

1.3. FMS Accounting Application

The FMS (Finanz Management System) application is an accounting and project management application used for managing urban redevelopment projects. It provides services for cities and smaller communities for managing statutory funded projects, recording all corresponding expenses and earnings and preparing funding requests.

The core objects managed by the application system and stored in the database are individual funding tasks that are usually associated with real estate, e.g., selling or buying properties, demolition, construction, or refurbishment works, and corresponding planning activities. While these tasks are closely related to information managed in spatial data management systems, the FMS application only provides a static image export for a specific task object but not an automatic map generation.

The FMS application is browser-based, thus allowing easy access via the web without installing special client software. It is written in Python and builds upon a web application framework (Zope, 2021; Zope toolkit, 2021) and the knowledge management framework loops (cyberconcepts loops, 2021). The primary storage of FMS is an object-oriented database (ZODB, 2020), but it also provides access to SQL databases for data storage and retrieval. The standard SQL database used for FMS is PostgreSQL FMS can readily access spatial data stored in a PostgreSQL database (which has the PostGIS extension installed).

1.4. Resilience

Initially, the FMS accounting application and the spatial database systems were strictly separated, despite considerable overlap of data stored in both systems. Thus, for example, information about building usage, quality and state of buildings, type and state of the refurbishment tasks were stored in both systems and had to be edited twice. This not only leads to additional work but also presents a source of potential data inconsistencies between the systems and delayed updates.

As the FMS does not contain any geometric information, the maps for each property or redevelopment area have been created manually in BricsCAD (commercial software) and uploaded as a static image export in FMS. If there are changes in the data, these map images have to be recreated and uploaded again. It is necessary to generate maps on the fly in FMS, showing the current state of the geometries such as land parcels and buildings and their attributional information visualized by corresponding layout symbols. Therefore, the main objectives of the EAI (Enterprise Application Integration) work are:

- provide spatial representations on the fly in FMS,
- show relevant information simultaneously in both systems with updated and consistent data,
- allow automatic update of relevant information in both directions.

As FMS can be easily extended and adopted to specific needs, the most feasible solution was to access the spatial database directly from FMS. The main prerequisite for this kind of connection is a set of strictly standardized tables in the spatial database, which in the following will be defined as generic representation (see section 1.5). This step was challenging as the database tables for the projects are initially created independently via QGIS layers in separate database schemas. Thus, it was necessary to provide an easy and safe way to fill this generic representation with data from each project schema.

The generic representation of spatial data and related information can then additionally be used for displaying dynamically generated maps in the web browser using the QGIS server together with the Lizmap rendering engine. As FMS is a browser-based application, these maps can also be included in the appropriate pages (e.g., those related to redevelopment tasks) in FMS.

1.5. Generic Representation for Spatial Data and Object

For unified access by application programs and the display of maps that represent a variety of properties of spatial data objects, a generic representation for all data with a simple set of tables was created. This structure allows the representation of all kinds of data for all cities/communities and projects: spatial data (different types of geometries: parcels, buildings, other areas, lines, points; see table geoitems) and an open set of additional attributes. For use cases where additional attributes must be included, the separate table for storing the attributes of the geometric object (see table geoattrs) allows a full SQL definition of the generic representation (see Figure 1) (Cyberconcepts geostore, 2021).

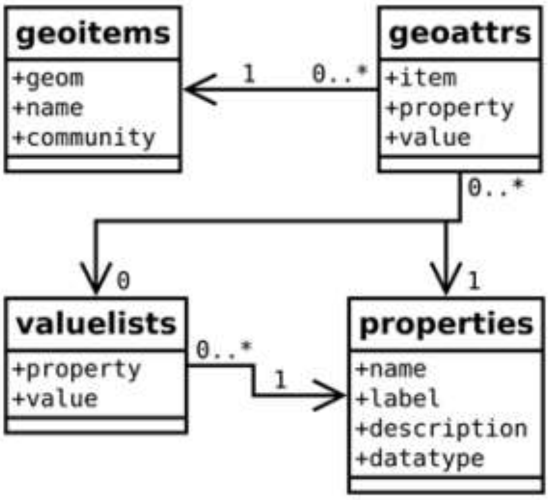

Figure 1. Simplified table structure of the generic representation

The table properties contain metadata related to the attributes stored in geoattrs; only attributes with a corresponding entry in the properties table can be stored in the geoattrs table.

As there are a lot of properties that have a fixed set of possible values (usually short texts, e.g., for building usage or quality, or project state), an additional table valuelists that contains predefined lists of values for these properties was defined. In this case, the value column of the properties table contains only the identifier of the value from the valuelists table.

Inserting attributes in a table separate from the objects themselves provides maximum flexibility: new properties or additional values can be introduced any time without any changes to the existing table structure, so no tables or columns will have to be added to the generic representation, yielding high stability for all kinds of access.

On the other hand, the distribution of related data across multiple tables makes the accessing of data and especially the displaying of maps with tools like QGIS more complicated. This complexity is addressed by a database view vgeoattrs that provides a full list of all spatial objects with their attributes, taken from the valuelists table when necessary (see Figure 2); thus the access by QGIS is greatly simplified (client and server).

```
create or replace view vgeoattrs as
  select i.id as item_id, i.geom, i.type, i.name as item_name,
         i.description as item_description, i.community,
         a.id as attr_id, p.id as prop_id,
         p.name as prop_name, p.label as prop_label,
         p.description as prop_description, p.datatype,
         p.domain as prop_domain,
         case when p.datatype = 25 then vl.value
              else a.txtvalue
         end as txtvalue,
         a.intvalue
    from geoitems i
      left join geoattrs a on a.item = i.id
      left join properties p on p.id = a.property
      left join valuelists vl on
        p.datatype = 25 and vl.property = p.id and vl.id = a.intvalue;
```

Figure 2. SQL code for creating the view vgeoattrs to allow easy access to the generic representation

Based on this view, QGIS layers can be easily created by using the filter functionality of QGIS.

2. Methodology

2.1. Integration Workflow

The workflow for each project (usually a city or community) to be managed by the system basically consists of three steps (see Figure 1):

- Initial set up of an import representation using cadastral data from ALKIS data and field data taken from Excel sheets or imported from spatial data collection tools like QField.

- Load the generic representation from the database schema set up in the first step using SQL scripts, typically run via the PostgreSQL command line tool pgsql.

Access the generic representation from QGIS, the web interface (using QGIS Server and Lizmap), and the FMS accounting application.

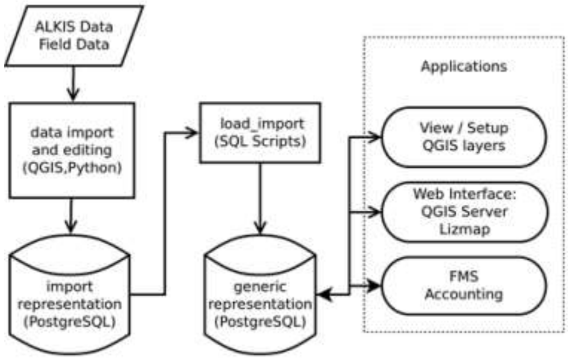

Figure 3. Components of the integration workflow

For each city/community, the basic geometries of parcels, buildings and streets are set up and stored in the PostgreSQL database using the corresponding ALKIS dataset. Additional data are supplied using QGIS (see also section 2.2).

The import representation corresponds to one schema per project /community that contains a fixed set of tables for different types of objects (parcels, buildings, other areas, lines, points) with columns for all properties of the respective type. These tables are created in each schema via a predefined SQL script so that in all database schemas, there is the same set of tables with the same set of table columns. If necessary, additional columns could be added to the tables to store additional properties.

To visualize spatial data and related information in FMS, one needs a strongly standardized data structure, the generic representation, with only one database schema (generic) that contains all relevant data from all communities and projects (see section 1.5 for a detailed description). This generic representation has to be filled (for each community or each project) via an SQL script (load_import.sql) that collects data from the tables and columns of an import representation and updates the geoitems and geoattrs tables in the generic representation.

The FMS application can thus retrieve and display data from the generic representation by direct access to the spatial database; maps created on the fly via the web interface can easily be embedded in the data pages of FMS.

2.2. Python Script for Map and Project Configuration

According to the integration workflow described in the methodology chapter, Python scripting will be applied for ALKIS data import and editing. Moreover, it will be utilized for viewing and setting up the QGIS layers. Starting from 0.9 release, QGIS supports Python language. It was chosen for software development because it is one of the most common programming languages (PyQGIS Developer Cookbook, 2020). PyQGIS is a Python environment inside QGIS with a set of QGIS libraries, including Python tools with enable access to libraries such as Pandas, Numpy, and Scikit-learn (Montaya, 2017).

The Python coding in the project mainly focuses on configuring attribute forms for widget types of different fields that had been created in PostgreSQL (data import and editing). This configuration, for instance, is compulsory for image acquisition on-site (see Figure 4).

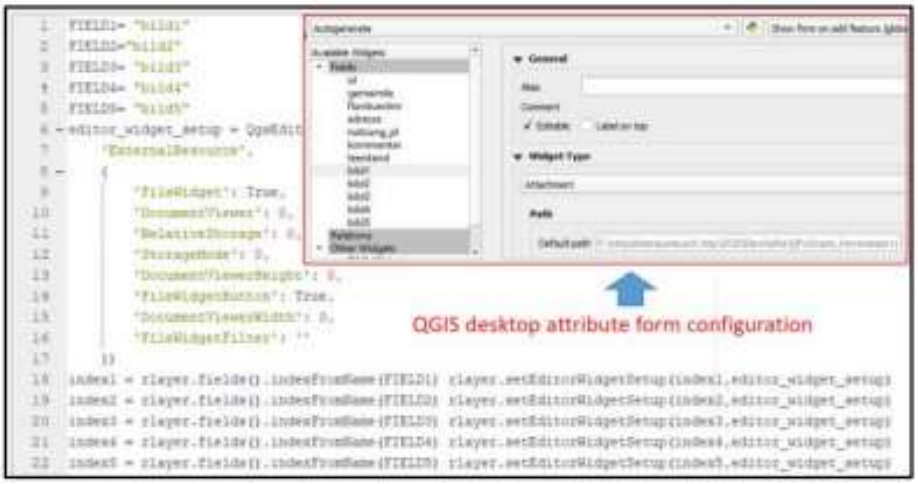

Figure 4. Python script for attribute form configuration for widget type "attachment"

According to predefined attributes for urban planning purposes in the import representation schema, such as, e.g., usage of a building, year of construction, heat demand, etc., the capability of choosing these different attributes has to be activated. Figure 5 shows the configuration result and feature attribute by running the python code.

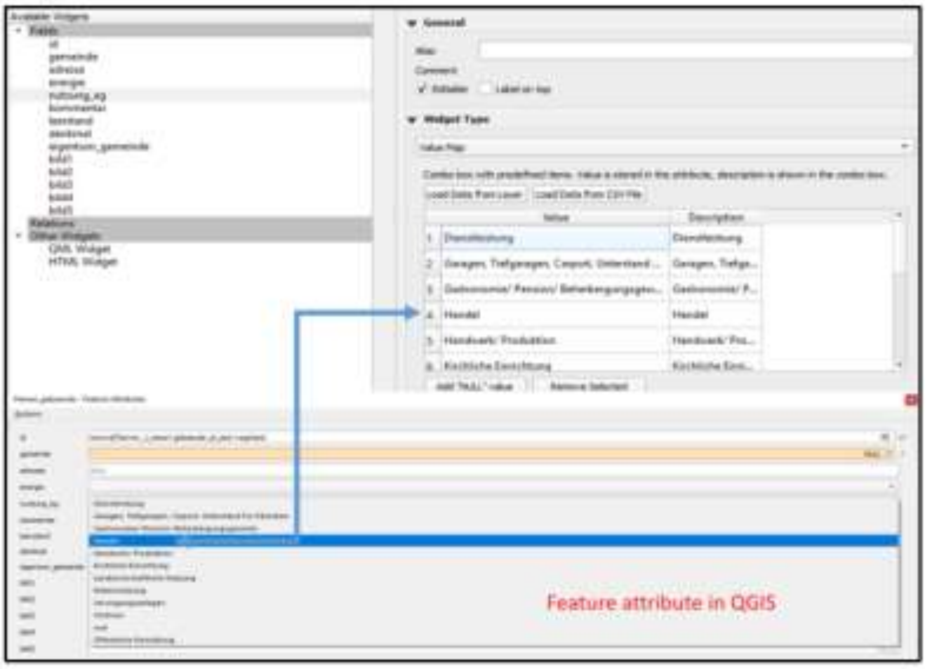

Figure 5. Widget type configuration in attribute form for feature attribute in QGIS desktop

In the second phase, Python programming is used to visualize the QGIS layers. By creating a styling button as a new icon in QGIS desktop, the process of assigning predefined symbols and different layout styles is much faster and easier. Furthermore, it allows the accessing of difficult symbols created in drawing software such as BricsCAD and Illustrator (see Figure 6).

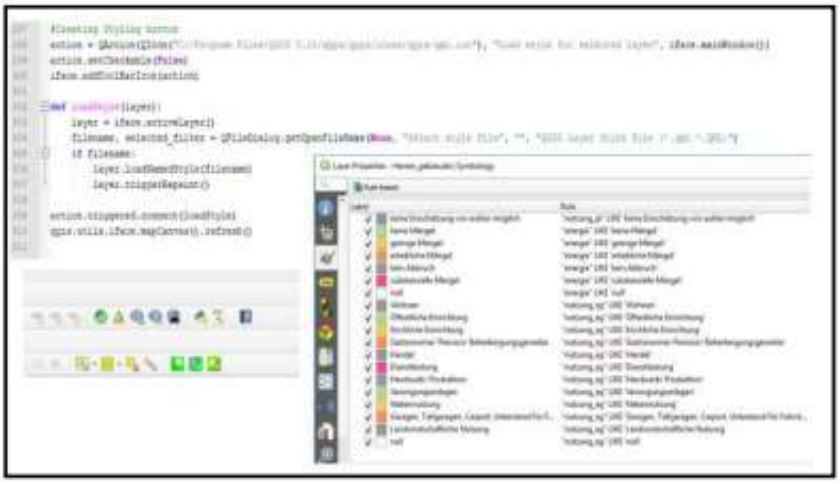

Figure 6. Python script for style configuration

The Python scripts will be updated and configured for all the important layers for the import representation schema in the PostgreSQL database.

2.3. Web Presentation with QGIS Server and Lizmap

As requested by municipalities and internal by the involved company itself, the maps created in QGIS desktop should be accessible to the public on the web. Therefore, the QGIS server, which employs QGIS as a backend for GIS functions and map rendering, and Qt library will be used for a graphical interface. “Qt is a free and open-source widget toolkit for creating graphical user interface which runs on different software and hardware platforms.” (Qt – About US, 2020).

By using the same graphical library (Qt) in QGIS desktop and QGIS server, the maps that are created on the desktop will have the same appearance on the web. (QGIS Documentation, 2020). Lizmap as a web client is the open source software that was founded by a French company “3Liz”.

As a requirement on the client side, Lizmap is installed on QGIS desktop as a plugin. It provides the possibility to add tools needed in the web map user interface (see figure 7). On the server side the visualization is based on the JavaScript library OpenLayers which handles the WMS requests to the QGIS server (Ostadabbas et al., 2019).

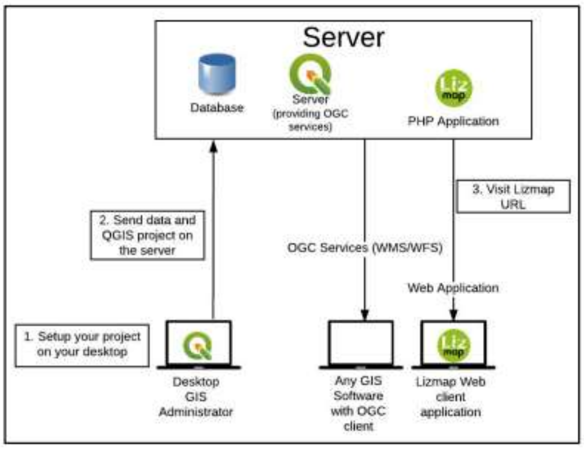

Figure 7. Lizmap Architecture (Lizmap Documentation, 2020)

Lizmap has some favorable predefined functionality for map tools such as print, measure tool, zoom history, address search and automatic geolocation. In addition, Lizmap provides “Lizmap search” in PostgreSQL tables. For activation of the “Locating by layer” and “Layer editing” functions, the WFS capabilities in the QGIS server should be activated. (see Figure 8). WFS capabilities provide the selection of layers for publishing and specify if they have permission for updating, inserting, and deleting operations.(QGIS Documentation, 2020).

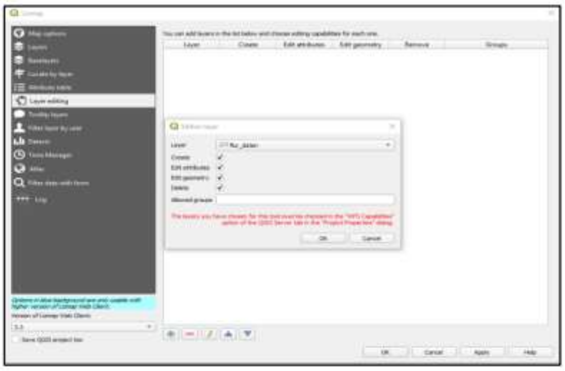

Figure 8. Activation of “Layer editing” in Lizmap plugin

Moreover, Lizmap allows the user to perform some operations in the web interface such as: create, editing attributes, editing geometry and deleting action. Those functions will be saved directly in the database and will be updated by assigning the defined symbology according to the map legend (see Figure 9, 10).

Figure 9. Lizmap web client application with different layer categories and symbologies

Figure 10. Creating a new geometry and automatic map updating according to defined symbols in the map legend

By assigning credits and restrictions to the administrators of the company and the municipalities, these changes can be done fast without installing GIS desktop software. Finally, the updated maps in PDF format and attributional information in CSV format are accessible to all users.

3. Conclusion

The described workflow represents an innovative integration process for the specific use case of administering and managing complex urban redevelopment areas extending over many years. The municipalities carrying out the various urban planning measures and being responsible for the legal accounting procedures could highly benefit from the developed Enterprise Application Integration System (EAI). All urban measures and financial transactions are related to spatial objects, whether a building or a parcel. Based upon this fact, the non-spatial database as used in accounting and project management systems will be coupled with the spatial database where all the cadastral geometries and attributes are stored. This integration shows the great potential of open- source software in respect to data aggregation and retrieving as well as automatic map generation and visualization for better documentation. A future application of the developed integration lies in connecting devices for data acquisition on-site, which could update the database on the fly and automatically generate Web GIS maps.

An important prerequisite for integrating data from different application systems is the definition of a common generic data structure that collects data from disjoint data sources. It allows providing updated maps via web interfaces which can be viewed not only in GIS desktop applications but in other web-based applications (like accounting and project management applications). In addition, information from other applications like accounting systems may be provided in the spatial representation.

4. Future Steps

Further research could be done regarding the connection of the developed application with a three-dimensional open open-source database like 3D City Database (3DCityDB) for 3D city modeling (Coors et al., 2016). This software allows the import, management, analysis, visualization, and export of virtual 3D city models through a database schema for relational database management systems. For visualizing, querying, and performing analysis on the 3D model, a JavaScript code could be written with CesiumJS graphical user interface.

