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Application of Geoinformatics in Environmental Management in Vietnam

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Abstract: ***Vietnam is a country with rich natural resources and diverse ecosystems, but it is also facing significant environmental challenges such as deforestation, pollution, and climate change. Geoinformatics, which refers to the application of geographic information systems (GIS), remote sensing, and spatial analysis, can play a vital role in addressing these challenges and promoting sustainable environmental management in Vietnam. This study aims to present a minireview on the application of geoinformatics and several limitations of geoinformatics application in environmental management in Viet Nam.***

Keywords: Geoinformatics; Environmental Management; Application; GIS; Vietnam

1. Introduction

Environmental management in Vietnam has become an increasingly important issue in recent years due to the country's rapid economic development and population growth. Vietnam faces many environmental challenges, including air and water pollution, deforestation, soil erosion, and biodiversity loss. Air pollution is a major problem in urban areas of Vietnam, with industrial and transportation emissions contributing to poor air quality. This can have significant impacts on public health. Vietnam's rivers, lakes, and coastal areas are also increasingly polluted due to industrial and agricultural activities, as well as inadequate wastewater treatment facilities [1]. Apart from air and water pollution, deforestation is a significant environmental issue in Vietnam, with forests being cleared for agriculture, urbanization, and other development activities. This can lead to soil erosion, loss of biodiversity, and other environmental impacts. Another important issue that needs to be addressed is climate change. Vietnam is particularly vulnerable to the impacts of climate change, including sea level rise, flooding, and extreme weather events.

To address these challenges, the Vietnamese government has implemented a range of policies and initiatives, including the National Strategy on Climate Change, the National Biodiversity Strategy and Action Plan, and the National Action Plan on Air Quality Management. Additionally, the government is working to improve wastewater treatment facilities, promote sustainable agricultural practices, and protect natural resources. Vietnam has also signed a number of international environmental agreements, including the Paris Agreement on climate change and the Convention on Biological Diversity, which demonstrate the country's commitment to sustainable development and environmental protection. While progress has been made, there is still much work to be done to ensure a sustainable future for Vietnam's people and environment [2].

Geoinformatics is a field of study that combines geospatial information technology with environmental management. It involves the collection, analysis, interpretation, and visualization of data related to the earth's physical features, such as its terrain, land cover, and natural resources. In environmental management, geoinformatics plays a crucial role in understanding and managing environmental issues. It enables the identification and monitoring of environmental parameters, such as pollution levels, land use change, and biodiversity, which are critical for making informed decisions on environmental management [3].

Geoinformatics also can help in the design of environmentally sustainable land use practices, natural resource management, and conservation efforts. By analyzing data on vegetation, water quality, air pollution, and other environmental indicators, geoinformatics can provide insight into the ecological impact of human activities and assist in developing solutions to mitigate them. The use of geoinformatics in environmental management can also help in disaster management and emergency response. By providing real - time data on environmental conditions, such as floods or wildfires, emergency response teams can respond more effectively, minimizing damage and protecting human life. Overall, geoinformatics is an essential tool in environmental management, providing the data and insights needed to make informed decisions on environmental policies and practices. Knowing the practical benefits of geoinformatics, Viet Nam has been using it as a valuable tool for environmental management. In this study, we would like to present a mini review on the application of geoinformatics in environmental management and preliminarily analyze some limitations of the tool application in Viet Nam.

