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Research paper

Utilization of Geographic Information System (GIS) for urban management of RachGia City, Vietnam

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Abstract: KienGiang province of Vietnam is the west coast of Mekong Delta, Vietnam where RachGia city is the provincial capital. In recent years due to impacts of climate change and extreme weather, the city's urban infrastructure has been affected by saline intrusion, flooding, collapsed house, etc. Modeling remote sensing is useful to determine rainfall. Climatic factors are affected by temperature, wind, rain, drought that people feel comfortable or not comfortable in the area because the planning and management are not well. The application of Geographic Information System (GIS) technology has supported the method such as analysis, overlap the urban infrastructure and climate change impacts layers to produce the assessment that will support urban management. The objectives of this study is to assess the impact of climate change on some of RachGia's infrastructures through the analysis of a number of thematic maps created from GIS Database. The database will be used by local agencies in urban management and development which take into account the climate change.

Keywords: climate, GIS, management, RachGia, urban, Vietnam

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1. Introduction

The contents of the construction management are illustrated in the report which containing several diagrams, drawings, models and explanations. The data of civil infrastructure and social infrastructure system in the current planning is mostly fabricated in form of drawings with the use of graphical software such as Autocad, Photoshop. Thus, the data of these construction plans is mostly used for demonstration and printing purposes only. With this data format, it would cause many difficulties to management work such as building spatial analysis directions. Geographic Information System (GIS) is a useful tool in integrating database systems associated with maps. The application of GIS technology in the field of construction management will improve the efficiency of urban management and development [1]. Especially in recent years for urban areas in the Mekong Delta region, which often suffer from frequent storms, tropical depressions, tornadoes and surges [2]. The effects of climate change which causing saline intrusion, inundation, river bank and coastline erosion, appear more and more frequently.

RachGia city, KienGiang province (Fig. 1) is one of the cities that are affected by climate change [3]. In recent years, the weather situation has becoming complicated and abnormal, causing seriously affected to the infrastructure, manufacturing and life of the people. Establishing a GIS database for urban infrastructure as well as the effects of extreme weather and climate change on that urban infrastructure are useful. Some examples can be taken such as the affected level of house, flooding residential land, saline intrusion into urban water supply infrastructure. It will help urban planning and socio-economic development master planning to be integrated with coping solutions and measures to adapt to the changing situation climate. The study objective is to assess the impact of climate change on some of RachGia's infrastructures through the analysis of a number of thematic

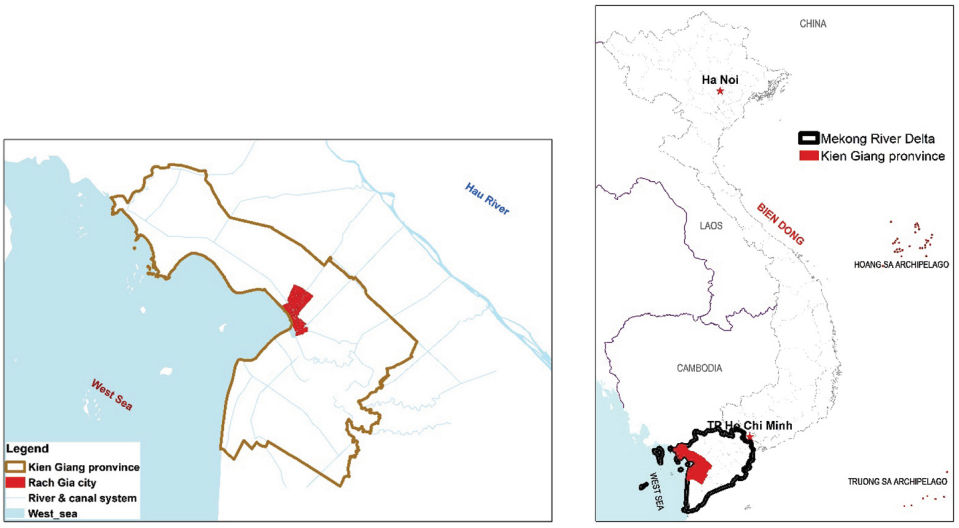

Fig. 1. Location of study area

maps created from GIS Database. The database will be used by local agencies in urban management and development which taking into account the climate change.