Another important future development is related to the way application systems access the spatial data: While directly accessing the spatial database is very efficient and fairly simple to be implemented, this is only possible if the application can be extended and thus requires the availability of the source code of the application. Therefore, in EAI projects, the applications usually have to be much more decoupled from one another: Instead of directly accessing the database of the other system, an application has to "talk" to this other system via a standardized interface, typically using a messaging-based integration service (see, e.g., Cyberconcepts integrator, 2021) providing a standard REST/JSON interface (JSON, Wikipedia, 2020). Then only the integration service would need access to the spatial database (the generic representation), and other applications could be connected to the spatial database via this service.

The described development would open the gate to other possibilities of integrating data from a larger set of applications and data sources: Using the Semantic Web standards, the generic representation with its open data model can be used as an RDF-compliant data storage (RDF, Wikipedia, 2020). This allows the representation of data provided in RDF format and thus the integration of official open-data sources as well as publicly available information from services like Wikidata (Wikidata, 2021). And moreover, vice versa, using this Web standard, information from the internal spatial database can be made accessible in mapping services like OpenStreetMap (OpenStreetMap, 2021).

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Augmented Reality Application in Historical Exploration in Germany

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Keywords: *Virtual Reality, Augmented Reality, 3D Modeling, AR, VR, ARCore*

ABSTRACT:
During World War II, many homes and historical sites were destroyed. Rebuilding all of the monuments is almost difficult. Augmented Reality serves a critical responsibility in preserving the memory of old structures such as historical palaces, and it is also growing as an emerging platform in museums and creative fields. In this project, we presented an Augmented Reality application that would allow users to view virtually recreated 3D structures from the past in the same location as they were previously. The application was created using the ARCore SDK for Unity and the Unity Game Engine. To recognize the 2D photos stored in the image database in Unity Game Engine, the program employed the Augmented Images APIs in ARCore. To complete the task, C sharp (C#) code was created. For the database, the image acquired by the camera should be planar and appropriately adjusted. In reference image gathering, shadow and occluded parts must be avoided. GIS software was used to obtain the spatial relationship between the image target and the position of the target (3D model). Finally, we created an Android (.apk) app and tested it in the field. After tracking the identified picture, the Augmented Reality application displayed the 3D model.

Surface Water Quality Assessment along Mahanadi River Using WQI and GIS

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Keywords: *Mahanadi River, Geospatial, Geomorphic, Hydrologic, Water quality index, Nemerow's pollution index, Pearson coefficient*

ABSTRACT:

Due to various environmental and natural or artificial disturbances, determining the purity of river water is an important task. The challenge is that getting the water quality within the standard permitted levels for drinking, industrial, and agricultural applications are deemed extremely challenging. The impact of agricultural operations and residential pollutants on Mahanadi Basin water quality was assessed. The purpose is to investigate the Mahanadi River's water quality using the water quality index method and GIS software. For an 18-year detection time, twenty parameters were collected (2000-2018). These constituents were measured to learn more about their geospatial distribution and pollution levels. A broad catchment area with 19 water quality sites was chosen because the rivers and streams pass through a geomorphic, geographical, hydrologic, and industrially diverse region. PH levels are slightly alkaline. Other parameter analysis results were compared to WHO-recommended maximum allowable limit values. In this investigation, the WQI values calculated vary from 28.28 to 60.10. The Mahanadi River has a well to poor water quality rating, according to the WQI map. However, two stations, Cuttack D/s and Paradeep, have low water quality. All of the other sites are in a good category. The most significant contaminants are TC, BOD, and TKN. As per Nemerow's pollution index, some parameters had greater values above the WHO's acceptable and allowed thresholds. Furthermore, Pearson's coefficient analysis demonstrated a significant and particular association between the variables under study. Despite the conflict between development and conservation, this result will undoubtedly aid policymakers in achieving sustainable environmental management.

1. Introduction

Water is crucial for all living things to survive. If it is susceptible to bacteriological, chemical, or physical threats, it may be a source of a growing number of chronic human disorders. It has a huge impact on the spread of viruses and health issues: it is estimated that 80–85 percent of infectious diseases are transferred through water (Lane et al., 2003). Although it is an important part of the environment, the quality of surface and ground water has long been degrading as a result of both natural and human-caused factors. Water quality is influenced by hydrodynamic, meteorological, environmental, geographical, and geological factors (Magesh et al., 2013; Uddin et al., 2018). The human activity that has a negative impact on water quality include mining, livestock farming, trash generation and disposal (industrial, municipal, and agricultural), increased sediment outflow or soil erosion owing to land degradation (Lobato et al., 2015), and heavy metal contamination (Sanchez et al. 2007). The overall quality of water is a significant and crucial concern all around the world. Furthermore, as people become more aware of the importance of drinking water quality to health policy and raw water quality to water bodies, the need to investigate surface water quality is becoming more pressing (Ouyang et al. 2005). Organic and inorganic causes degrade surface waters, rendering them unfit for a drink, business, cultivation, recreational, and other uses (Carpenter et al., 1998; Jarvie et al., 1998; Simeonov et al., 2004; Sanchez et al., 2007; Kazi et al. 2009). As a result, a water quality monitoring system is essential for the safeguarding of freshwater supplies (Pesce and Wunderlin, 2000).

The nature of geochemical forces is revealed by river basin geochemistry, helping individuals understand exo-genic component movements in the continent-river-ocean network (Giridharan et al., 2010). Water's hydro-geochemical qualities have a big influence on how it is used in domestic, agricultural, and industrial applications. Water's chemistry and taste are influenced by its interactions with the lithologic entities through which it passes (Subramani et al., 2009). Experts believe that potentially hazardous materials pollution will eventually reach humans through the usage of polluted water (Rehman et al., 2018). According to Boyd (Boyd et al. 2006), primary care specialists consider that pathogenic pathogens are the most major and important concern among the contaminants in drinking water. These germs will cause disease epidemics, causing serious health difficulties for a huge segment of the population. Geo-genic (natural disruption of the mineral belt) and human (mineral extraction, fertilizers, and liquid wastes) act both contribute toxins into the environment (Muhammad et al., 2011; Devorak et al., 2020). It is a valuable resource and arguably the most vulnerable aspect of the environment to heavy metal contamination (Mano et al., 2017; Ciazela et al., 2018). Water is becoming more recognized as one of the most important natural resources in the future. Water scarcity is becoming more prevalent around the world, and pressure on current water supplies is increasing as a result of rising demands in a variety of sectors, including domestic, industrial, agricultural, and hydropower generation.

To investigate the chemistry and safety of the river's flow, several processes have been implemented (Afsin et al., 1997; Subramani et al., 2005; Moller et al., 2007; Shastry et al., 1972; Aston et al., 1974; Lizcano et al., 1974; Nunes et al., 2003; Tsegaye et al., 2006). (Yidana and Yidana, 2010) investigated the limitations on the water level and the severity of the regulating elements at various places in the flow system using traditional graphical approaches, multidimensional quantitative tools, and GIS. They also adopted the water quality index (WQI) approach to see if the freshwater in the field of research was drinkable. The WQI was used by (Kannel et al., 2007) to investigate regional and periodic water quality differences in the Bagmati river basin. (Devbels et al., 2005) calculated WQI using nine elemental compositions obtained on a routine basis at 18 samples collected in the Chillan River basin in order to assess the basin's geographical and temporal variability in water quality. Horton was the first to propose the use of a WQI in 1965 (Brown et al., 1970) . Following that, several authors devised various ways for calculating WQIs (Debels et al., 2005; Saeedi et al., 2009; Tsegaye et al., 2006). Based on the use of standard metrics for water characterization, the WQI has been considered as one criterion for surface water classification. It concludes with a discussion of water quality for most home applications. WQI is a numerical tool that converts a large amount of water characterization data into a single number that indicates water quality (Bordalo et al., 2006; Sanchez et al., 2007). Emerging countries have recently encountered considerable challenges in maintaining water quality when promoting sanitation and hygiene (Carvalho et al., 2011; Debels et al., 2005; Kannel et al., 2007; Ortega et al., 2016). Even rich countries have endeavored to maintain or conserve water due to concerns about algal blooms and eutrophication of waterways (Abbasi 2012; Debels et al., 2005), as well as the delivery of water and sanitation services to an ever-growing population. Water quality assurance necessitates the collecting of huge files, which can be difficult to interpret and compile.

The (WQI) model is one of many water quality data evaluation methods that have been created. There have been many different WQI systems presented, each with its model definition, parameter weightage, and sub-indexing and aggregation techniques (Debels et al., 2005; Jha et al., 2015; Kannel et al., 2007; Sun et al., 2016). However, due to increased water consumption and diminishing water supply, achieving this feasible goal remains a challenge (Li and Qian, 2018). As a consequence of rising financial independence and industrialization. Many developed and emerging countries' waterways have worsened to alarming levels in recent times due to rapid employment generation, mainly in developing nations, and fertilizer waste from fields containing crop residues (Omonona et al. 2019; Tripathi and Singal, 2019). The usage of fertilizers manures and water channels substantially impacts water quality (Ali et al., 2019; Rashid et al., 2019). Water quality is crucial for public health and eco processes, and its degradation in poorer countries has resulted in health implications such as diarrhea, malnutrition, hepatitis, anemia, and tooth holes (Memon et al., 2011). Rising population, gigantic modernization, and livestock grazing, as well as insufficient governance of home, commercial, and urban wastes, decayed soil, and transportation infrastructures, have all contributed to the rapid deterioration of watersheds (Zhao et al., 2011; Ouyang et al. 2006; Masoud et al., 2014]. According to (Giri and Singh 2014), the quickening of urbanized and economic output near water sources has manifested in river pollution, water effluent, and the disintegration of entire hydrological integrity. Natural and anthropogenic factors cause diversity in the demand and supply of stream water in different rivers around the world (Gupta et al., 2011). Water quality surveys are the most generally accepted procedure for evaluating biological grievances in river ecosystems, and different seasons and time discrepancies in main environmental aspects are extremely useful for determining pollutant concentrations (Wang et al., 2016). We employed the Mahanadi River as a subject of study for the first time in this paper, building 19 major observation stations across the riverbed and recognizing and reviewing 20 20 biochemical parameters in river water. There was an 18-year reporting phase. The main objectives of this study are:

a) To examine the river water's physicochemical aspects.

b) Establish the Mahanadi River's water quality using WQI testing and build a WQI diagram using GIS.
c) To describe how each water quality metric affects the WQI scores.
d) Examine whether the water is suitable for consumption, gardening, or commerce.
e) To evaluate the effect of waterways on river basins, as well as to identify the water quality aspects that influence observed changes in watersheds (natural and anthropogenic factors).
f) Nemerow's Pollution Index (NPI) is used to quantify the principal contaminant existing in sample water and, primarily on the NPI rating, to decide whether the sample is contaminated or non-contaminated.
g) Discover the sources of contamination that are influencing water quality.
h) The overall findings could help managers better understand the space-time progression of Mahanadi Watersheds, allowing them to better identify the main types of contamination at various locations throughout the river basin.

2. Study Area

The Mahanadi basin spans 141,589 km2 and accounts for roughly 4.3 percent of India's total land area. It is situated between 8030 and 8650 east longitudes and 1921 and 2335 north latitudes. The Mahanadi River, which travels from west to east before draining into the Bay of Bengal, is one of India's major rivers. The main tributaries are the Hasdeo, the Seonath, the Mand, the Ib, the Bhadar, the Jonk, the Ong, and the Tel. It drains 50 109 m3 each year, with a high discharge of 44,740 m3 s1 (Chakrapani and Subramanian 1990; Sundaray et al. 2006). The river begins as a little torrent in Chhattisgarh's southeast region, draining the eastern side of the plain region (Central India). Pharsiya village, 6 kilometers from Raipur's state capital, has a pool at the height of 442 meters(of Nagri town). Agriculture is the primary source of income for the local population. The river flows west during the first 56 kilometers of its voyage, passing through scattered hills and a small valley with little impact from industrial activity. Near Kanker, four tiny streams join the river, taking an abrupt northwest turn. Agriculture is the main source of income in the Kanker district. This area is rich in mineral deposits, including iron ore, quartzite, and garnet. The Pairi River joins on its right at Rajim after approximately 113 kilometers of unbroken flow. Apart from agriculture, Rajim's people primarily rely on tourism, with a few industries such as a steel mill and a rice mill also present in the city. Seonath, the Mahanadi's first notable tributary, flows into the Mahanadi 13 kilometers upstream in Bilaspur District, at Sheorinarayan.

When compared to Past River places, the Bilaspur district might be considered developed. The Mahanadi river turns east after going through a sangam of rivers of almost identical breadth that spans 138 kilometers. At Sheorinarayan town, the tributary Jonk joins from the right. The Hasdeo tributary joins it from the left after about 17 kilometers near Mahuadih.The Mand river joins it from the left later at Chandrapur. In the Mahuadih and Chandrapur areas, there is a lot of farming. The Mahanadi leaves Chhattisgarh and enters Orissa after a 28-kilometer journey. Near Bagra, the Ib River joins from the left. In the area, there is a big tract of woodland with little human activity. The river also feeds into the stony beds of the Hirakud dam, which is across the Mahanadi from Sambalpur City. The dam has a height of 61 meters and a length of 4.8 kilometers. The Hirakud Dam has far-reaching social implications, giving water and energy to those who are in need. The dam is responsible for flood control, irrigation, hydropower generation, and navigation. Sambalpur is home to a varied mix of businesses, including bauxite, coal, and dolomite.

After passing through a series of rapids below the city, the Mahanadi River takes a southerly turn and splits into two sections around Charpali town, eventually reuniting around Dhama. The Mahanadi flows south for 11 kilometers below Dhama before turning southeast for 45 kilometers to Sonepur town. Around 11 kilometers upstream of Sonepur, the Ong River enters the Mahanadi from the right. After a slight shift to the southeast around Sonepur, where the Eastern Ghats Mountains begin, the Tel, the second-largest tributary, enters. The river separates into two arms again around Haudh, and the valley narrows drastically for the next 23 kilometers beyond Athmalik, going through the incredibly narrow Satkosis Gorge. The water quality station, Tikarpara village, is about 6 kilometers below the commencement of the narrowest pass. In the basin, Tikarpara is a well-known tourist resort. The river crosses the Eastern Ghats at Baramul, where the gorge terminates. Between the villages of Baramul and Baideshwar, the Mahanadi valley is flat with minor hillocks. Below Baramul, the river widens again, reaching a width of 1.6 km. It flows near Pathpur through the Kaimundi gorge. The river widens and bends left beneath this gorge, eventually arriving at the Naraj delta 11 kilometers west of Cuttack, the state capital. Below this delta, the Mahanadi River splits into two channels, and after breaking into numerous watery tributaries, it eventually debouches into the Bay of Bengal around False Point. The river in question is

851 kilometers long, 357 kilometers in Chhattisgarh and the remainder in Orissa (Jain et al., 2007). The research region is illustrated with the basic topographic maps and required stations (Figure. 1).

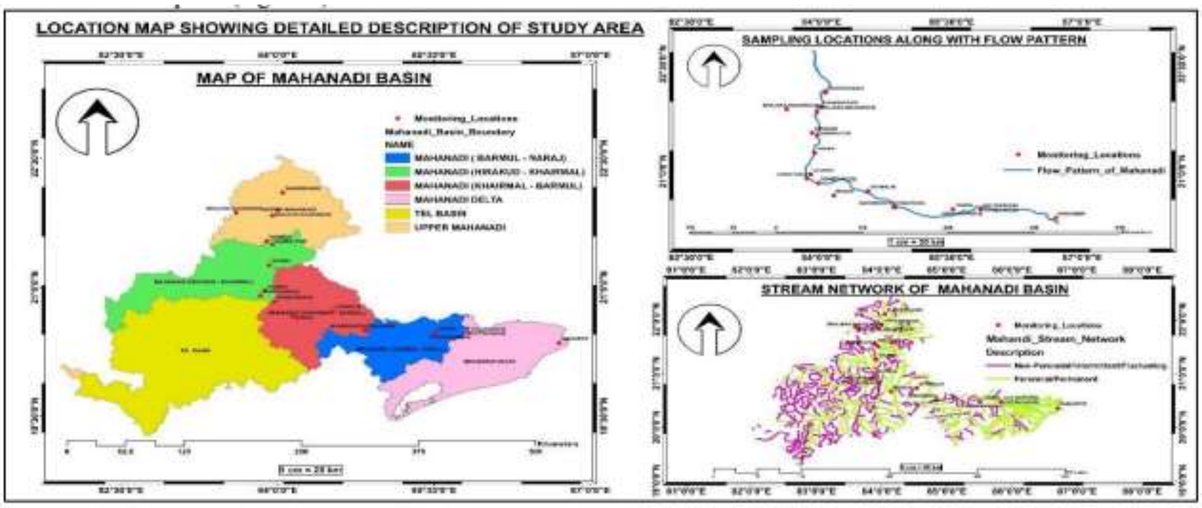

Figure 1. Creating a new geometry and automatic map updating according to defined symbols in the map legend

3. Sampling Procedure

This research aimed to figure out the physicochemical and bacteriological quality of waterways in Odisha's Mahanadi basin. Before being used, all sampling equipment, were cleaned with a cleanser, washed thoroughly with distilled water, immersed in 10% HNO3 for 24hrs, re-rinsed with deionized water, and air dried (Wondimagegne et al. 2016). Twenty water samples were collected from 19 sites using diverse water sources, with the reasons for each site being highlighted in the report (Table 1). Pre-rinsed 250 mL polyethylene bottles were used to collect water samples from nineteen different sites at each site. At the site, some physio-chemical parameters of water samples were collected, and samples from each location were combined in a one-liter polyethylene container with 2 mL nitric acid added to decrease metal adsorption on the plastic bottles walls. The sampling date and location were then written on the sample containers (Gebremedhin et al., 2015). The samples were transported to the lab in an icebox and kept at 4°C until processed. All of the samples were frozen and stored until they were needed for chemical analysis.

STATIONS SYMBOL	STATIONS	JUSTIFICATION ON SITE SELECTED
R1	HIRAKUD	Reservoir that serves multiple purposes (irrigation and Hydroelectricity)
R2	SAMBALPUR	Influence of home sewage water upstream of Sambalpur municipality
R3	SONEPUR(U/S)	Downstream of a prominent tributary's convergence (River Ong)
R4	SONEPUR(D/S)	Downstream of a large tributary's intersection with drainage and sewerage outflow (River Tel).
R5	TIKARPADA	Captive breeding site for crocodiles, as well as a sanctuary
R6	NARSINGHPUR	Modern agricultural operation in a populous area
R7	CUTTACK(U/S)	Cuttack municipality is built upstream.
R8	CUTTACK(D/S)	Significance of Cuttack's waste water emission and Jagatpur Commercial Estate's toxic waste release
R9	PARADEEP	Implications of the Paradeep Manufacturing Area's Waste Water Export
R10	SUNDERGARH	Water intake point and major human settlement
R11	JHARSUGUDA	Impact of industrial and mine discharges, water intake point
R12	BRAJARAJNAGAR(U/S)	Water quality before industrial impact. Water intake point and major human settlement
R13	BRAJARAJNAGAR(D/S)	Impact of industrial and mine discharges, water intake point
R14	DHAMA	To assess water quality improvement along Dhama stretch
R15	ULUNDA	To assess water quality improvement along Ulunda stretch
R16	BOUDH	Sub-divisional town
R17	ATHMALIK	Sub-divisional town
R18	TIGIRIA	Municipal sewage
R19	CHOUDWAR(D/S)(BIRUPA)	Downstream of Choudwar town

Table 1. Water Sampling Intake Points and its site justification

4. Result and Discussion

Physicochemical Characteristics of the Water Samples: Key physicochemical characteristics of the studied water samples were collected and analyzed during an 18-year interval (2000-2018) given in (Table 2).