2. Applications of geoinformatics for environmental management in Vietnam

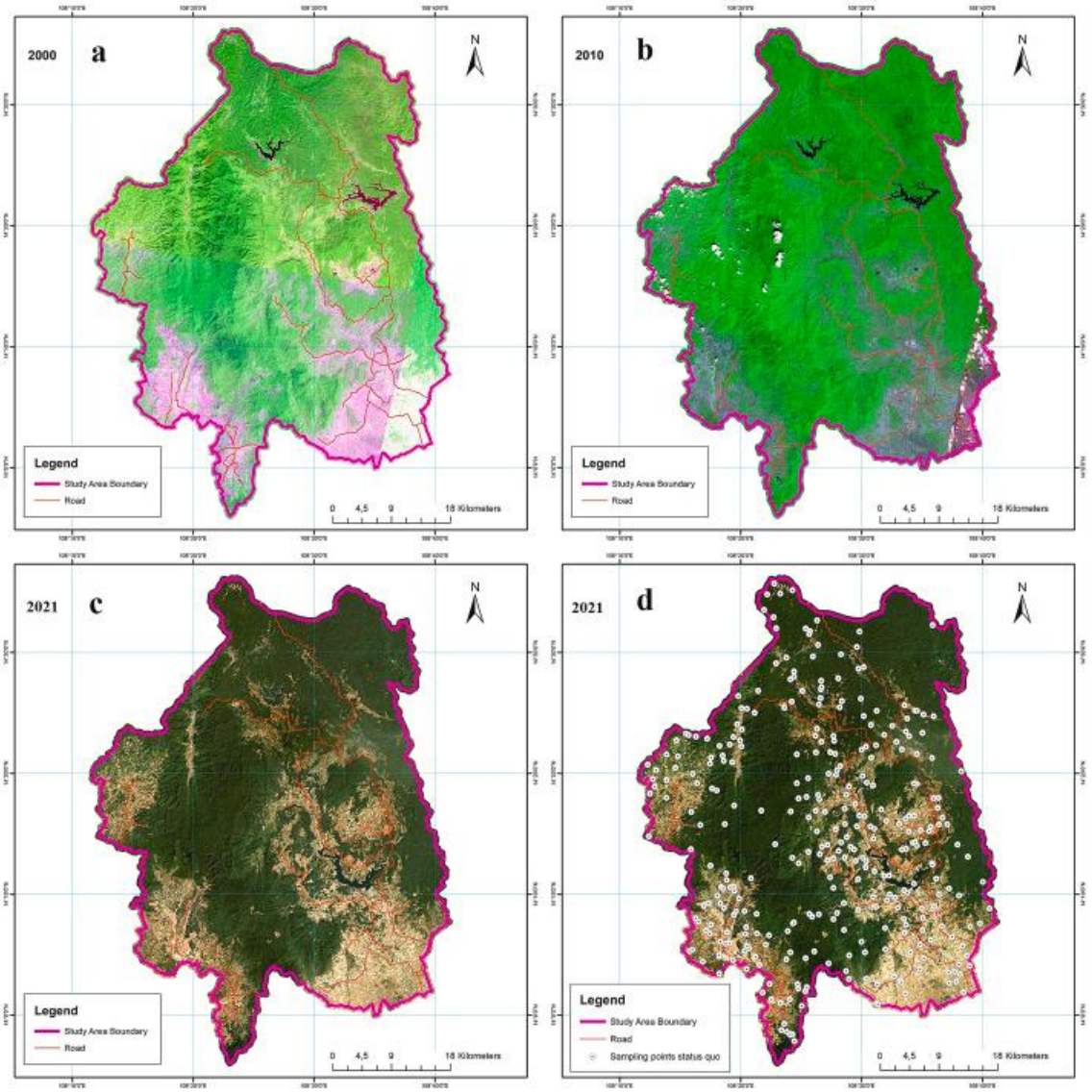

Figure 1: Temporal remote sensing images of 2000, 2010, 2021 (a, b, c) and 2021 photo key sample test points (d) in the Kon Ha Nung Plateau area using SPOT - 4 satellite [5]

One key application of geoinformatics in environmental management in Vietnam is in the monitoring and assessment of land use changes. With the rapid pace of urbanization and industrialization, there is a pressing need to monitor and manage land use changes to mitigate their impacts on the environment. Geoinformatics can provide valuable data and tools to help policymakers and planners make informed decisions on land use planning and management [4]. Remote sensing imagery is the most suitable tool for monitoring, managing, and evaluating land - use overlay fluctuations, especially forest cover for large areas. Dinh D. B. and coworkers have recently used SPOT 4 and Planet remote sensing data to assess land - use status fluctuations in the Kon Ha Nung Plateau area, Vietnam, between 2000 and 2021 [5] (Figure 1).

According to the findings, the rate of natural forest loss in this area from 2000 to 2010 was 0.32 percent per year, with over 6500 ha converted to various uses. Instead of shifting between different types of land use, the rate of natural forest loss gradually declined (0.09 percent/year) between 2010 and 2021. From 2000 to 2010, the amount of forests, perennial crop land, and annual crop land tended to increase; however, from 2010 to 2021, the area of plantation forests fell significantly, while perennial crop land and annual crop land continued to expand. According to the findings, the rate of natural forest loss in this area from 2000 to 2010 was 0.32 percent per year, with over 6500 ha converted to various uses. Instead of shifting between different types of land use, the rate of natural forest loss gradually declined (0.09 percent/year) between 2010 and 2021. From 2000 to 2010, the amount of forests, perennial crop land, and annual crop land tended to increase; however, from 2010 to 2021, the area of plantation forests fell significantly, while perennial crop land and annual crop land continued to expand (Figure 2). Furthermore, the results provide a better understanding of the current position and role of the government apparatus, cadres, and ethnic minorities in the socioeconomic development associated with forest protection and development on the Kon Ha Nung Plateau. The findings of this study could serve as a foundation for developing policies to effectively protect and manage forest resources, as well as for planning the development of the local forestry industry in a timely and effective manner.

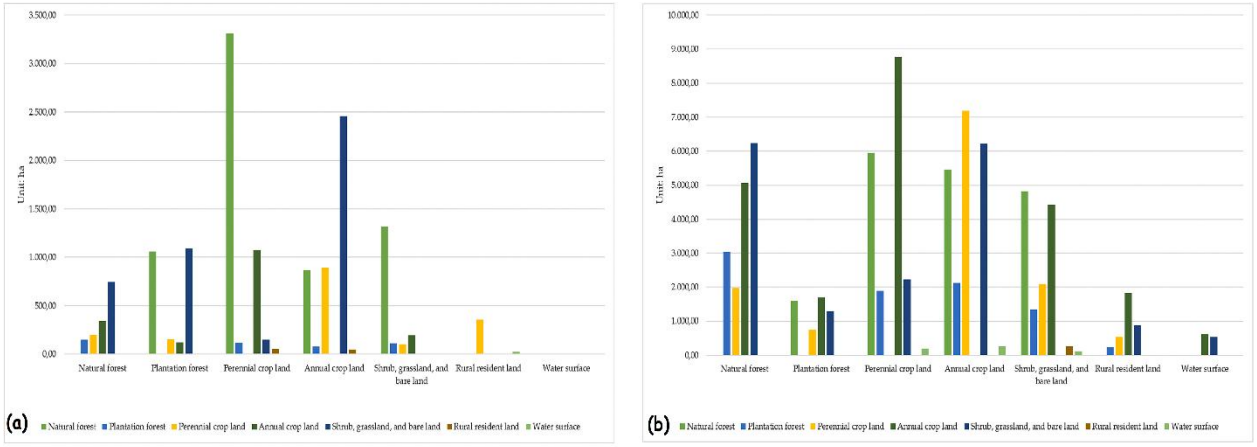

Figure 2: Area converted between types of land use in the Kon Ha Nung Plateau during intervals of 2000 - 2010 (a) and 2010–2021 (b) [5].

Another area where geoinformatics can be useful is in natural resource management. Vietnam is home to diverse natural resources, including forests, water resources, and minerals, and the sustainable management of these resources is critical for the country's economic and environmental well - being. Geoinformatics can provide valuable data on the distribution, status, and trends of these resources, which can inform policy and management decisions. Recently, unlocking the energy recovery potential from sustainable management of bio - resources in Hanoi was conducted based on GIS analysis [6]. In particular, Dao M. K. and colleagues examined the spatial distribution of pig farms, identified optimal locations for biogas plants, and assessed the potential benefits of introducing biogas production to meet electricity demand and reduce GHG emissions using GIS suitability analysis, cluster analysis, and the analytic hierarchy process technique. The results show that two biogas plants with a capacity of more than 1 MW and three with a capacity of more than 250 kW can be optimally installed, meeting 1.75 percent and 0.76 percent of the electricity demand of Son Tay and Thach That, respectively (Figure 3). They calculated that implementing the three proposed scenarios will cut GHG emissions by 84, 777 tons of CO2 equivalent per year compared to the existing situation or baseline scenario. The findings provide an excellent chance to improve local energy security using renewable energy while efficiently reducing GHG emissions.