SL NO	PARAMETERS	MINIMUM	MAXIMUM	MEAN	STDEV	SKEWNESS COEFF.	KURTOSIS COEFF.
1	PH	7.74	7.92	7.82	0.05	0.02	-0.84
2	DO	7.26	7.83	7.68	0.14	-1.87	3.66
3	BOD	1.05	2.40	1.36	0.34	1.84	4.19
4	TC	1212.40	42529.20	5151.25	9193.97	4.15	17.64
5	TSS	28.63	74.90	39.33	11.56	1.89	4.06
6	TOTAL ALKALINITY	70.40	100.90	85.71	8.24	0.07	-0.61
7	COD	6.76	21.88	11.25	3.96	1.63	2.52
8	NH3-N	0.51	1.93	0.66	0.31	4.03	16.97
9	FREE AMMONIA	0.02	0.06	0.03	0.01	2.04	5.71
10	TKN	3.28	11.80	5.73	2.07	1.49	2.94
11	EC	138.10	7779.35	580.86	1743.33	4.36	18.99
12	TDS	82.30	13230.60	812.80	3007.19	4.36	19.00

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10	TKN	3.28	11.80	5.73	2.07	1.49	2.94
11	EC	138.10	7779.35	580.86	1743.33	4.36	18.99
12	TDS	82.30	13230.60	812.80	3007.19	4.36	19.00

13	B	0.03	0.55	0.08	0.12	4.02	16.85
14	SAR	0.41	16.59	1.34	3.69	4.36	18.99
15	TH	51.20	2195.20	186.45	486.60	4.35	18.97
16	CL_2	9.65	4904.91	269.23	1122.58	4.36	19.00
17	$S0_4^{2-}$	4.97	376.07	26.43	84.68	4.36	18.99
18	F	0.26	1.00	0.37	0.17	3.26	11.13
19	NO_3	1.29	2.70	2.00	0.41	-0.22	-0.66
20	FE	0.60	2.61	1.31	0.46	1.04	2.41

Table 2. Computational examination of Mahanadi River water quality parameters (2000-2018)

Hydrogen Ion Activity (pH): The pH of water is a critical indicator of water quality since it is regulated by carbon dioxide and the carbonate-bicarbonate balance. It is a significant variable in surveillance because it affects many biological and chemical activities within a water body, as well as all water system and rehabilitation operations. In most natural streams, the pH ranges from 6.0 to 8.5, with smaller amounts in diluted waters with high organic matter content and increased rates in eutrophic waters, groundwater brines, and salt lakes (APHA 1912; APHA 2012). The Ethiopian drinking water recommendations and the (WHO 1996; WHO 1997; WHO 2004; WHO 2005; WHO 2006; WHO 2008; WHO 2011) have established a pH range of 6.5 to 8.5 as a suitable limit. The current water samples had pH levels ranging from 7.7 to 7.9, with a mean of 7.8 mg/l. According to the findings, all water samples have PH values greater than 7, indicating that the water is slightly alkaline. According to (CPCB 2015) criteria, PH values between 6.5 and 8.5 correspond to the Class A, B, C, D, and E categories (Table 3). According to the results, stations R1 through R19 are good and suited for all drinking classes. In this diagram, spatial variation and contour plots are depicted (Figure 2).

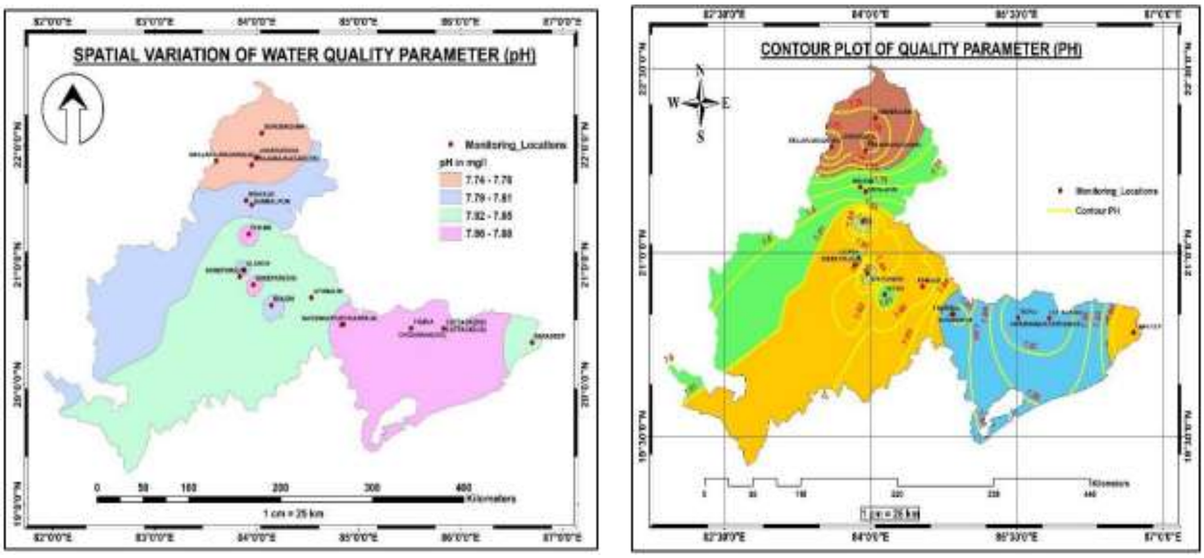

Figure 2. Spatial variation and contour map diagram showing the concentration of PH

CLASS	USE
A	Drinking water supply that has not been treated conventionally but has been disinfected
B	Outdoor showering that is well-organized
C	Supply of drinking water that has been treated conventionally and disinfected
D	Fish farming and wildlife rehabilitation
E	Horticulture, industrial cooling, or sewage treatment

Table 3. Categorization based on usage

Dissolved Oxygen (DO): The concentration of DO is a critical factor in keeping aquatic habitats in balance. It is frequently used to evaluate the quality of water resources (Qadir et al., 2002; Sanchez et al., 2007). In aquatic life, it is a significant limiting force. Photosynthesis produces oxygen, which is used to maintain oxygen saturation in aquatic habitats (Boyd, 2015). The level of DO in the water fluctuates based on the concentration of water-soluble salts, biological activity in the water, water temperature, and atmospheric gas partial pressure on the water surface (TAS et al., 2010). The concentration of cyanide in river water is around 10 mg/l. It is the most significant metric for assessing water quality since it impacts aquatic life and the dispersion of aquatic organisms (Rabee et al., 2011; Naubi et al., 2016). It varied from 7.26 to 7.83 mg/l in this study, with an annual mean of 7.68 mg/l, more than 6 mg/l more than the WHO's threshold. Higher levels were recorded downstream of city wastewater discharges due to local household wastewater. This was driven by the fact that rising temperatures in river systems hinder the breakdown of ambient DO, as proved by (Kumarin et al., 2013). Furthermore, (Yang et al. 2007) revealed that high DO quantities were associated with greater microbial activity, which requires a lot of oxygen to metabolize and decompose organic waste. According to the CPCB, the figure for Class A should be less than 6 mg/l, Class B should be less than 5, and Class C and D should be less than 4. All of the sites have results that are higher than the CPCB's regulatory limits, indicating wastewater contamination from both domestic and municipal sources. In this diagram, spatial variation and contour plots are depicted (Figure 3).

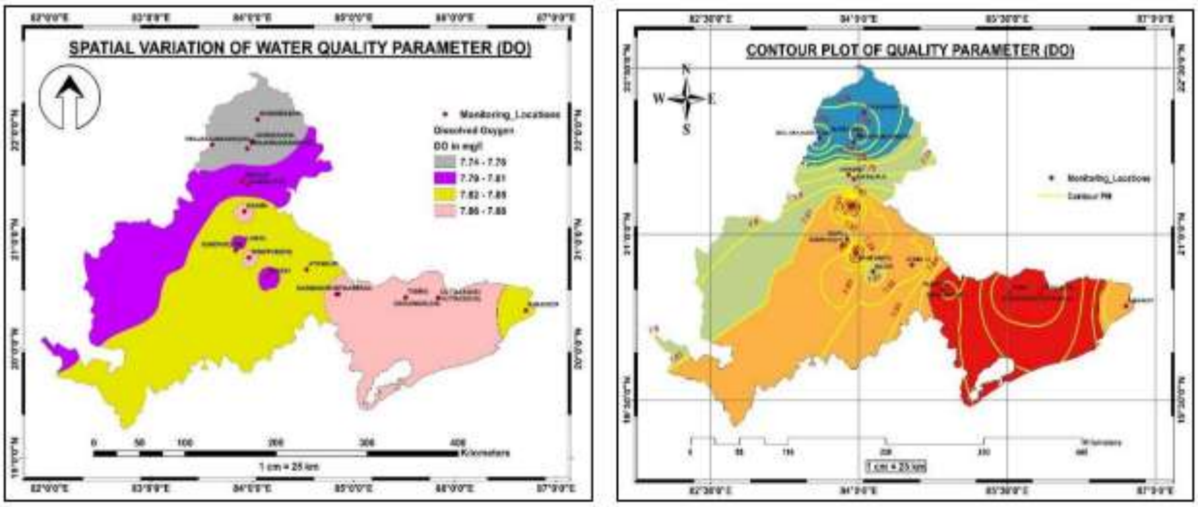

Figure 3. Spatial variation and contour map diagram showing the concentration of DO

Biochemical Oxygen Demand (BOD): It is a critical indicator of water quality. It's a measure of the oxygen required by adapted microbes to break down organic materials in water biologically, and it is a sign of organic pollution in water (Chau and Jiang, 2002). A higher BOD value is caused by an overabundance of organic material in water resources (WHO 2011). It is the amount of oxygen consumed by bacteria in the laboratory over five days to break down organic molecules (Smitha and Shivshankar, 2013). BOD in drinking water should not exceed 5 mg/l, according to the BIS. It ranged from 1.05 to 2.40 mg/l in our study, with an annual mean of 1.36 mg/l. According to the WHO's quality criteria of fewer than 5 mg/l, it was generally low (WHO, 2011). According to the findings, limited or no mixing of organic compounds has aided in lowering the BOD level in this river water. In this diagram, spatial variation and contour plots are depicted (Figure 4).

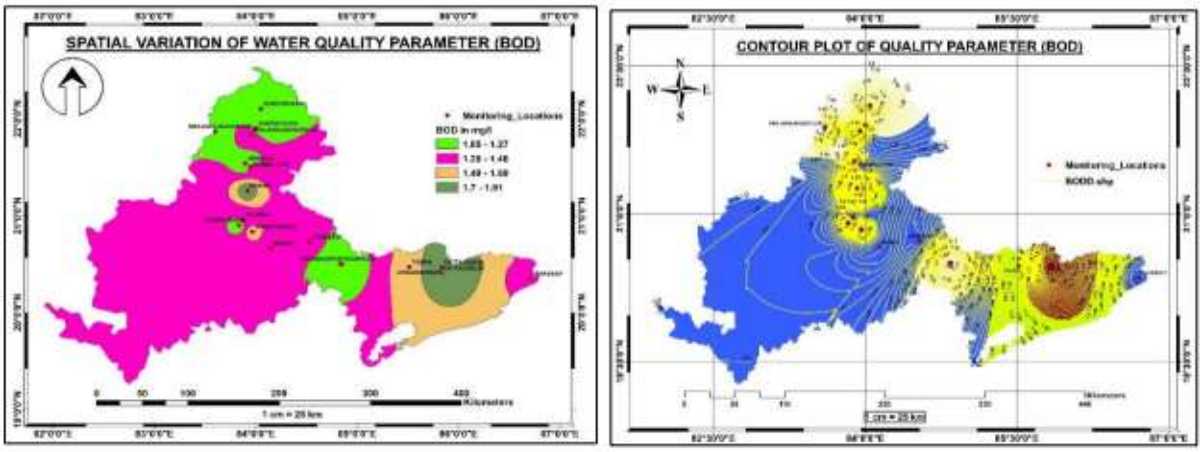

Figure 4. Spatial variation and contour map diagram showing the concentration of BOD

Total Coliform (TC): Total coliform is currently used as a bacterial contamination indicator, while faecal coliform is used as a faecal contamination indication in water. During the study period, the TC count of the water samples ranged from 1212.4 to 42529.3, with a mean of 5151.3 per 100 ml. The value of TC should be less than 50 for Class A, 500 for Class B, and 5000 for Class C, according to (CPCB 2012) recommendations. According to the findings, all of the stations are within the prescribed limits and fall into the Class C category, with the exception of Cuttack D/s, Paradeep D/s, and Chowdwar D/s, which have values larger than 5000 and hence do not fall into the Class C category. For effective monitoring and maintenance, these stations require adequate treatment. In this diagram, spatial variation and contour plots are depicted (Figure 5).

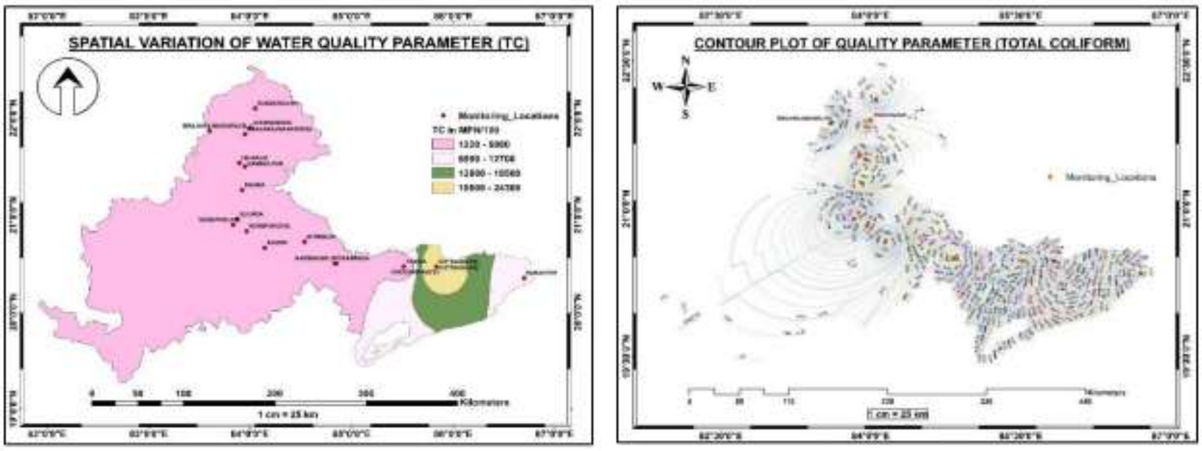

Figure 5. Spatial variation and contour map diagram showing the concentration of TC

Total Suspended Solids (TSS): TSS usually refers to bigger able solids. It can have an adverse effect on the fish population by acting directly on the fish, trying to prevent the rapid implementation of fish eggs and larvae, amending motion and migration of fish, and reducing the absorption of disinfecting agents (solids may protect effective contact between the disinfecting agents and the target organism). TSS concentrations ranged from 28.63 to 74.90 mg/l on average, with a mean of 39.33 mg/l. The readings should be less than 100 mg/l, according to (CPCB 2012). The permitted limits are met at all sample locations. Geospatial maps represent geographical changes and contour plots (Figure.6).

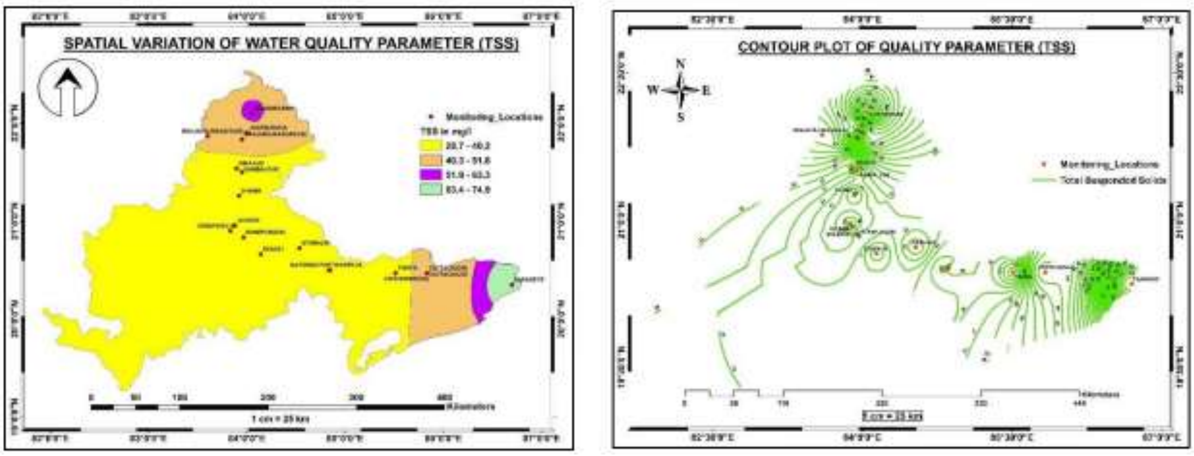

Figure 6. Spatial variation and contour map diagram showing the concentration of TSS

Total Alkalinity (TA): The capacity of water to neutralize an additional acid is measured by alkalinity. , The alkalinity of natural water, should be greater than 20 mg/l (as calcium carbonate) for freshwater aquatic life. Prior to treatment, the maximum alkalinity of water used as a supply source for many companies ranges from 120 to 500 mg/l (as calcium carbonate). However, the alkalinity in bottled and canned soft drinks should not exceed 85 mg/l (as calcium carbonate). Alkalinity concentrations ranged from 70.40 to 100.90, with an average of 85.71. According to WHO guidelines, all sampling locations are within the specified limits, i.e. (values should be less than 500 mg/l). Spatial variations and contour plots are represented by a geospatial map (Figure 7).

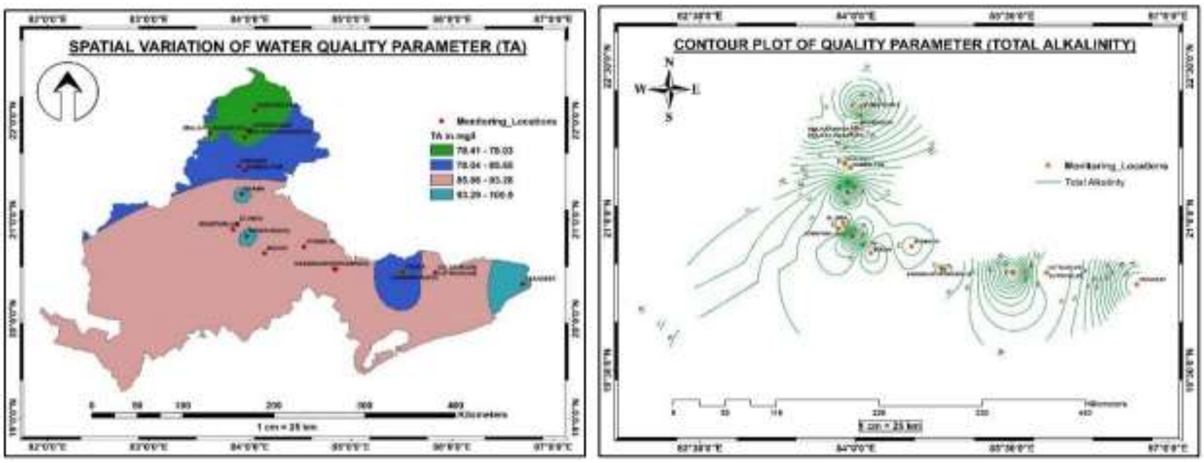

Figure 7. Spatial variation and contour map diagram showing the concentration of TA

Chemical Oxygen Demand (COD): Chemical Oxygen Demand measures how much pollution these compounds cause (COD). It's often used to figure out how much waste there is (Kazi et al., 2009).. For water quality to be designated as outstanding or good, certain European countries have a maximum COD limit of 20 and 25 mg/l, respectively. Under the Environment Protection Act of 1986 in India, the maximum allowed limit for an industrial effluent discharged onto the inland surface is 250 mg/l. Since discharge regulations are often predicated on the assumption of 10 times dilution, it is perhaps safe to assume that a COD content of 25 mg/l or less is the desirable limit in a water body, even in India. According to the study, levels range from 6.8 to 21.9 mg/l, with a mean of 11.2 mg/l and minor seasonal changes. All of the stations had levels below 25 mg/l, indicating safe to drink. Geospatial maps represent geographical changes and contour plots (Figure 8).

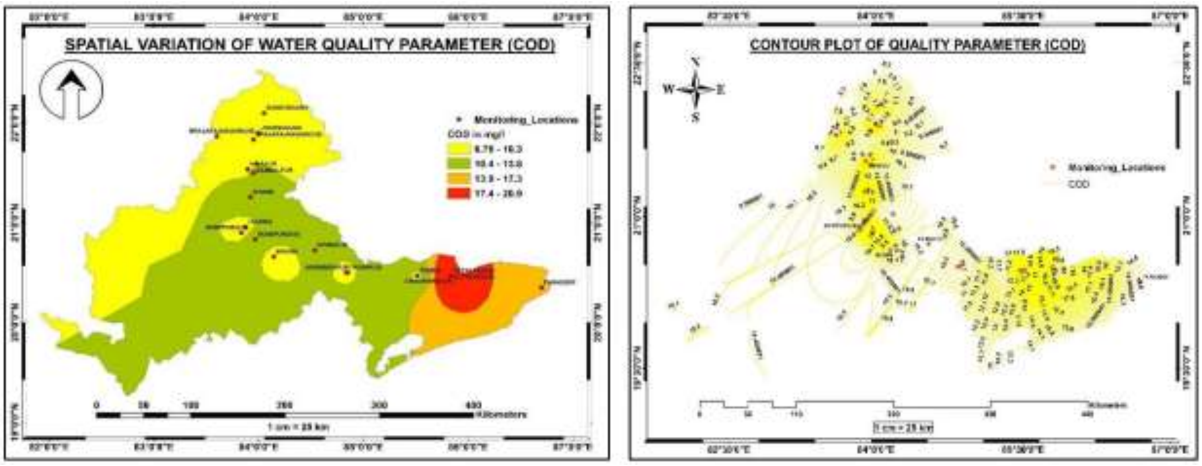

Figure 8. Spatial variation and contour map diagram showing the concentration of COD

Ammoniacal Nitrogen and Free Ammonia: Manufacturing and animal operations, as well as chloramine treatment, all contribute to ammonia in drinking water. Ammonium levels increases due to heavy agriculture in the catchment area of the water supply. As a result, ammonium is a symptom of contamination from germs, sewage, and animal waste. Ammonia concentrations lethal to a number of fish species range from 0.2 to 2.0

mg/l. The EPA's parametric value for ammonium is 0.3 mg/l, whereas the WHO and CES recommend 1.5 mg/l as a safe level. In the current studies, ammoniacal nitrogen concentrations ranged from 0.5 to 1.9 mg/l, with a mean of 0.7 mg/l, while free ammonia levels ranged from 0.51 to 1.93 mg/l, with a mean of 0.66 mg/l. According to (CPCB 2012), the value of ammoniacal nitrogen and free ammonia should be less than 2 mg/l. According to the report, all of the sampling sites for both incidents are within the CPCB's standard levels. All sites are safe according to WHO standards, with the exception of Choudwar D/s, which has a value of 1.93 mg/l, which is higher than 1.5 mg/l, and its free ammonia values are within WHO 2012 norms. All sites are classified as Class D. Geospatial maps represent geographical changes and contour plots (Figure 9).

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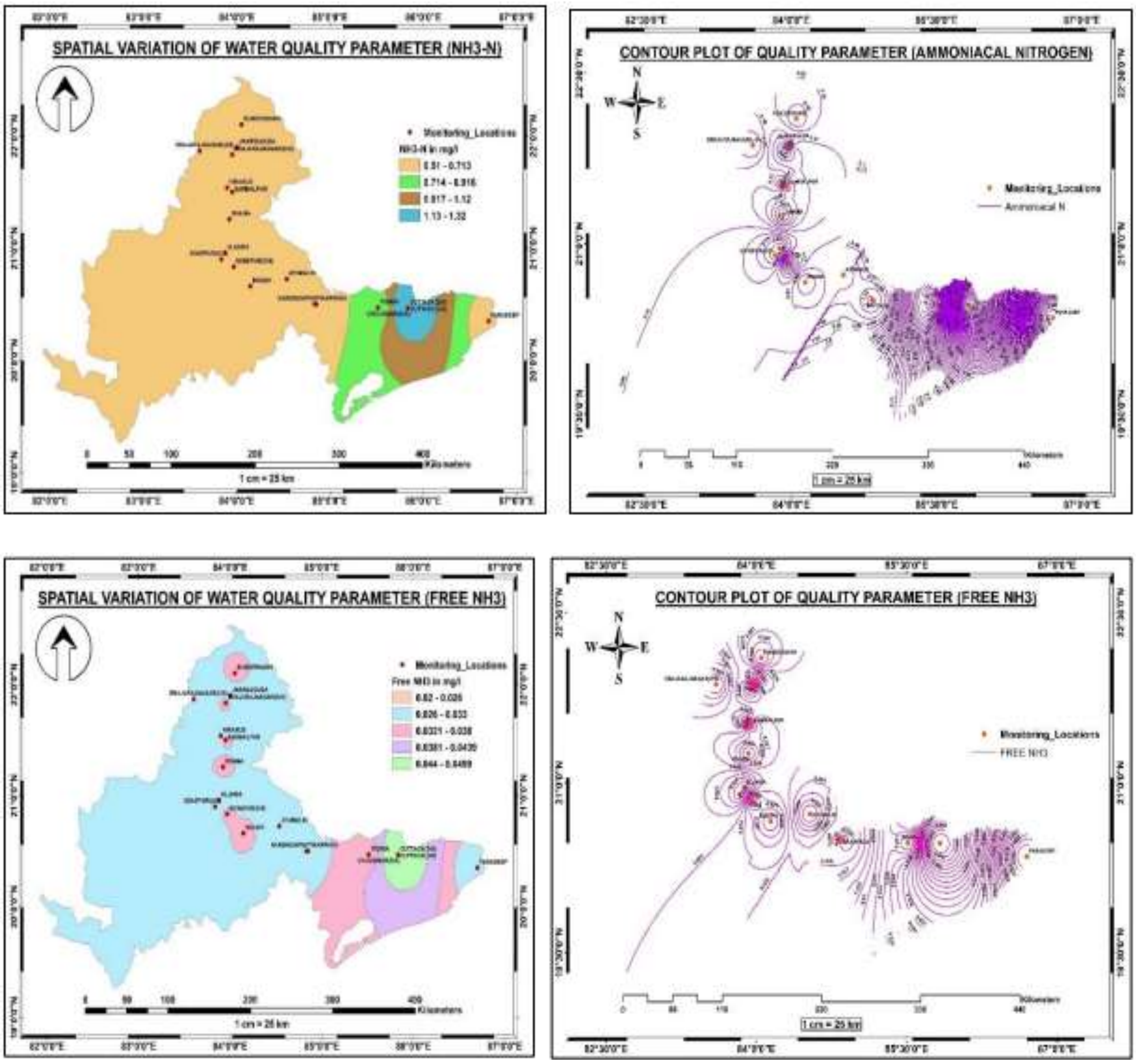

Figure 9. Spatial variation and contour map diagram showing the concentration of NH3-N and Free NH3

Total Kjedahl Nitrogen (TKN): For stagnant water, TKN levels are particularly essential since greater TKN values indicate a risk of eutrophication or a higher level of ammonia in the water, which can be harmful. TKN levels range from 3.28 to 11.80 mg/l, with a mean of 5.73 mg/l. The readings are higher than the (CPCB, 2012) acceptable limit of 3 mg/l. As a result, all sampling locations are affected by organic contamination, lowering the water quality. Geospatial maps represent geographical changes and contour plots (Figure 10).

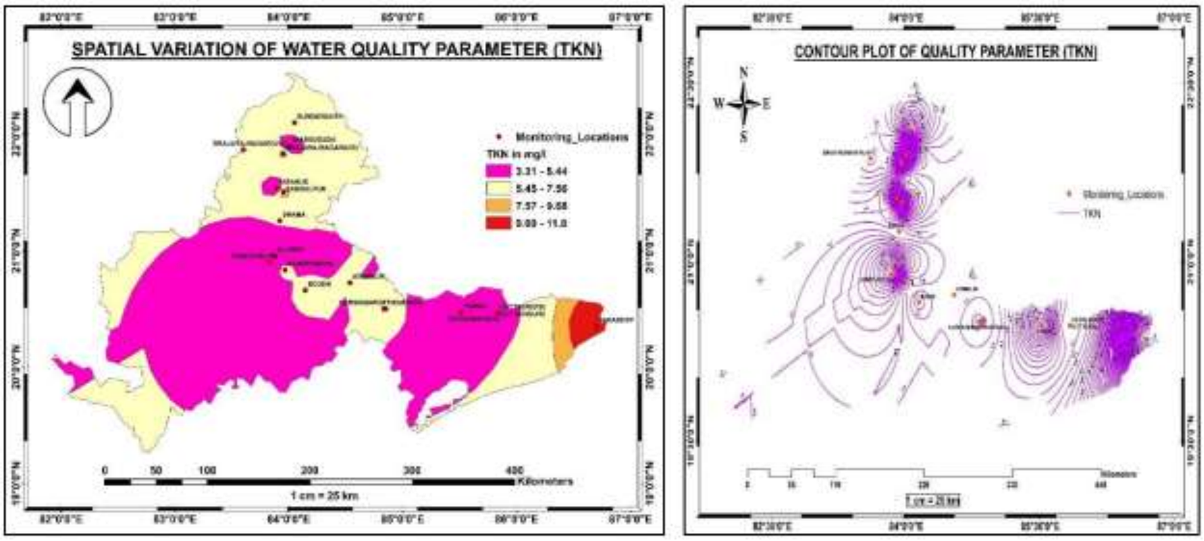

Figure 10. Spatial variation and contour map diagram showing the concentration of TKN

Electrical Conductivity (EC): The potential of a substance to convey an electrical current is measured by its electrical properties in water. The existence of ions, their overall abundance, mobility, and measurement temperature all affect this capacity (Prosser et al., 2001). Since conductivity yields a reasonable estimate of the number of dissolved components in water (Muhammad et al., 2004), it is an important aspect of water quality measurement. The EC value ranged from 138.10 to 7779.35 s/cm in this investigation, with a mean of 580.86 s/cm. The highest permitted conductivity level is 1000 s/cm, according to the (USEPA 2004). The conductivity limit set by the WHO is 400–1200 s/cm. As a result, with the exception of Paradeep, all of the investigated samples' EC values were within the permitted limit for drinking. Lower EC values were reported by (B. A. Meseret, 2012] (496 s/cm) and A. Gebreyesus et al 2013] (3700 s/cm). Except for paradeep, which was rated as bad, all samples taken were rated as excellent (EC (S/cm): 100–250) based on Richard's classification (Richards, 2013). Geographic changes and contour plots are depicted on geospatial maps (Figure 11).

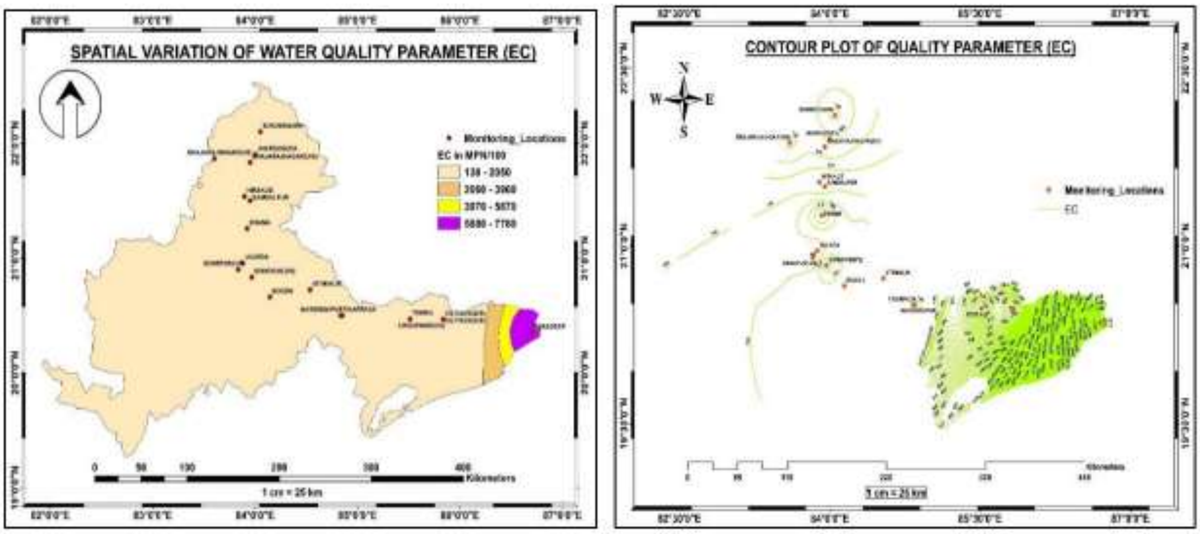

Figure 11. Spatial variation and contour map diagram showing the concentration of EC

Total Dissolved Solids (TDS): According to (Talling 2009), urban and agricultural outflow, as well as leaching of soil contamination, are the main sources of TDS. The concentrations of total dissolved solids in this sample ranged from 82.30 to 13230.60 mg/l on average, with an average of 803.69 mg/l. According to rules (WHO, 1997), the most acceptable and highest allowable amounts are 500 mg/l and 1000 mg/l, respectively. Consequently, with the exception of Paradeep, all total dissolved solids readings in the examined area were within the expected limits for drinking. As a result, the low TDS levels in the water from the chosen sites indicated that it was being used for drinking and other domestic purposes. Geographic changes and contour plots are depicted on geospatial maps (Figure 12).

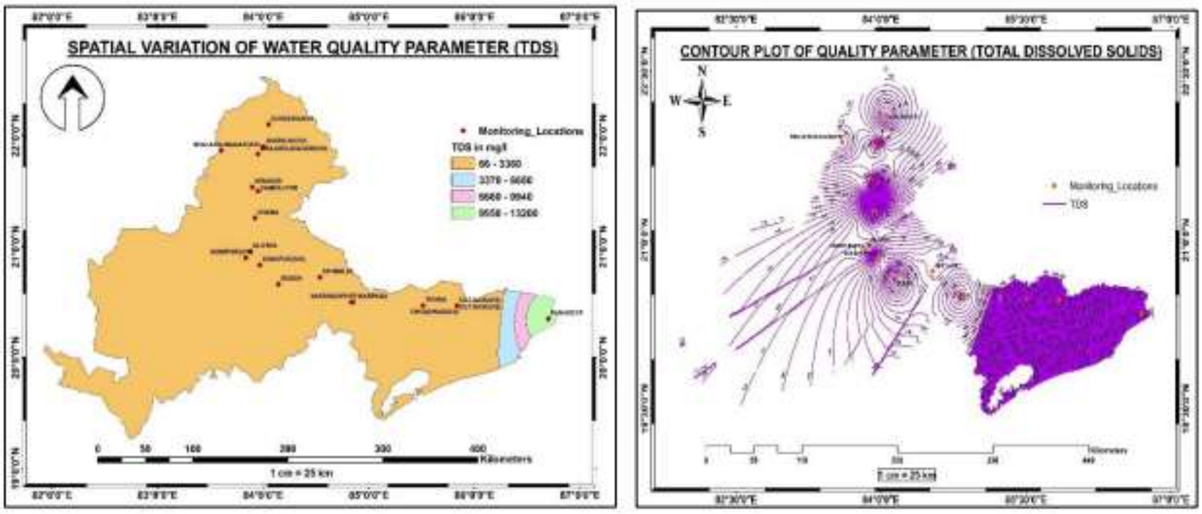

Figure 12 . Spatial variation and contour map diagram showing the concentration of TDS

Boron: Although boron is necessary for plant growth when it exceeds 2 mg/l in irrigation water, it becomes hazardous to most field crops, disrupting the plant's metabolic functions. Its concentrations range from 0.03 to 0.55 mg/l, with an average of 0.08 mg/l. The results should be less than 2 mg/l, according to CPCB 2012. All of the samples are within the acceptable ranges and fall into the Class E category. The spatial map is depicted in (Figure. 13).

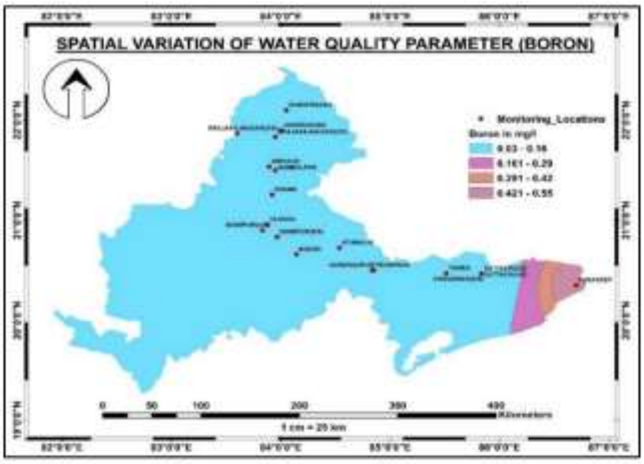

Figure 13. Spatial variation diagram showing the concentration of Boron

Sodium Absorption Ratio (SAR): SAR is a factor that quantifies the sodium risks of water and is used to assess the number of sodium ions contained in soils. It is also known as salt content or alkali danger, and it is a crucial metric for measuring the adequacy of irrigation water (Srinivasamoorthy et al. 2014). Water is categorized into four classifications based on SAR values: SAR = 10 indicates excellent (sodium hazard class S-I), SAR = 10 – 18 signifies well (sodium threat class S – II), SAR = 19 – 26 depicts doubtful/fair poor (sodium threat class S – III), and SAR > 26 is unsuitable (sodium threat class S – IV) (Wilcox 1955; Richards 1954). S – I is used on any type of soil and for every type of crop, S – II employed in a permeability-rich coarse-grained or organic soil, S – III depicts that it'll be damaging to all soils, and it'll necessitate adequate drainage and a lot of gypsum leaching, S – IV indicates Inappropriate (Very high sodium water). SAR values classify the fluids for irrigation reasons (Richards 1954). With a mean of 1.34 mg/l, the SAR value ranges from 0.41 to 16.59 mg/l. According to Richard's categorization, all R1 to R19 samples are "good (sodium threat class S-I)" for irrigation (Sundaray et al., 2009) and fall into the Class E group. Geospatial map has shown spatial changes and contour plot of SAR results for both seasons along sample stations (Figure 14).