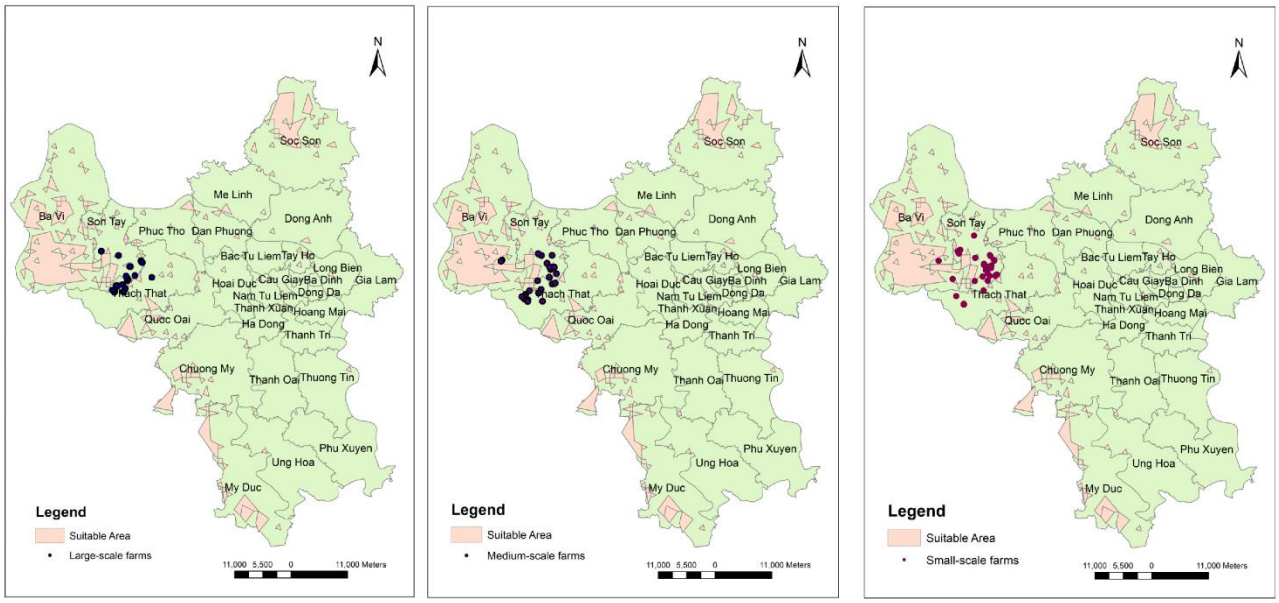

Figure 3: Three proposed scenarios according to large, medium, and small - sized farms with the number of pigs per farm being more than 1600 heads, from 650 to 1600 heads, and less than 650 heads, respectively [6].

Geoinformatics can also be used to assess and monitor environmental pollution in Vietnam. With rapid industrialization and urbanization, pollution has become a significant environmental challenge in the country. Normally, MsExcel software is utilized to manage the findings of environmental monitoring parameters on distinct electronic spreadsheets, whereas AutoCAD software is used to present the map separately. Some units employ international Geographic Information System (GIS) software, such as ArcGIS, ArcInfo, MapInfo, Microstation, in conjunction with open software like WEB - GIS, ELIS, ENVIM to create a data background map. Notwithstanding the automated data processing capabilities of Excel spreadsheets, they present limitations in terms of data accessibility and sharing, as only specific data sets can be accessed at a time, typically on a quarterly or yearly basis.