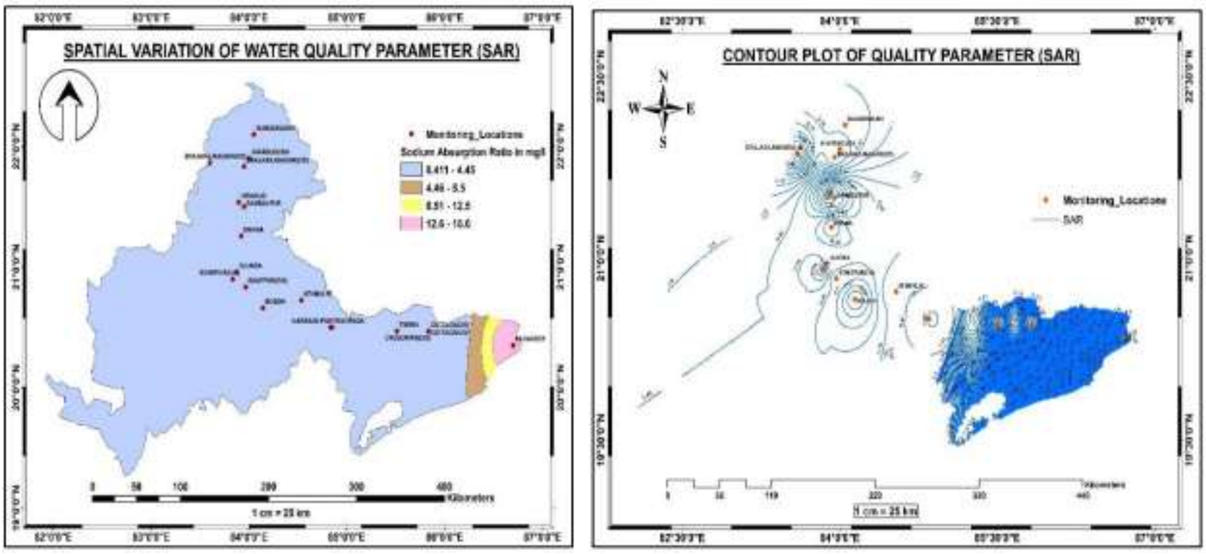

Figure 14. Spatial variation and contour map diagram showing the concentration of SAR

Total Hardness (TH): The dissolved calcium and magnesium carbonates in surface water are measured by total hardness (TH). Although the WHO recommends a maximum hardness of 600 mg/l, the overall perception is that 300 mg/l is sufficient. According to (WHO 1996; WHO 1997; WHO 2003; WHO 2004; WHO 2005; WHO 2006; WHO 2008; WHO 2011) categorization, 0 – 75 suggests moderate, 75 – 150 indicates fairly hard, 150 – 300 denotes strong hard, and > 300 implies very strong hard. The most ideal limit is 100 mg/l. In the research area TH spans from 51.20 to 2195.20 mg/l, with an average of 186.45 mg/l. All values are just under 300 mg/l, with the exception of subsurface, making it suitable for all activities in all sampling locations. As a result of the data, it may be deduced that hardness classification is "strong hard." Geospatial maps represent geographic variations and contour diagrams (Figure. 15).

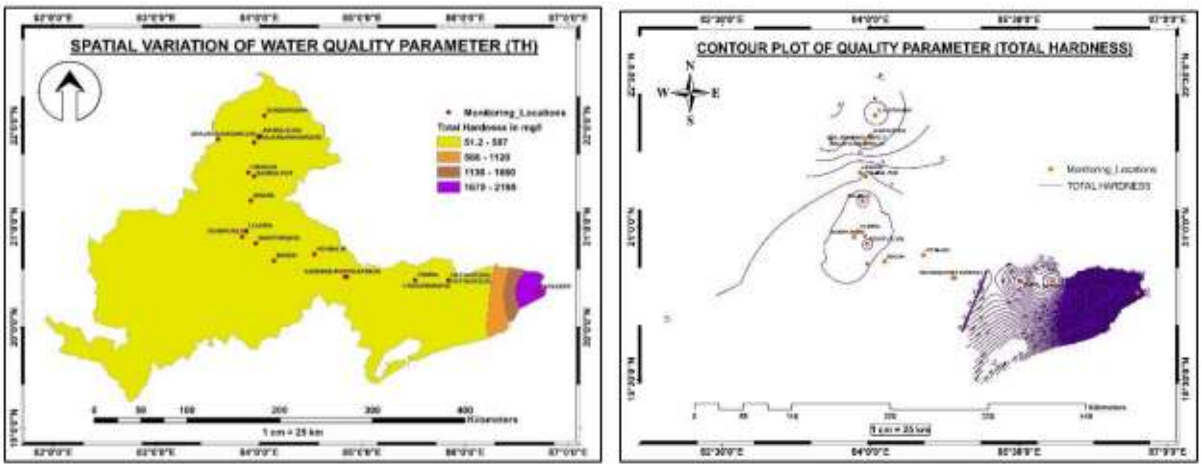

Figure 15. Spatial variation and contour map diagram showing the concentration of TH

Chloride (Cl-): Another ion typically seen in irrigation waters is chloride. It is necessary for crops at low concentrations, but at greater levels, it can be hazardous to sensitive crops. Its toxicity manifests itself in the form of leaf burns or leaf tissue death. In most cases, plant injury begins at the leaf tips and spreads back down the edges as severity grows. Early leaf drop or defoliation happens in extreme circumstances. Chloride in irrigation water is the most common source of toxicity. The maximum amount of chloride allowed in drinking water is 250 mg/L (1000 mg/L if no other source is available) (BIS 2012). Surface water samples in the research area had chloride concentrations ranging from 9.65 to 4904.91 mg/l, with an average of 269.23 mg/l. Except for Paradeep, all sampling locations are within limits. Geospatial maps represent geographic variations and contour diagrams (Figure. 16).

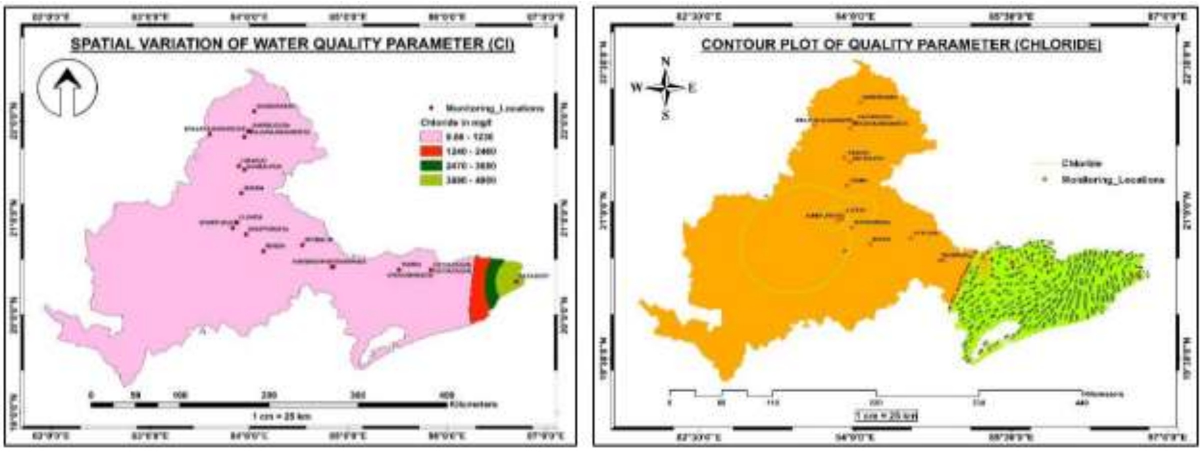

Figure 16. Spatial variation and contour map diagram showing the concentration of Cl

Sulfate ($SO4^{2-}$): Sulfate is a common ion in the earth's crust, with concentrations ranging from a few milligrams per liter to a few milligrams per liter in water (Bartram et al., 1996). Anions are a sort of ion that can be found in practically all types of water. (WHO, 2008) drinking water quality criteria indicate an $SO4^{2-}$ threshold level of 250 mg/l. Sulphate levels in drinking water must not exceed 200 mg/L (400 mg/L if no other source is available) (BIS 2012). The sulphate concentrations in this study's data ranged from 4.97 to 376.07 mg/l, which is higher than Asa and Kristin's greatest sulphate quantity reported for drinking water (3.374 mg/l) (Asa and Kristin, 2013). Only one of the samples in this investigation, paradeep, showed levels above the permitted limit. The approved level, according to (USEPA, 2004), should be less than 250 mg/l; thus, the analyzed samples retrieved were below the acceptable drinking threshold. Geospatial maps depict geographic differences and contour diagrams (Figure. 17).

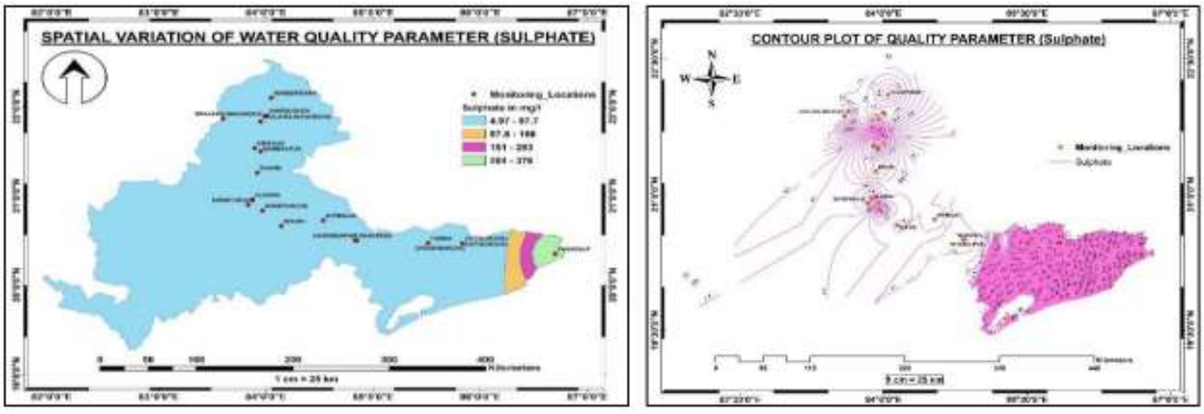

Figure 17. Spatial variation and contour map diagram showing the concentration of $SO4^{2-}$

Fluoride (F^-): Fluoride levels in drinking water of 0.7–1.2 mg/l help avoid gum disease. If the dose is exceedingly high (more than 1.5 mg/l), tooth discoloration or blotchiness may develop. Fluoride concentrations in water samples ranged from 0.26 mg/l to 1 mg/l in this study, with an average of 0.37 mg/l. Fluoride levels in all tested water samples were below allowed limits, according to WHO and Ethiopian drinking water quality requirements. With the exception of Choudwar D/s, which had a fluoride level of 1 mg/l, the readings were lower than those reported earlier by (Gurmessa, 2015; Gebreyesus, 2013) (0.9–2.6 mg/l). Fluoride added to water sources at concentrations greater than 0.6 mg/l F has been proven to lower the risk of infection in growing children, with the largest benefits appearing at 1.0 mg/l. The Forum on Fluoridation (2002) advised lowering fluoride levels in drinking water to a range of 0.6–0.8 mg/l, with a target of 0.7 mg/l, in light of recent worldwide and Irish research revealing an increase in the prevalence of dental fluorosis. Geospatial maps depict geographic differences and contour diagrams (Figure 18).

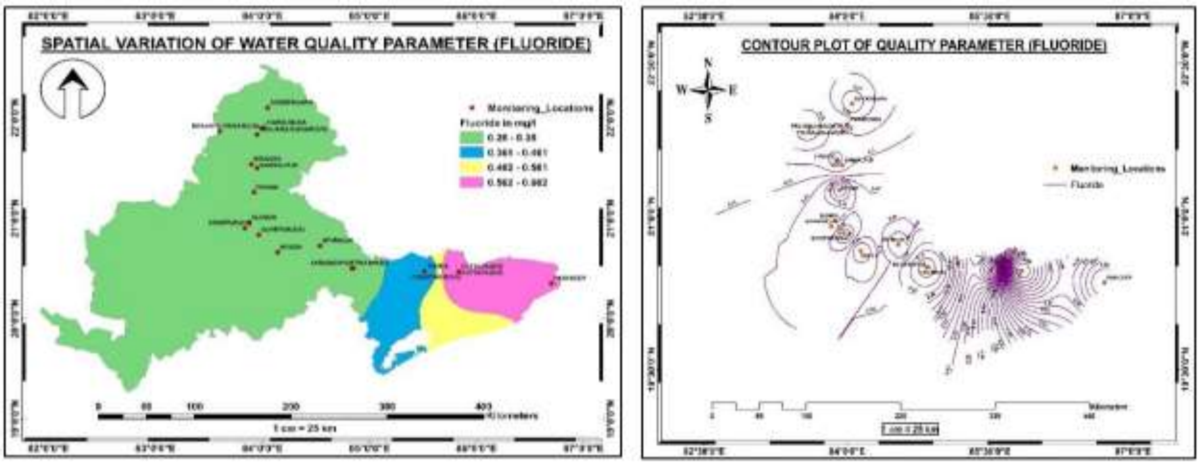

Figure 18. Spatial variation and contour map diagram showing the concentration of F

Nitrate: Nitrate is the most common nitrogen source for most plants; it is commonly employed as a fertilizer. Its concentrations in surface water are typically modest, although they can rise due to agricultural land leach or runoff, as well as interference from human and animal wastes (WHO 2004). The quantities of nitrate in the samples analyzed ranged from 1.29 to 2.7 mg/l, with a mean of 2 mg/l, well below the 50 mg/l maximum allowed level set by the Compulsory Ethiopian Standard (CES) (CES, 2013) and the World Health Organization (WHO). This demonstrated that the NO3 concentration in the water in the study area is safe for drinking and other household purposes. Furthermore, the majority of the water samples analyzed contained lower levels of nitrate than (Meseret et al., 2012; Gebreyesus, 2013) i.e. (3–12.76 mg/l) and (1.33–3.42 mg/l) reported earlier (Gebreyesus, 2013). The highest nitrate limit in drinking water that the (WHO 1993) considers acceptable is 45 mg/L. All of the sampling locations in our study are within the parameters, making them safe to drink and use for cultivation.. Nitrates in drinking water are harmful, causing blue baby disease and methaemoglobinemia in children, as well as gastric carcinomas. Geographic variations and contour diagrams are represented by geospatial maps (Figure 19).

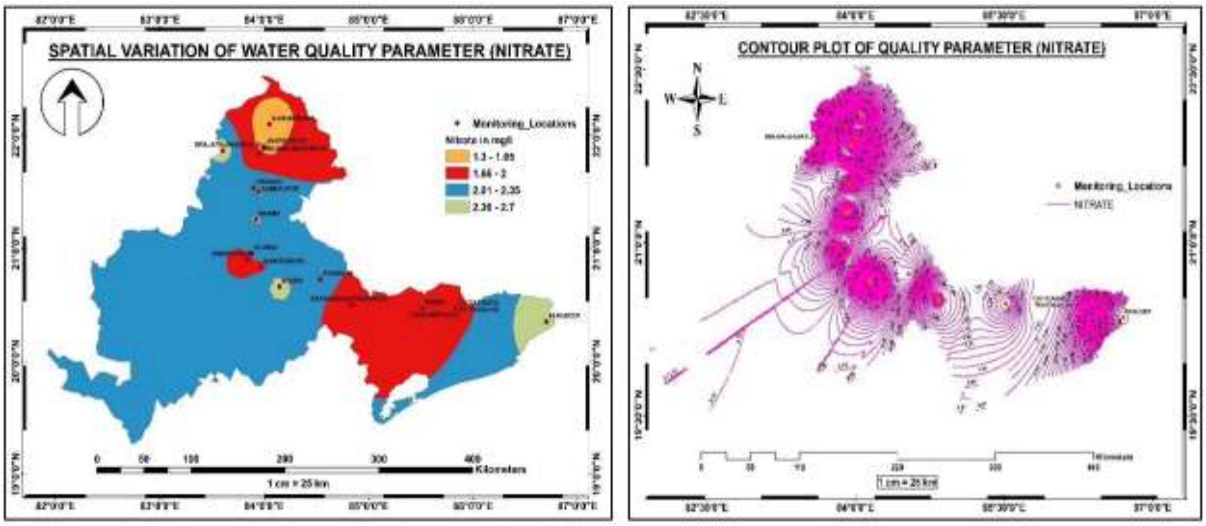

Figure 19. Spatial variation and contour map diagram showing the concentration of Nitrate

Iron (Fe): It is a vital component of the human body that is necessary physiologically in a variety of ways (Moore 1973). Despite the fact that iron poses no health risks, it is still considered an inconvenience when ingested in big amounts (Dart 1974). It discolors clothing and kitchen appliances. It is unsuited for food and beverage processing, as well as dyeing and bleaching. The maximum acceptable value of iron in drinkable water is 0.3 mg/l, while the maximum allowable value is 1.0 mg/l (Sharma and Chawla 1977). According to the (WHO, 2004), levels up to 2 mg/l (ten times the normal value) do not pose a health risk. Water with a color less than 2 mg/l but greater than the nominal value (0.2 mg/l) can turn brown, muddy, or deposit sediments on clothes washed in it or food cooked in it. Levels in the samples tested ranged from 0.60 to 2.61 mg/l, with just an average of 1.31 mg/l. The iron levels in the river water were higher than the EPA's benchmark value of 0.2 mg/l, and they were outside the WHO and CES's permitted threshold of 0.3 mg/l, according to this report. A somewhat higher iron concentration could be due to the type of the aquifer delivering water (Shigut, 2017). The taste of water with an iron content greater than 0.3 mg/l might be unpleasant. Chronic iron overload is caused by haemochromatosis, a congenital disorder that causes increased iron absorption as well as disorders that require repeated transfusions (WHO, 1996). Iron elimination plants should be established before drinking at stations like Paradeep. Geographic variations and contour diagrams are represented by geospatial maps (Figure 20).

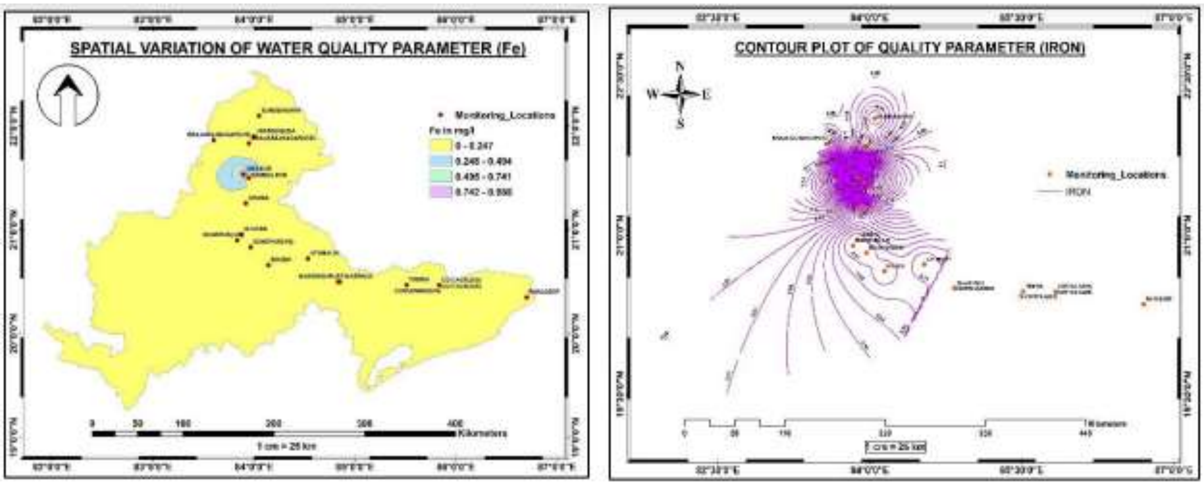

Figure 20. Spatial variation and contour map diagram showing the concentration of Fe

PEARSON'S CORRELATION ANALYSIS

Pearson's correlation model is a great mathematical formalism for displaying the level of focus between two factors (Belkhiri et al., 2011). In fact, the correlation coefficient is performed to measure the interrelation and strength of linkage amongst variables. At a meaningful scale of p less than 0.05, a correlation coefficient value of +1 demonstrates a perfect association between the factors, -1 indicates a better relationship among variables, but the data points vary inverse proportion (Mudgal et al., 2009), and a zero score shows no relationship among variables (Mudgal et al., 2009). In general, reliability coefficients greater than 0.7 are thought to be highly associated, whereas values between 0.5 and 0.7 are thought to be moderately associated. As shown in the diagram, it clearly depicts the interdependence of factors (Table 4).

PARAMETERS	PH	DO	BOD	TC	TSS	TOTAL ALKALINITY	COD	NH3-N	FREE AMMONIA	TKN	EC	TDS	B	SAR	TH	CL	$S0_4^{2-}$	F	NO_3	FE
PH	1.00																			
DO	0.05	1.00																		
BOD	0.49	-0.59	1.00																	
TC	0.36	-0.77	0.77	1.00																
TSS	-0.23	-0.54	0.04	0.25	1.00															
TOTAL ALKALINITY	0.45	-0.15	0.34	0.14	-0.04	1.00														
COD	0.57	-0.39	0.66	0.62	0.17	0.50	1.00													
NH3-N	0.29	0.13	0.15	0.12	0.07	0.06	0.72	1.00												
FREE AMMONIA	0.53	0.08	0.39	0.31	0.04	0.02	0.75	0.88	1.00											
TKN	-0.18	-0.54	0.13	0.15	0.73	0.23	0.16	-0.14	-0.10	1.00										
EC	0.05	-0.42	0.03	0.08	0.74	0.46	0.21	-0.06	-0.15	0.71	1.00									
TDS	0.05	-0.42	0.02	0.08	0.74	0.45	0.20	-0.07	-0.16	0.71	1.00	1.00								
B	0.10	-0.41	0.07	0.11	0.71	0.48	0.33	0.10	-0.01	0.67	0.98	0.97	1.00							
SAR	0.16	0.14	0.02	0.03	0.14	0.12	0.67	0.97	0.78	-0.08	0.04	0.03	0.20	1.00						
TH	0.06	-0.42	0.03	0.08	0.74	0.46	0.22	-0.05	-0.14	0.70	1.00	1.00	0.98	0.05	1.00					
CL_2	0.04	-0.42	0.02	0.08	0.75	0.45	0.20	-0.06	-0.16	0.71	1.00	1.00	0.98	0.04	1.00	1.00				
$S0_4^{2-}$	0.06	-0.42	0.03	0.08	0.74	0.45	0.21	-0.05	-0.15	0.71	1.00	1.00	0.98	0.04	1.00	1.00	1.00			
F	0.28	0.01	0.12	0.06	0.30	0.36	0.74	0.88	0.70	0.14	0.37	0.36	0.51	0.93	0.38	0.37	0.38	1.00		
NO_3	-0.10	-0.26	0.15	-0.08	0.08	0.52	0.25	0.09	-0.05	0.47	0.42	0.41	0.47	0.18	0.42	0.41	0.41	0.33	1.00	
FE	0.19	-0.20	-0.05	0.14	0.75	0.02	0.17	0.16	0.24	0.54	0.68	0.68	0.69	0.17	0.68	0.68	0.68	0.36	0.01	1.00

Table 4. Pearson correlation matrix of water parameters over a period of (2000-2018)

The data model was developed combining the analysis findings of twenty parameters (PH, DO, BOD, TC, TSS, Total Alkalinity (TA), COD, NH3-N, Free NH3, TKN, EC, TDS, B, SAR, TH, Cl-, SO42-, F-, NO3-, Fe), the most suitable water quality indices to designate any co-variation (2000-2018). (Table 4). The results demonstrate that there are some very high positive correlations between the factors like BOD-TC, TSS=(TKN, EC, TDS, B, TH, Cl-, SO42-, Fe), COD-(NH3-N, Free NH3), NH3-N--(Free NH3, SAR, F), Free NH3--(SAR, F), TKN--(EC, TDS, TH, Cl-, SO42-), EC--(TDS, TH, Cl-, SO42-), TDS--(B, TH, Cl-, SO42-), B--(TH, Cl-, SO42-), SAR--F, TH--(Cl-, SO42-), Cl---SO42-, strong negative correlation between DO---TC, moderately positive correlation between PH-COD, PH-Free NH3, BOD-COD, TCCOD, TA-COD, COD-SAR, TKN-B, EC-Fe, TDS-Fe, B-F, Fe, TH-Fe, CL-Fe, SO4-Fe and moderately negative correlation between DO--(BOD, TSS,TKN). Except for TSS, COD, Free NH3, TKN, and NO3-, PH has weak and extremely weak positive associations with all other metrics. The results clearly show that values less than 0.5 are weakly linked with the other variables, implying that parameters vary directly proportional. Some of the characteristics were found to be quite negative, indicating that the changes are inversely proportional. In general, relations between combinations of water quality parameter levels show that chloride, sulfate, TKN, Free NH3, and NH3-N values strongly correlate with contaminant indicators, including nutrients and trace metals. This obviously indicates that manmade pollution in the study region has caused these nutrients and trace metals like (Fe) to have excessive amounts.

CALCULATION OF THE WQI: The Water Quality Index (WQI) is a ranking that takes into account the impact of a number of different water quality criteria (Sahu and Sikdar, 2008). It's a handy tool for expressing water quality in a clear and simple manner by merging multiple water quality parameters into a single-valued unit with a lower number of values (Sener et al., 2017; Wang et al., 2017). A unique sort of quantitative averaged function is used to convert the raw analytical results of numerous water quality parameters with varying values and units into a numerical result (Cude 2001). Numerous WQIs were proposed by some academics and countries based on different water quality measures, and the indexes are now used all over the world. (Horton 1965) proposed the WQI, which was initially used to examine the quality of drinking water (Brown et al. 1970; Misaghi et al. 2017; Kumar et al. 2018). It has been estimated using (Pesce and Wunderlin's 2000) approach and is represented by eq. (A).

$$WQI_{sub} = k\frac{\sum_{i=1}^{n} C_i \cdot P_i}{\sum_{i=1}^{n} P_i} \longrightarrow \boxed{A}$$

Where the standardized value allocated to each component is Ci, while the weightage of the parameter is Pi, K is a discretionary constant that could be anywhere between 1.0 and 0.25, relying on the researcher's visual examination of river toxicity. A score of 1.0 is assigned to water with no obvious contamination, while a value of 0.25 is assigned to substantially contaminated water. These findings are then examined to the (BIS 10500, 2012) and World Health Organization (WHO 2006) standard guideline values. WQI was calculated to determine the acceptability of water for drinking and biotic ecosystems (Sweta et al., 2011; Boateng et al., 2016). (Table 5). Total 20 parameters were examined for WQI calculation, including PH, DO, BOD, TC, TSS, Total Alkalinity (TA), COD, NH3-N, Free NH3, TKN, EC, TDS, B, SAR, TH, Cl-, SO42-, F-, NO3-, and Fe, and the desired threshold of each characteristic was employed according to BIS guideline.

WQI LEVEL	WATER QUALITY RATING
0-25	EXCELLENT
26-50	GOOD
51-75	POOR
76-100	VERY POOR
>100	UNFIT FOR DRINKING PURPOSES

Table 5. Water Quality Ratings Using Various Water Quality Index Methodologies (Shweta et al., 2013; Ali et al., 2018; Tyagi et al., 2013; Alsaqqar et al., 2015)

SAMPLING SYMBOL	MONITORING STATIONS	WATER QUALITY INDEX(WQI)	WATER QUALITY RATING(WQR)
R1	HIRAKUD	28.28	GOOD
R2	SAMBALPUR	34.59	GOOD
R3	SONEPUR(U/S)	28.58	GOOD
R4	SONEPUR(D/S)	34.42	GOOD
R5	TIKARPADA	32.86	GOOD
R6	NARSINGHPUR	32.39	GOOD
R7	CUTTACK(U/S)	33.61	GOOD
R8	CUTTACK(D/S)	52.00	POOR
R9	PARADEEP	60.10	POOR
R10	SUNDERGARH	34.63	GOOD
R11	JHARSUGUDA	28.32	GOOD
R12	BRAJARAJNAGAR(U/S)	31.40	GOOD
R13	BRAJARAJNAGAR(D/S)	34.44	GOOD
R14	DHAMA	33.97	GOOD
R15	ULUNDA	28.68	GOOD
R16	BOUDH	32.68	GOOD
R17	ATHMALIK	33.69	GOOD
R18	TIGIRIA	34.75	GOOD
R19	CHOUDWAR(D/S)(BIRUPA)	32.6	GOOD

Table 6. Water Quality Index (WQI) along Mahanadi River

The Mahanadi River's water identification is made for drinking purposes in this investigation. The WQI protocol was used to examine the river's water quality. For each sample site, PH, DO, BOD, TC, TSS, Total Alkalinity (TA), COD, NH3-N, Free NH3, TKN, EC, TDS, B, SAR, TH, Cl-, SO42-, F-, NO3-, and Fe were used to calculate the WQI value. For performance analysis, the findings of all 19 sampling points' analyses were used. The World Health Agency's (WHO, 2008) limits were also included in the computations. The distributed maps of the water quality measures, as well as the resulting WQI maps, are created using Geospatial System (GIS) approach. To obtain WQI score, the weights for each water quality indicator were determined based on their respective weights in the sheer functionality of water and drinking. (Table 6) shows that the computed WQI scores range from 28.28 to 60.10, with an average of 34.84. WQI readings are divided into five categories as per the grading of water quality (Jonnalagada and Mhere 2001), with 0-25 indicating excellent, 26-50 indicating well (good water), 51-75 indicating poor, 76-100 indicating very poor, and > 100 indicating unsafe for drinking. Furthermore, the Mahanadi River's water quality is in the Good to Poor category for drinking, owing to the intake of municipal wastewater pollutants, as well as fertilizers discharged along the river's bed. The water quality in R1 to R7 and R10 to R19 sites is good; however, the water quality at Paradeep and Cuttack D/s is bad. It leads to wastewater discharge, leather products, and marble manufacturers. Because it is located downstream, it is assumed to receive urban effluents, causing the water quality to worsen and endangering human health. The water appears to be drain water from a city. The water is practically still here, and pollutants have not dispersed. In terms of WQI, all of the stations perform well quantitatively, and this is due to massive pollutants being diffused and washed away by intense rainwater.

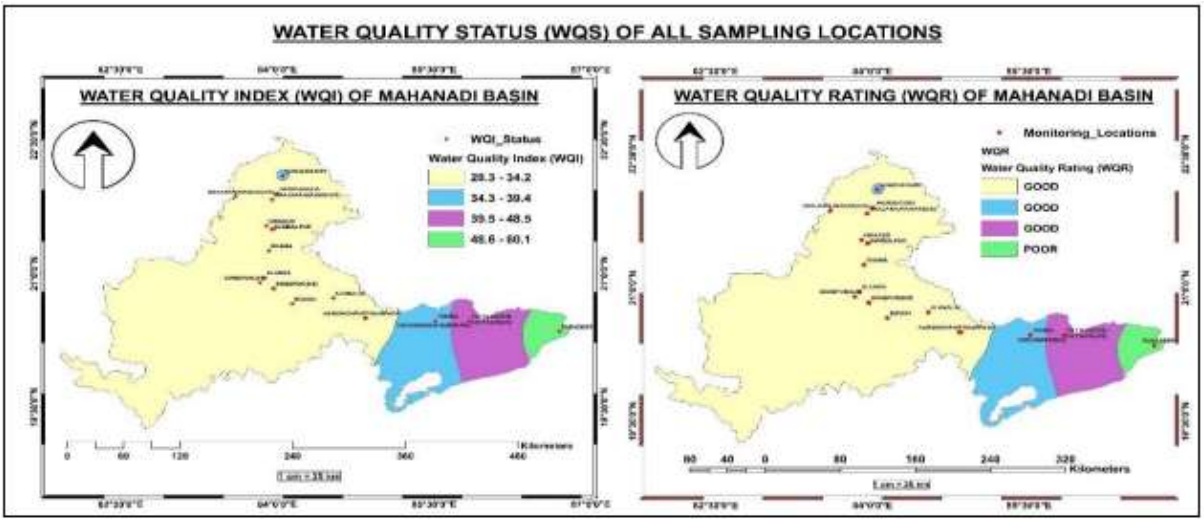

Figure 21. Map of Water Quality Index (WQI) and Water Quality Rating (WQR)

NEMEROW'S POLLUTION INDEX (NPI) ANALYSIS

It is the most basic approach to determine the water quality index. The NPI for river water was computed by multiplying the total amount of each element in surface water by its average background concentration value (Mohan et al., 2007; Swati et al., 2015).

C.F. = Cn/ Sn ------------- (I)

Where Cn denotes the percentage of the parameter whose identification is indicated by n, and Sn denotes the nth parameter's predefined allowable limit. Mahanadi sampling stations were identified as a result of the appraisal. In light of Eq. (I), NPI > 1 can be classified as contamination, implying that it is present in excess quantity or quantity and has the ability to trap water bodies, whereas NPI =1 can be classified as non-contaminated and considered safe for consumption. The values obtained of the various types of NPIs for all of the Mahanadi basin's 20 elements are shown in (Table 7)

STATIONS/PARAMETERS	HIRAKUD	SAMBALPUR	SONEPUR(U/S)	SONEPUR(D/S)	TIKARPADA	NARSINGHPUR	CUTTACK(U/S)	CUTTACK(D/S)	PARADEEP	SUNDERGARH	JHARSUGUDA	BRAJARAJNAGAR(U/S)	BRAJARAJNAGAR(D/S)	DHAMA	ULUNDA	BOUDH	ATHMALIK	TIGIRIA	CHOUDWAR(D/S)(BIRUPA)
PH	0.917	0.916	0.919	0.926	0.922	0.924	0.932	0.929	0.921	0.912	0.910	0.910	0.912	0.925	0.918	0.918	0.919	0.927	0.924
DO	1.275	1.269	1.297	1.297	1.292	1.291	1.306	1.210	1.240	1.295	1.283	1.285	1.254	1.288	1.288	1.277	1.287	1.300	1.298
BOD	0.210	0.262	0.222	0.320	0.210	0.218	0.248	0.480	0.278	0.215	0.219	0.214	0.300	0.381	0.268	0.278	0.269	0.299	0.276
TC	0.403	0.800	0.276	0.636	0.502	0.766	0.472	8.506	1.602	0.440	0.542	0.358	0.612	0.684	0.242	0.375	0.722	0.465	1.171
TSS	0.364	0.307	0.311	0.326	0.381	0.328	0.342	0.466	0.749	0.563	0.423	0.412	0.516	0.299	0.286	0.355	0.304	0.315	0.425
TOTAL ALKALINITY	0.409	0.417	0.445	0.490	0.434	0.462	0.392	0.437	0.505	0.352	0.387	0.387	0.381	0.485	0.441	0.435	0.458	0.389	0.442
COD	0.291	0.396	0.319	0.450	0.330	0.345	0.338	0.661	0.484	0.225	0.247	0.243	0.323	0.442	0.313	0.316	0.343	0.329	0.729
NH3-N	0.268	0.306	0.256	0.312	0.269	0.279	0.360	0.356	0.290	0.271	0.278	0.272	0.311	0.310	0.255	0.265	0.275	0.360	0.963
FREE AMMONIA	0.012	0.013	0.010	0.016	0.014	0.012	0.017	0.019	0.012	0.016	0.010	0.011	0.013	0.016	0.010	0.014	0.012	0.017	0.028
TKN	0.746	1.680	0.824	1.157	1.173	1.061	0.794	1.209	2.359	1.502	0.656	1.247	1.598	1.090	0.778	1.130	1.090	0.768	0.901
EC	0.077	0.080	0.080	0.096	0.085	0.084	0.079	0.085	3.457	0.061	0.065	0.066	0.070	0.097	0.083	0.088	0.085	0.079	0.088
TDS	4.215	3.165	4.658	5.235	5.562	5.077	4.888	5.054	508.869	3.512	3.742	3.735	4.127	5.276	4.710	5.531	5.070	4.870	0.018
B	0.018	0.024	0.019	0.021	0.026	0.019	0.016	0.032	0.277	0.014	0.015	0.015	0.017	0.015	0.031	0.048	0.031	0.039	0.065
SAR	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.017	0.001	0.001	0.001	0.001	0.001	0.000	0.001	0.000	0.001	0.174
TH	0.245	0.255	0.272	0.288	0.254	0.255	0.248	0.274	7.317	0.171	0.186	0.185	0.195	0.289	0.274	0.257	0.253	0.246	0.344
CL	0.039	0.043	0.062	0.045	0.039	0.041	0.045	0.053	19.620	0.041	0.043	0.041	0.044	0.043	0.060	0.043	0.042	0.044	0.076
SO_4^{2-}	0.037	0.038	0.032	0.038	0.035	0.035	0.046	0.042	1.880	0.025	0.027	0.025	0.025	0.036	0.032	0.034	0.034	0.043	0.046
F	0.279	0.301	0.317	0.361	0.303	0.306	0.322	0.320	0.630	0.261	0.280	0.272	0.297	0.362	0.324	0.302	0.349	0.363	1.005
NO_3	0.045	0.053	0.039	0.044	0.037	0.044	0.029	0.039	0.060	0.031	0.029	0.056	0.044	0.053	0.048	0.056	0.048	0.041	0.050
FE	0.332	0.311	0.218	0.342	0.485	0.480	0.563	0.459	0.870	0.639	0.408	0.422	0.355	0.311	0.199	0.443	0.447	0.527	0.508

Table 7. Pollution Index (PI) values of Mahanadi River over a period of (2000-2018)

The article has demonstrated that factors with NPI > 1 are contaminated, whereas parameters with NPI 1 are noncontaminated. DO is the most contributing characteristic in all sampling locations, promoting a higher pollution index and, as a result, leading to a major pollutant. Attributed to the prevalence of industry, oil refineries, and paper pulp manufacture, TC is a significant contamination source for Paradeep, Cuttack D/s, and Choudwar, deteriorating the purity and potentially transmitting to man through drinking and bathing. It also occurs as a result of densely populated and productive farming activity. In all samples collected except Hirakud, Sonepur, Cuttack U/s, Jharsuguda, Tigiria, and Choudwar D/s, TKN contributes more pollutants, whereas, for variable TDS, NPI > 1 is present in all locations except Chowdwar owing to the combination of aluminium and power plants at Hirakud dam, charge chrome industry, and power plant at Choudwar D/s. Furthermore, the effluent from a paper mill in Jagatpur and two existing fertiliser factories in Paradeep is dumped directly into the river. The concentrations of TH, chloride, and sulphate are larger in paradeep and fluoride in Choudwar D/s, implying that municipal sewage wastes provide the majority of the elements found in the riverbed. It can also be generated by man-made and home sewage issues. There are also various steel, aluminum, electricity, sponge iron, and other businesses in the area upstream of Hirakud Dam and surrounding the dam, according to this study. Liquid waste and runoff from quarrying, livestock, enterprises, and agriculture have altered the physiochemical attributes of river water.