AutoCAD, on the other hand, lacks the ability to create manageable databases (CSDL) and is primarily used for graphic design (Aided Drawing). While GIS software excels in mapping spatial and attribute data, it has certain shortcomings in representing environmental parameters and tracking time. Similarly, environmental software has a strong focus on monitoring environmental parameters but requires improvement in spatial calculations for mapping purposes [7]. As mentioned above, Geomatics is the science of collecting, storing, and processing data, combining the sciences of Geodesy and Informatics. It links all the software as just referred to forecast and provide a way to thoroughly deal with environmental pollution. Geoinformatics can provide a spatially explicit understanding of the distribution and extent of pollution, which can inform mitigation and remediation efforts [8]. Trinh H. T. and co - workers have proposed to use geoinformatics through GIS MapInfo and Water Quality Indexto evaluate the water pollution and the factors that influenced the groundwater quality of the Holocene (qh) and Pleistocene (qp) aquifers in the coastal zone of NinhThuan province [9]. The groundwater in Vietnam was assessed through an advanced ensemble machine learning model (RABANN) that integrates Artificial Neural Networks (ANN) with RealAdaBoost (RAB) ensemble technique [10] (Figure 4). The model studies showed that both models performed well in the training phase of assessing groundwater potential (AUC ≥ 0.7), whereas the ensemble model (AUC = 0.776) outperformed the single ANN model (AUC = 0.699) in the validation phase. This demonstrated that the RAB ensemble technique improved the performance of a single ANN model. The ensemble generated model can be applied for groundwater potential mapping of different locations and countries toward more efficient water resource management by making small changes to the input data. The findings will be useful in improving the DakNong province's groundwater condition and therefore in solving the population's water - borne disease - related health problems.

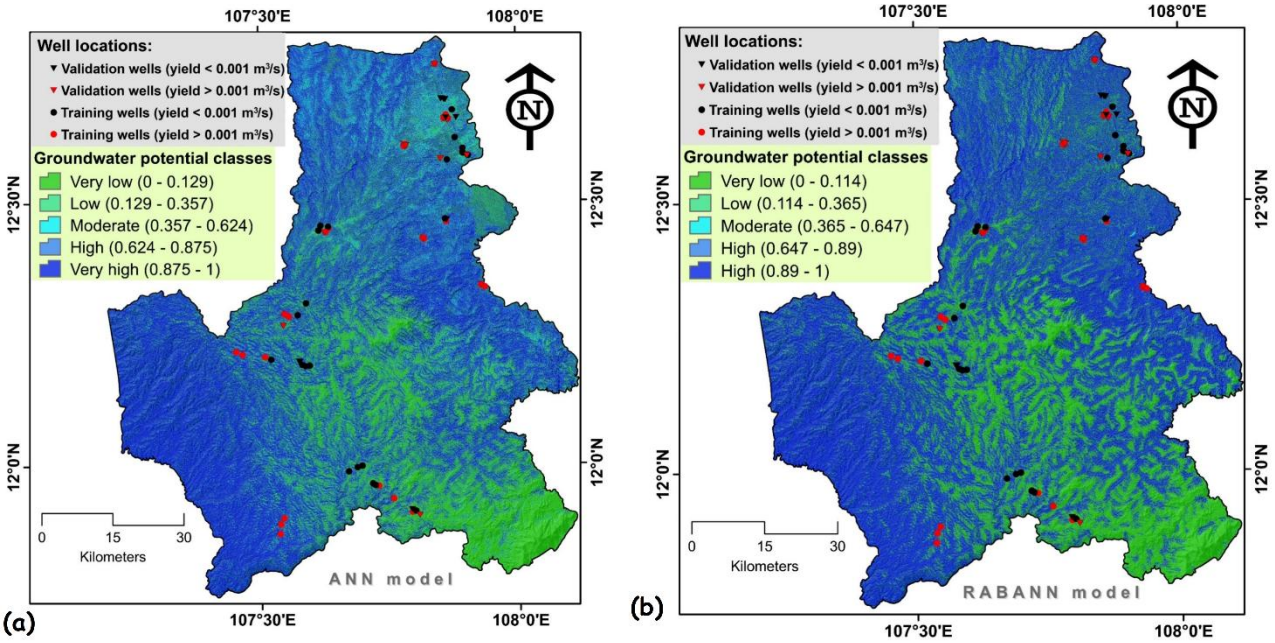

Figure 4: Groundwater potential maps produced using (a) ANN (Artificial Neural Networks) and (b) RABANN in the DakNong province [10]