STATIONS SYMBOL	STATIONS	CLASS (Table 3)	PARAMETERS RESPONSIBLE FOR DOWNGRADING THE WATER QUALITY
R1	HIRAKUD	C/D/E	[TC, TKN]
R2	SAMBALPUR	C/D/E	[BOD, TC, TKN]
R3	SONEPUR(U/S)	C/D/E	[TKN]
R4	SONEPUR(D/S)	C/D/E	[TC]
R5	TIKARPADA	C/D/E	[TC, TKN]
R6	NARSINGHPUR	C/D/E	[TC, TKN]
R7	CUTTACK(U/S)	C/D/E	[TC, TKN]
R8	CUTTACK(D/S)	C/D/E	[BOD, TC, TKN]
R9	PARADEEP	NOT CONFORM TO ANY CLASS	[EC, TKN, TDS, TH, CL, SULPHATE]
R10	SUNDERGARH	C/D/E	[TC,TKN]
R11	JHARSUGUDA	C/D/E	[TC, TKN]
R12	BRAJARAJNAGAR(U/S)	C/D/E	[TC, TKN]
R13	BRAJARAJNAGAR(D/S)	C/D/E	[TC, TKN]
R14	DHAMA	C/D/E	[TC]
R15	ULUNDA	C/D/E	[TC]
R16	BOUDH	C/D/E	[TC]
R17	ATHMALIK	C/D/E	[TC]
R18	TIGIRIA	C/D/E	[TC]
R19	CHOUDWAR(D/S)(BIRUPA)	C/D/E	[TC, TKN]

Table 8. Class and parameters responsible for downgrading water quality along with sampling sites

The results revealed probable pollutants as well as the water quality class (Table 8). This degradation is the result of a combination of natural and manmade causes. The discharge of untreated urban wastewater into surface water systems is the most significant cause of anthropogenic contamination. Agriculture, mining, land drainage, and the release of effluents from businesses and oil refineries are among non-point sources that contribute significantly. This scenario is causing the natural architecture of river systems to be disrupted, causing water quality to degrade day by day, and has become one of the world's most serious environmental issues. The river flows across agricultural areas where intensive agriculture and animal farming are practiced. In a geospatial map, the temporal distribution and graphic depiction of distinct classes and characteristics of each concerned sampling site are depicted (Figure 22).

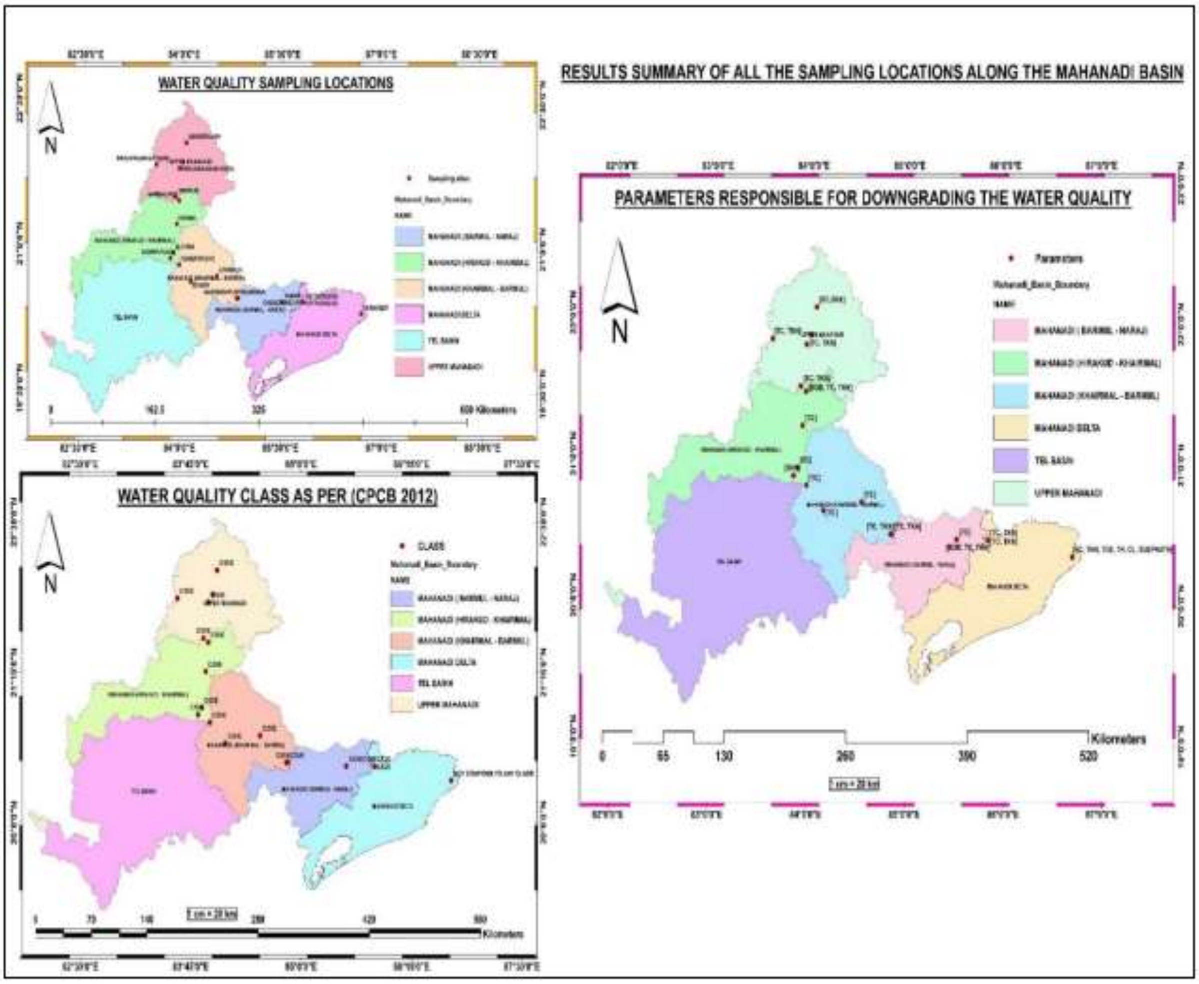

Figure 22. Summary results of all sampling locations which contributes contamination/pollution

5. Conclusion

The Mahanadi River's water quality and viability as drinking water were tested in this investigation. Nineteen collection sites have been identified, and 20 quality parameters were picked for annual analysis and verification to ascertain the water quality. The outcome of the various physicochemical investigation shows that the river water specimens have alkaline features. Due to local domestic sewage, larger DO values were reported downstream of city sewage water flows, demonstrating wastewater contamination from both residential and governmental origins. As per the WHO's quality attributes of fewer than 5 mg/l, BOD was generally low (World Health Organization, 2011). In the case of TC, all of the stations are within the prescribed limits and fall into the Class C category, with the exception of Cuttack D/s, Paradeep D/s, and Chowdwar D/s, which have values more than 5000 and hence do not fall into the Class C category. For effective monitoring and maintenance, these stations require adequate treatment.

According to WHO guidelines, TSS, boron, and TA are all within permissible ranges. All locations have COD levels less than 25 mg/l, indicating that they are safe to consume. The quantity of ammoniacal nitrogen and free ammonia will be less than 2 mg/l, thus according CPCB 2012. According to the report, all samples collected for both incidents are within the CPCB's required level. The TKN readings are higher than the acceptable limit of 3 mg/l ((CPCB 2012). As a result, all sampling locations are affected by organic contamination, lowering the water quality. Except for Paradeep, all of the samples studied had EC values that were within the acceptable range for drinking. Apart from Paradeep, all TDS readings in the observation group were well below the permissible limit for human consumption. As a corollary, the low TDS levels in the water from the chosen sites demonstrated that it was being used for drinking and other household purposes. All sites R1 to R19 are graded "excellent (sodium danger class S-I)" for agriculture (Sundaray et al., 2009) and fall into the Class E group for SAR, according to Richard's classification. TH measurements are less than 300 mg/l, other than Paradeep, indicating that the hardness classification is “strong hard.” Raised concentration in our bodies may cause blood levels to rise and bodily fluids to increase. Except for deep, all sampling locations are well within the limitations. Increased sulfate intake through drinking water can cause diarrhea in humans, while excess magnesium in surface water has a laxative impact on the human system. Only one of the samples, Paradeep, exhibited levels higher than the acceptable limit. In this study, fluoride levels in water samples spanned between 0.26 mg/l to 1 mg/l, with an average of 0.37 mg/l. Fluoride levels in all tested water samples are still within allowed limits, according to WHO guidelines. The highest nitrate limit in drinking water that the WHO considers acceptable is 45 mg/L. (1993). Most sampling locations in our study are all within the limitations, making them appropriate for irrigation and drinking. Sites such as Paradeep, where iron removal plants should be installed prior to consumption.

In the case of the Pearson matrix, the obtained results demonstrate very strong positive correlations between BOD-TC, TSS= (TKN, EC, TDS, B, TH, Cl-, SO42-, Fe), COD-(NH3-N, Free NH3), NH3-N—(Free NH3, SAR, F), Free NH3—(SAR, F), TKN—(EC, TDS, TH, Cl-, SO42- It denotes that the elements change as a result of linear dependence. Some of the characteristics were quite negative, indicating that the changes are inversely related. Because of the influx of residential and industrial wastes, as well as farming practices deposited across the river's banks, the Mahanadi River's water quality is in the Good to Poor category for consumption. The locations R1 to R7 and R10 to R19 have acceptable water quality, whereas Paradeep and Cuttack D/s have low water quality. It leads to wastewater discharge, leather products, and limestone manufacturers. Because it is located downstream, it is assumed to acquire industrial sludge, causing the water quality to deteriorate and endangering human health. In the case of the NPI method, the most essential indicators/parameters that are accountable for contamination or polluting agents are DO, TC, TKN, TDS, TH, Cl, SO42-, and fluoride. The physic-chemical qualities of river water have been regulated by effluent and runoff through mines, livestock, enterprises, and watering. The parameters that cause the water quality to deteriorate are emphasized in the table. The Mahanadi River's water is generally good, with few exceptions in urban areas and areas with limited mobility. A few of the indices that define agricultural appropriateness forbid the use of water for irrigation. Water that is suitable for drinking and agriculture is not suitable for use in industry. Conservation and preventative administration strategies are required for the river.

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Water Rights Ownership: Institutional Arrangements of the Aflaj Systems in the Sulatante of Oman

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ABSTRACT

Empirical water rights information collected through a sample using the three aflaj (singular falaj) types in Oman have been investigated and examined. The primary objective is to evaluate and document the historical methodology undertaken to develop different institutional arrangement based upon the three existed water collection/extraction process. There are three aflaj types exist in Oman; daudi, ghaili and ayni. It has been believed that the physical variation of these three extraction processes contributed greatly upon the historical development of the institutional arrangements. Hence, an attempt is made to answer the following research question 'To what extent the development of the aflaj institutional arrangements reflected upon the original physical variation collection/extraction process? The finding clearly identified two different flow-distribution systems; the first known as the 'raddat' and the second referred as the 'sharib'. In addition, it has been found that based upon each falaj overall flow capability (sometime used the term water flow security) the security of the water rights; explicit and implicit have been developed accordantly. While the duadi type are characterized by constant water flow and high discharge rate, co-exit institution which secure an explicit water rights. In contrast, since the ghaili types which characterized with unsecured water flow supply normally obtained from oasis surface water initiated implicit institution water rights arrangements.

1. Introduction

In the literatures water rights, in general, have been analysed within two concepts; equitably and efficiency. The first concept is very much concerned with the social aspect in distributing water among those benefiting and have legal access to it. Whereas, efficiency concept related to the economic aspects and how valuing water as a commodity, they use the term like efficiency and pricing approach or sometime efficiency and market approach. Although these two concepts considered very important in analysing a complex matter like water within social context, they became a challenge. This is attributed to two main reasons; first, it is difficult to adjust between social (equitably) and the private benefit (efficiency). For instance, while several researchers have been calling for a well-defined property rights and establishment of a water market within the efficiency water pricing approach [1, 2], other are against to the idea of establishment of a water market because, as they think on one hand, water is a social commodity [3] and on the other hand may be prone to a market failure.

Among the factors which contributed to the market failure is the physical characteristic of a watercourse [4-6]. This created a problem when the objective is to assert a privately water rights over a watercourse. Here of the physical nature of the resources (mobility and large size) very often included within the framework in analysing such problem [7, 8]. For instance, in the past, Dales [7] used the concept of implicit and explicit water prices to reflect the fact that naturally water being so large to the extent difficult to use a measurable unit for pricing. Here he attempted to explain the difficulty in initiating a water ownership compared with land, which as the asset-unit is very small-few square yards.

With this in context, many researchers and water proficiencies studied several of the ancient small community-managed irrigation systems worldwide. In the aim to learn lessons in assigning solving problem of water complexity. For example, the Nepal farmer-managed irrigation system [9], the communal tenure in Swiss villages [10], canal irrigation system in India [11] and indigenous water distribution system in Andean village, Peru [12]. Although these provided much discussion with respect to the indigenous knowledge of water distribution, little knowledge found to the legal water right ownership. It is the ancient system aflaj (singular falaj) in Oman provided wider contribution over the matter since millennium [13]. However, the substantial literatures initiated by John Wilkinson whom identified two main categories of ownership; mobile property and fixed property. The mobile property represented all type of water ownership which include three main subdivisions; wells of all types, aflaj (irrigation system), and the water distributing channels. The fixed property represented by the land, building, bridges and villages walls [14-16], did not placed the aflaj water rights within the context of the physical water extraction process variation. Although later studies such as; Abdel Rahmnn and Omezzine [17] and Zekri and Al-Marshudi [13] placed the system within a competitive market and tradable water rights frameworks, provided limited insight into institutional arrangements. It is acceptable to place the system within the context of competitive tradable water rights, but these institutional arrangements must be evaluated within the three aflaj type's physical variation.

Using the primary data collected by the authors in the northern part of Sultanate of Oman, this paper will document and present the finding of water rights and the concept of ownership. As we will discuss later in detail, various type of falaj water rights exists some of which belongs to certain historical known users such as the endowment water rights (locally known as waqf), some belongs to the state (the treasury) (in the past this known as bat-al-mal) and some rights belong to the system itself. The fieldwork was conducted over a period of four years; 2014 to 2017 in several governing region at the Northern part of Oman. It is important to note that the finding on this paper is the overall revealed result of the comprehensive study indicated earlier, as a partial finding from this study in the form a case study can be further viewed elsewhere [18, 19] but I will not tough upon here.

2. Problem Background

Although water considered as a prerequisite of all sorts of social and economic development, difficulty arise in how to balance/adjust between the notion water being a social commodity or an economic commodity. This is stem from that fact that the tradition idea of treating water as free good has been replaced by new perspective that water can be treated either as social good or economic commodity [4, 20, 21]. First those who hold the view that water is a social good have looked into several factors including its necessity to life and perquisite of society social development [22, 23] and its association with agrarian and industrial revolution [8]. Second, those who hold the view that water is an economic commodity stem from the fact that water is becoming scarce and its demand is increasing.

One of the more recent issue, which is closely related to the economic argument, is the possibility of asserting private ownership or establishing a well-defined water rights to a watercourse. [20, 24]. The argument here is that a well-defined rights tend to suit the transaction within a private market system and yield the highest value of the resources [1, 25].

Although substantial discussions have been found in the literatures, the problem remained. The problem discussion were concentrated over two main issues: the large size of the resource and how to measure it quantity using a measuring unit. In the past, Randall [5] indicated that private ownership cannot be initiated with a large size of resource, stating "the physical nature of the resources is to be blamed" (pg. 133). The measuring unit usually required during the process of transacting the resource within a private market system. The difficulty, as briefly illustrated by Coase [26], is the fact that a factor of production is usually thought of as a physical entity, which the businessman acquires and uses (e.g. an acre of land, a ton of fertilizer) instead of a right to perform certain physical actions. Dales [7] applied implicit and explicit water prices and how they are reflected by the fact that water is mobile and naturally water being so large to the extent difficult to use a measurable unit for pricing system like land of being immobile, as earlier mentioned.

However, in general, water researchers and economists in the past and present theoretically attempted to discuss solutions and to introduce many regulatory measures under the framework of institutional setting. This is very much concerned in formulating rules in managing water rights structural setting. With this regard, we belief there are significantly two main elements must be taken into consideration when analyzing a watercourse institutional arrangements. The first element is concern with legal context of how the define appropriation resource unit operate. This normally can take in the forms of rights which then divided into two main categories; 1) rights assigned for access/extraction of the resource units? 2) Rights assigned as private and public ownership. The second element the fluctuating factor of the watercourse which must be again taken into consideration because not only affect stream benefit distributive mechanism, but the legal identity.

3. Methodology and Study Site

The major approach adopted for studying the setting of the water rights over a watercourse through investigation of the current structure of the aflaj water rights and their currently operated institutional arrangements. The implication of these rights and their institutional arrangements on water distribution, ownership and renting are then evaluated in terms of how closely the criteria for a well-defined water rights freely exchanged within a water market are met. This is conducted over the investigation over the main selection criteria which is based on physical part of the system on original water collection process among the three aflaj types.

Although the aflaj system collect water through mountainous rainfall infiltration, they slightly different in the physical water extraction process; whether from direct supply from the aquifer or surface of the oasis. For instance, the daudi falaj extracts water from the upper part of the aquifer in the mountains, the ghaili falaj extracts water from the surface of an oasis, while the ayni falaj extracts its water from a spring which naturally comes to the surface, mainly in limestone rocks [15].

Supportive evidence with respect to this physical water collection process among the three types can be found from the last agricultural census and the aflaj National Inventory.

Governate/ region	Number of active *falaj* with respect to type			Total		Irrigated area (acres)	Annual water supply (mm^3)
	Daudi	*Ghaili*	*Ayni*	Number	Pecentage		
Al-Batinah	153	674	382	1209	40%	6,458	104
Al-Sharqiyah	193	253	215	661	22%	5,819	115
Al-Dhahiliya	183	149	169	501	17%	8,132	135
Al-Dahira	86	273	114	473	16%	4,626	79
Muscat	12	52	109	173	6%	1,463	26
Total	627	1401	989	3017		26,498	459

Table 1: Aflaj population over the five main governing regions in Oman

Table 1 summarizes the aflaj population, type of falaj and farming pattern over the five northern concentrated regions. Although the highest numbers of falaj systems are found in Al-Batinah region (40%), the largest irrigated area and annual water supply are found in the Al-Dhahiluya (Interior) region. This is attributed to the fact that while daudi type dominates the Al-Dhahiliya region (37%), they are more constant and characterized by holding high discharged rate. As a result, the daudi irrigate an area of 20% of the total cropped area of the whole country while ghaili 8% and ayni 10% [13].

Using a case study approach, nine aflaj located over four main areas; Nizwa, Smail, rustaq and Tawwi in the northern part of the country, were selected. These areas belong to three main region: Dakhiliya (the interior) hold the area of Nizwa and Smail, Southern Al- Batinah hold the area of Rustaq and Al-Sharqyah hold the area of Tawwi (Fig. 1). It is important to note that within commonly in each village in Oman, one or two falaj are capable in irrigating the whole village settlement. An example of the duadi aflaj system is the popular falaj known as falaj daris located in the historical city of Nizwa while falaj is the al-samdi located in the ancient town of Samail represent an example of the oasis falaj type.

The study used primary as well as secondary sources of information. These sources were structured over the preparatory data collection framework. First, information related to the primary sources which is based on in-depth interview in the various villages, with repeated visits and time spent interacting with people in these communities. Second, to identify the main stakeholder's bodies which have close contact with the system. These can be divided into two main categories: the private stakeholders including private community members, such as the aflaj committee members (wakeels, areefs, auctioneers, recorders and aflaj historical expertise) and individual farmers, and the public official bodies, such as the most relevant Omani official Ministries. The most contacted Ministries is Ministry of Regional Municipality and Water Resources and Ministry of Awqaf and Religious Affairs.

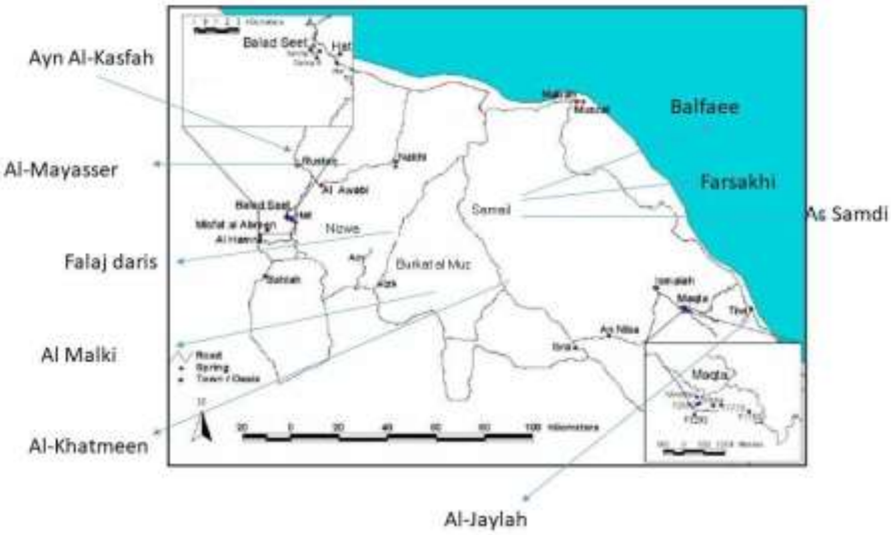

Figure 1: Location of the studied aflaj over the Northern part of Oman

4. Result

In the study areas two main factors have been identified which contributed greatly in controlling the present uncertainty and risk during the process of formulating the aflaj institutional arrangements. The first factor is how to designate a distribution mechanism to achieve two folded purposes; First, fair distributive mechanism in accordance to the original water physical extraction process. Second, how to develop a socially accepted water rights. The second factor closely relate to the requirement for a regular system maintenance. This again must be developed based upon the physical water extraction variation.

1.1. The *aflaj* water collection process

While a thorough understanding of the historical overall aflaj-flow distribution, three methods of the original water-collection/extraction process exist. Hence, our study identified, in general, that there are three different water extraction process exist in northern Oman as follow:

- Perennial flow by which water extracted from the upper part of the aquifer in the mountains by a natural means of flowing through gravity no mechanical devices are used. It is important to note that daudi is a word very often employed by the Omani to designate the traditional-construction engineer of a long tunnel which normally attached deep into the lower part of the aquifer since millennium. Hence the name attached daudi falaj to identical systems which hold similar characteristics.
- Seasonal fluctuated flow by which water normally extracted from the surface of wadi (oasis). This is locally known a ghail. The word ghail has been employed by Omani refereed to all ghaili aflaj system which uses the flow of the permanent oasis flow. Hence, they constructed short and open channel to convey water to the irrigated area.

- Perennial spring flow by which extract water from a spring which naturally comes to the surface, mainly in limestone rocks. Hence, *ayn* is a word very often employed by the Omani to designate a natural occurring phenomenon of perennial flow since millennium.

From the three above illustrated physical extraction processes, the following identified aflaj institutional arrangements and associated water rights classification prevailed.

Falaj name	Location / walayat	Falaj type	Circulation/rotation system
daris	*Nizwa (F0500)*	*daudi*	*raddat*
al-mayasser	*Rustaq (F1446)*	*daudi*	*raddat*
al-malki	*Izki (F0606)*	*daudi*	*raddat*
a-khatmeen	*Birkat al-mawz (F3071)*	*daudi*	*raddat*
ayn al-kasfah	*Rustaq (F2750)*	*ayni*	*raddat*
as-samdi	*Samail (F1714)*	*ghaili*	*sharib*
al-mihaydith	*Samail (F1714)*	*ghaili*	*sharib*
al-farsakhi	*Samail (al-alayah)*	*ghaili*	*sharib*
al-jaylah	*Sur (al-Jaylah)*	*ayni*	*sharib*

Table 2: The identified *aflaj* with the two rotation systems; *raddat* and *sharib*

Table 2 shows the two identified aflaj distribution systems; 'raddat' and 'sharib' for the studied aflaj system in northern of Oman. By far, almost all the daudi aflaj, except al-mihaydith in the town of Samail, follow the raddat system while all the ghaili type (as samdi, balfahee, falsaki) included another two from other types (al-mihaydith,, and al-Jaylah) attached with the sharib system. This finding can be interpreted as follow: while the original hydrological characteristics/source of water collection greatly varies, initial of a rotation system were developed accordantly. For example, since the daudi type in Oman characterized by a high discharge rate and constant flow (high reliability), usually linked with the explicit raddat system. This is attributed to the fact that these aflaj normally extract/collect water from the deep of the aquifer. For instance, the average discharge rate recorded for the most popular aflaj within this category; daris in the city of Nizwa and al-khatmeen in the district of Burkatal-Moz, were 332 and 159 litre per second respectively. In contrast, since the ghaili type characterized by seasonality and low flow, normally attached with the implicit 'sharib' system. This is attributed to the fact that water collected/extracted from the surface of an oasis (wadis). For example, the average discharge rate recorded for the most popular aflaj within this category, as-samdi and balfaa aflaj in the ancient village of Samail, were 64 and 31 litter per second respectively. Finally, despite that the two ayni aflaj (ayn al-khasfah and al-Jaylah) which are characterized by a constant flow water supply, large variation exists with respect to the discharge rate. For instance, the discharge rate for ayn al-khasfah is 64 liter per second while al-Jaylah is merely 4.4 [27]. This historically have greatly influenced the institutional arrangements of these two aflaj in terms of the most appropriate distribution system. Therefore, ayn al-khasfah falaj which extract water from a rocky limestone sprinkle supply (hold a constant flow (like daudi) attached with a raddat explicit water rights while al-Jaylah which is characterized very little discharge rate (like ghaili) linked with the implicit sharib system (see Table 2). How sharib and raddat are operated?

1.2. The sharib system

This system (mean to fulfil thirst) can be defined from its institutional context as to deliver the amount of water implicitly proportionally to all water shareholders. It is significantly important to emphasis the term proportionally as to allow use of the flow but not a right to own. They say to hold a sharib. Hence, they say the overall flow of water is proportionally (sharib) to all irrigators no actual measuring units were find. Therefore, a very simple seven day of the week circulation have been developed. By implication a complete day flow of the falaj is implicitly measured by 'sharib' starting from the day of Sunday, hence, they say Sunday sharib. Then the next circulation is assigned for the Monday sharib and so on till completing the seven days of the weeks. Now, the Saturday sharib is assigned for the falaj rent, hence it is auctioned on Friday noon and irrigated on the next day.

1.3. The raddat system

This system (mean to re-scheduling/turn) can be defined within its institutional context as a tool designated to deliver the amount of water explicitly to well-defined water rights holders. It was developed explicitly with several locally innovated units. Hence, they say the overall flow of water is must be delivered through precise amount to the well-defined water rights holders. By implication historically this system was developed and designated to suit the free exchanges of the water rights. Because of this, the survey found that water ownership only have been identified within this system.

1.4. Water ownership definition

Based on the above illustrated identified aflaj flow rotation system, water rights ownership must hold its own definition. First, historically aflaj water flow in Oman must be operated only through these two commonly distributive systems; sharib and raddat. Hence, the main purpose of these two systems is to differentiate between the two identified water rights institutional arrangements as follow: since the ghaili type extracts its water from the surface of an oasis (locally refereed as wadis) and they very much depend upon regional fluctuated rainfall, low level of security prevailed. One of the major concerns of these type of falaj is the flow can be reduced dramatically. Consequences, this may create high level of dispute among shareholders if privately owned rights were attached. In contrast since the daudi type aflaj extract water deeply from an aquifer (constant flow and high discharge rate), reflect the high level of security. This place them in a more security of private ownership. Hence, an explicit water rights along with several innovated measuring units (under the raddat system) have been linked.

Combining the identified distribution systems and the physical extraction variation among the three types, it is apparent that water rights ownership only found within the raddat identified aflaj. This leads us to further explain the finding concerning the raddat measuring units as follow: First, it has been found that only with the explicit raddat system water rights must be registered and documented over the local measuring units; athar and qiyas, hence, they say a particular irrigator hold one athar and 24 qiyas which means he or she are entitle (or had the right to the water flow) of water flow measured over this registered unit. Originally, an athar unit were developed as follows: a threemeter high stick is anchored at the centre of a flat area where there is little shade to prevent the sun from shining directly on the stick. Then the area to the west and east of the stick is divided into 24 sections; these divisions are equal to one athar. Now, each section known as qiyas which is originally

derived from the process of measuring a thing so that it is used to reflect a volume. In the past they used a container made of copper with unit lines marked on the inside. Qiyas is considered as the smallest unit within the context of the falaj distributive system. Therefore, they since one athar is divided into 24 qiyas, same saying an athar equal to 24 qiyas.

Second, certain historical background which particularly contributed toward the development of various organizational water rights. While water ownership separated from land ownership, free exchange of water rights by various organizations have been developed dated back several centuries ago. Two main organizational bodies have been identified by the survey which owned water rights. These are wqaf (endowment) and bayt-al-mal (state). These only found with the daudi aflaj types. In our study areas two main water rights in general have been identified; private rights and public rights. Several important characteristics have been prevailed. First, the private owned right holds an official court recognition through a well-local documented registration. Second, the public rights cannot be owned by individual, they are only owned by organization. Therefore, three main types of these public organizational rights have been identified wqaf (endowment), bayt-al-mal (state) and the common (renting) right (see Table 3).

	Private owned rights	Public			Total
		bayt-al-mal	endowment (waqf)	Common (renting) right	
daris	25	24	39	12	100
al-mayasser	65	6	19	10	100
al-malki	74		15	11	100
al-khatmeen	39	46	4	11	100
ayn al-kasfah	91	3	6	None	100
Average	**59**	**20**	**17**	**11**	**100**

Table 3: Percentage distribution of the explicit water right among the two categories; private and public

Table 3 shows the percentage distribution of the radat identified aflaj. By far, the most significant water category is the private right at overall average of 59 percent. The remaining 41 constituted for the public rights; bayt-al-mal (state) 20 percent endowment (waqf) 17 percent and the common (renting) right 11 percent. Readers are directed to our previous publication for more details regarding these public water rights [19]. It worth noting that our uses of the term public rather than common stem from the fact that these water rights belong to the community which represent in the actual sense a public wealth. For example, the endowment (waqf) rights normally assign to a charity organization as a donating public wealth, the bayt-al-mal water rights belong to the states expenditures and the common (renting) right normally leased/rented to generate income for the system regular maintenance expenditures. Figure 2 summarized the overall finding.

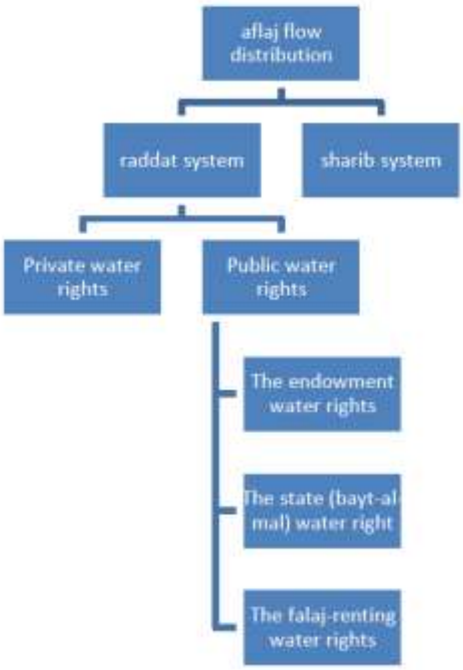

Figure 2: Simplified of the overall water rights finding

5. Summary

Based on the above illustrated finding with respect to the water rights definition within aflaj communities system, one probably can apply the concept used by Dales [7] and Zekri and al-marshudi [13], the explicit and implicit, to differentiate between the existed aflaj water rights. Therefore, the first principle that differentiate water rights within the aflaj system in Oman is the fact that rights are classified in accordance to the physical water extraction variation into two main types; the explicit and implicit rights.

- Explicit water rights. These can be freely traded through the locally-innovated exchanging units. Hence can be sub-divided into small unit if is required during the process of inheritance sub-division or if required over transacting process say suppose an irrigator own more than an ather explicit right and wants to sell one or two ather.
- Implicit water rights. These cannot be sub-divided into smaller units because it is linked proportionally to the overall flow of a particular falaj. However, during the inheritance process the proportional flow only will be assigned as a flow but not as right.

The second principle concerning water ownership in Oman is how to institute the private water rights. Private water rights ownership holds special meaning within the Omani aflaj institutional arrangements. Two features are very often associated with private ownership. First, they must be attached with explicit/reliable water flow extraction process. As discussed earlier, that the two common distributive systems ‘raddat’ and ‘sharib’ have reflected the original hydrological characteristics of each falaj, by which governed the development of water rights. For example, since the daudi type aflaj characterized by constant flow and high discharge rate, institutionally linked with the raddat system. Hence it is only with the explicit raddat system which only recognized by all the national level and have the

6. Conclusion

An investigation of the aflaj water rights and their associated institutional arrangements is, in many respects, an assessment of the overall aflaj-shared community ancient assets. The main issue over this investigation, however, is not merely the existed water rights along their associated institutional arrangements meet the efficiency criteria of water usage, it is whether the original water collected sources, represented by the law of water supply, reflected the original development of these water rights. The picture drawn from this investigation indicates that while there are co-exist two kind of water rights within the two different water flow distribution mechanisms/ systems (raddat and the sharib), only the explicit water right attached with the raddat system allowed to be exchanged freely within a competitive water market. Development of a distributive mechanism to deliver a commonly public owned water without governing rules, is normally not accepted by the community and in many cases, it causes disputes among members, especially the majority seek water within this arid region.

First, in situation where the flow is regular and water supply fairly stable, community developed raddat explicit water rights. These have been developed and generated over a well-developed existing water rights structure where only the private water rights holders only allowed to exchange their rights freely within a competitive water market. In addition, several local innovated units used with the transaction (buying, selling and renting) procedure like the athar and qiyas were found within the raddat system. Second, in situation where the flow is irregular and water supply unstable, community developed implicit sharib system. These have been developed with no defined water rights structure where the private owned rights are not allowed. Out interpretation of not allowing a private ownership within the implicit sharib system can be related to the fact that during dry years a major concern is the reduction of the flow dramatically and as a result create high level of dispute among shareholders if privately owned rights were developed. While in the literature the major challenge to assert a private water right is the physical characteristic of a watercourse, Omani historically treated ownership carefully with particular consideration of the water course physical characteristics.

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Open Source

Non-governmental GeoNode in Nepal: Challenges and Opportunities

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Keywords: *Open Geospatial Data, GeoNode, GeoNepal, Nepal, Data Sharing, SDI*

ABSTRACT

There is a growing demand for the use and application of geospatial data in Nepal. Several governmental and non-governmental organizations as well as researchers collect, use, and store huge amounts of geospatial data annually for different purposes. However, there is no or very limited publicly available open data for re-use. The data seekers need to individually contact the potential data holders through personal and professional contacts. This is not only inefficient but also has a limited chance of getting a dataset with proper metadata.

GeoNode is an open-source based web platform that can be customized to host geospatial metadata and data. The Department of Geomatics Engineering of Kathmandu University has set up its own GeoNode (https://geonepal.info/) to provide access to a range of spatial and non-spatial data like administrative boundaries, Openstreetmap (OSM) daily extracts, Demographic, Hazard, and climatic data collected and curated by non-governmental organizations. Furthermore, the subsets of global and regional products that are not widely known in Nepal are also made available.

However, the implementation is not without challenges. Lack of data sharing culture and license policy has restricted organizations to share data in public platforms like GeoNode are some of the major hurdles. In this presentation, we will highlight the importance of the need for data sharing in the context of a developing country like Nepal and will discuss its implementation challenges and possible solutions.

Evaluation of free and open-source (FOSS) mobile data collection tools (MDCs) to enhance field data collection for urban planning in Zambia

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Keywords: *Free and open-source, Urban planning, Mobile data collection*

ABSTRACT

Mobile data collection (MDC) has been gaining popularity as the primary method of data collection in many professional fields such as public health, environment, conservation, and research. The popularity of MDCs has been attributed to their advantages in data collection over inefficient, expensive and labour-intensive paper data collection methods. MDC provides faster data collection, reduction in data collection costs, high data quality and readiness for data analysis. However, despite these advantages, the adoption of these MDC tools by urban and regional planners in Zambia has been slow, which has made urban planning losing an opportunity to routinely collect data important for planning, tracking SDGs and address what Devarajan (2013) describes as Africa being in a “statistical tragedy” where many countries still use outdated data which are not comparable over time and are sourced by old methods of data collection. Given this context, the aim of this research paper is to identify and evaluate the mobile data collection tools currently in Zambia mainly focusing on free and open-source MDCs.

Purposive sampling was used to identify participants in the survey as only a few planning and planning departments and firms have used at least one MDC tool in their planning activities. The attitudes that surround MDC include the use of tools for mapping spatial data, undertaking social-economic surveys and community surveys as some of the cases. The tools were identified, evaluated, and piloted to assess how they can be used in the urban planning context. MDC tools relevant for urban planning were those which scored high on ease of use, inclusion of questions types, publicly available output formats, the availability of skipping logic, ability to pick coordinates and the ability to analyze criteria.

The research condenses for the first time the important criteria/factor that planners in Zambia need to consider when deciding which MDC application to use for different planning data collection needs. After the evaluation and piloting Kobocollect/ODK was found to be most appropriate for data collection projects which capture more detailed attribute data such as for social-economical surveys, household surveys, community surveys, and environmental surveys. While the use of Input and Qfield MDC applications to be more suited for survey that requires collection of spatially related data which is relevant for settlement upgrading projects, site reconnaissance surveying, building inspections, infrastructure monitoring land parcel identification by taking desktop GIS to the field.

Workshop

Introductory Workshop on Google Earth Engine and its Application in Hazard Assessment

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Keywords: *Google Earth Engine, Remote sensing, Hazard assessment, Satellite*

ABSTRACT

Working with a large sum of remote sensing data has always been a challenge. The main challenges are downloading a large amount of data, having a powerful machine to process the data, excessive time consumption. Google Earth Engine has been invented to address these challenges. It gives geospatial researchers free access to multi-petabyte remote sensing data e.g., to Landsat imageries dating back to the 1970s, Sentinel satellite family data, MODIS and etc. The new data are added to its repository on a daily basis. The user would only need an internet browser and an internet connection to access, process, and perform analysis in a single epoch or time-series manner at a global scale in a matter of seconds.

The aim of this workshop is to offer the audience with an introduction to the Google Earth Engine platform. To better realize to benefits of using Google Earth Engine, the workshop will also present the real-life examples of Google Earth Engine being used in hazard assessment applications and researches of different domains.

Alumni session and Professional Development

Opportunities for Geospatial professionals in Mapping Industry

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Keywords: *Mapping industry, Geospatial professionals, Online maps*

ABSTRACT

Mapping Industry, is a vast and dynamic sector where all intelligence meet and create accessible and beautiful maps for users. From geometry creation to selling it as a service, it requires wide range of expertise such as software engineer, AI/ML expert, spatial scientist, data scientist, social scientist, project manager, designer and many more. This evolving industry needs Spatial knowledge, which is one of the major know-how to play role. Currently, key players in the global online map services are Apple Maps, Google Maps, Here, TomTom, MapBox, OSM etc. Some of these maps had/have very influential team from Germany consisting of experts coming from whole Europe. Along with the Map services, Germany has a huge job market for Geospatial experts. Every state, city, different departments, research organisations, private data analytic/production companies, start-up has a demand of Geospatial scientists. I have had the opportunity to be involved in the Apple Maps since 2018 and definitely this has been the most exciting experience in my 10 years of professional career.

As an alumni of HFT Stuttgart, I would like to share how my masters degree in Photogrammetry and Geoinformatics with previous experiences in urban planning contributed in entering this sector. I would also include some suggestions regarding getting involved in geo-information sector of Germany as a foreign expert and answer any additional questions that the participants might have.

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