Apart from the assessment of surface water quality, geoinformatics have been used for flood risk analysis at Vietnam. In the study of utilizing remote sensing and GIS - based hydrological modeling for flood risk analysis, Dang T. N. A and Kumar L. used a Digital Elevation Model in a GIS framework with the water level in rivers as an input to examine the tidal floods in Ho Chi Minh City (Figure 5). It is indicated that rainfall - induced floods in this metropolis are not a big concern with flood levels of 2 - 10 cm, however tidal floods are a significant issue with flood depths of 10 - 100 cm. Furthermore, increasing impervious surfaces and decreasing flow length areas due to urbanization, combined with tidal effects, contributed significantly to increased flood risk. These findings have implications for flood risk mitigation measures in the area, such as regulating urbanization processes with adequate infrastructure and boosting runoff infiltration capacity with optimal drainage systems [7].

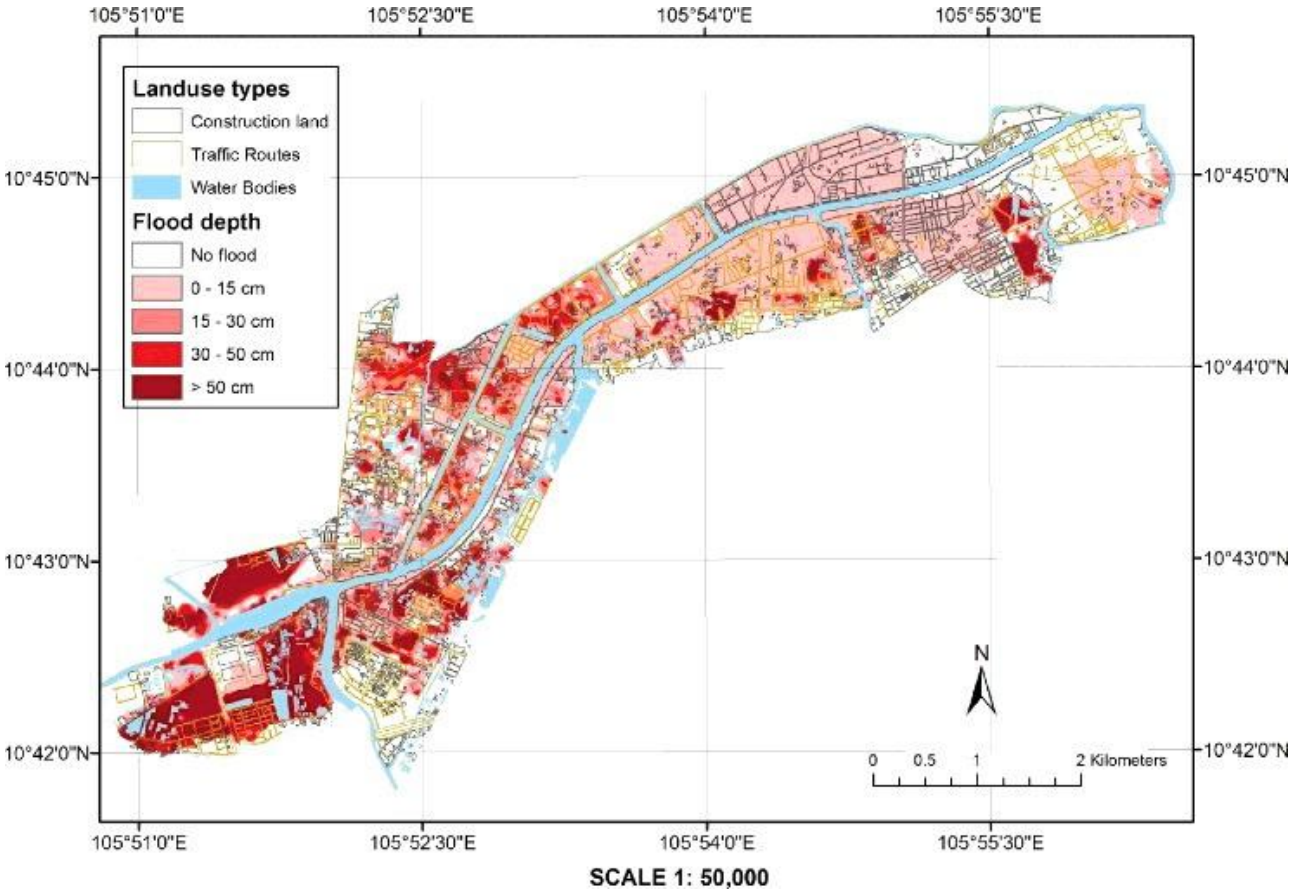

Figure 5: Map of simulated flooding caused by both rainfall and tides in District 8 of Ho Chi Minh City in the year 2010 [7]

3. Limitations of geoinformatics application in Vietnam

While geoinformatics can be a valuable tool for environmental management in Vietnam, there are also some limitations to its application. Some of these limitations include data availability, technical capacity, funding and resources, limited integration, and lack of user engagement.

One of the primary limitations of geoinformatics in Vietnam is the lack of reliable and up - to - date data on environmental conditions. While there is some data available from government sources, it may not be complete or may be of low quality. Up to now, Vietnam only had launched a total of six satellites, in which the first one named Vinasat - 1 was launched in 2008. This is a communication satellite only used for television broadcasting, telecommunications, and internet services. It was not until 2021 that Vietnam was equipped with a nanosatellite (NanoDragon) designed for observation of the earth's atmosphere to study weather patterns and climate change. Also in this year, a remote sensing satellite with high - resolution imagery was first launched into space to monitor land resources, urban planning, and natural disasters. Additionally, data from remote sensing platforms, such as satellite imagery, may be limited by cloud cover or other factors. Vietnam is located in Southeast Asia and has a tropical monsoon climate, characterized by high temperatures and humidity, with distinct wet and dry seasons. Therefore, the country experiences frequent rain and thunderstorms, which can lead to more cloud cover [11].

Another limitation of geoinformatics in Vietnam is the limited technical capacity for data analysis and modeling. While there are some researchers and organizations in Vietnam with expertise in geoinformatics, there may not be sufficient capacity to develop and maintain complex models or decision support systems. This is due to the shortage of high - quality human resources in geoinformatics. Currently, there is only one university that provides specialized training in the field of geoinformatics.

Funding and resources: The development and implementation of geoinformatics applications can be resource - intensive, requiring significant funding and technical resources. In Vietnam, there may be limited funding available for these types of initiatives, particularly for organizations outside of the government.

Geoinformatics applications may be limited by the lack of integration with other environmental management tools and processes. For example, while geoinformatics can be used to develop decision support systems, these systems may not be integrated with other management tools, such as environmental regulations or monitoring programs.

Finally, the effective use of geoinformatics applications for environmental management in Vietnam may be limited by the lack of user engagement. Decision - makers and stakeholders may not be familiar with the use of geoinformatics or may not trust the data and models generated by these tools.

4. Conclusion

Overall, geoinformatics has great potential to promote sustainable environmental management in Vietnam. By providing valuable data and tools for monitoring and decision - making, geoinformatics can help policymakers and managers make informed decisions to protect and conserve the country's natural resources and promote sustainable development. However, there are still several limitations that need to be addressed to fully realize its benefits such as data availability, technical capacity, and lack of user engagement. Addressing these limitations will be important for the effective use of geoinformatics in environmental management in Vietnam.

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