2. Literature reviews

In some developed countries such as United States and Korea, the first successful steps of GIS application in urban management is to complete the National Spatial Data Infrastructure (NSDI), which is the foundation for the development and application of GIS for specialized fields [4]. In the US, GIS has been applied to both urban management and development. Advanced management assistance system has been developed based on GIS technology. For example, a management assistance system called "WHAT IF?" has been developed and developed, allowing simulation of urban development scenarios [5]. Korea has implemented the establishment of a national GIS system, currently GIS is being applied in setting up advanced systems: U-city smart city, advanced application optimization and management decision support system [6].

For urban management in Vietnam, because the Government of Vietnam as well as the Ministry of Construction have no legal documents to put GIS application into practice, urban management work still mainly follow traditional technology with supporting from AutoCad design software and presentation software [7]. However, several Vietnamese research institutes, leading by the Vietnam National Institute of Urban and Rural Planning and departments of construction of Vietnamese, have been applied recent GIS projects in building databases and creating thematic maps to support management, assessing the existing (land, technical and social infrastructures, . . .) and identifying the potential of urban development [8]. Integrating climate change issues into strategies, programs, and planning is to adjust technical infrastructure management, urban residential areas under variable scenarios subjecting to climate change. The contents of the assessment will contribute to the support of central and local state management agencies to work out priority action plans to cope with climate change and sea level rise in construction and managerment of urban technical infrastructure, which facing increasing challenges of climate change. Within the scope of the construction industry, one of the important tasks is to assess the impacts of climate change on technical infrastructure (especially in urban areas where high population density is combined with rapid socio-economic development activities) [9]. In the Mekong Delta region where has been identified as being particularly vulnerable to extreme climate events and climate change, the Asian Development Bank (ADB) and the Vietnam Institute of Meteorology, Hydrology and Environment (IMHEN) have made a Report on Climate Change Impact and Adaptation Research in the Mekong Delta: Climate risk in the Mekong region of Ca Mau and Kien Giang provinces, Vietnam [10]. The report provided a brief overview of the results of the modeling and vulnerability assessment as well as presented detailed maps of climate change impacts and district level vulnerabilities at current as well as to be expected. Assessing the impact of climate change on the urban technical infrastructure system, thereby proposing coping solutions as a basis for formulating action plans for the construction of urban technical infrastructure.

3. Research methodology

Existing statistical and data analysis methods, inheriting the results of research projects already implemented (statistics, document analysis, special data, copies of status quo map). To carry out the inheritance work, authors had collected additional data to build infrastructure database. The research has implemented two sub-processes as follows [11]:

- Spatial data is divided into themes (climate, salinity level, typhoon, traffic, housing, water supply and drainage, etc.) and entity classes (regions, roads, points, and layers of decorative text if needed); attribute data associated with spatial data. GIS data established on the original scale 1/10000, VN2000 projection, 104°30′ longitude axis.
- Use conversion tools spatial format and attributes data; convert VN2000, WGS84 coordinate systems. Database is projected into Geodatabase. Other sources of data which have different projected but are also registered in GIS, then converted to the same frame of reference.

In order to obtain research objectives, the authors establish research procedure to include following steps: (1) Problem statement, (2) Establishment of research objectives, (3) Literature reviews on the field of GIS application for urban planning, (4) Data collection from the literutures as well as from the field of RachGia city, (5) Data analysis, (6) Result discussion, and (7) Conclusions and recommendation. Throughout the whole paper, all mentioned steps have been accomplished totally to obtain all research targets.

4. Data collection

Once collected, the data is standardized into Arcgis format data (shape file), with the aim to synchronized with national data system so the study has used the Vietnam 2000 national frame of reference [12]. The data is collected from the local administration entities and other various sources to be used in the study (Table 1). From the collected data, the information layers are established: hydrology, land use, digital elevation map (DEM), . . . the DEM is established based on using elevation data points processed by Inverse distance weighted of Eba (2013) [13]. Data collection is from followings sources: (1) Spatial Data collected from KienGiang Province's Department of Construction, RachGia City People's Committee and Southern Institute of Water Resources Research of Vietnam for RachGia City Digital Elevation Map (DEM) at Scale of 1:10000, Existing Maps of Urban Infrastructure: Transportation, Water Supply and Sewage [14], RachGia Existing Land

Table 1. Record of Flooded Urban Area

Land classification	Area (ha)	Proportion (%)
Residential land	1 517	100
Saline instrusion residential land	150	10

Used Map in 2012–2021, Saline Intrusion in the Mekong Delta Map, and Bourdary Map of Flooting Area on RachGia city, Kien Giang Province [[14]; and (2) Attribute Data collected from KienGiang Statistics Department for Statistical Year Book of RachGia City from 2003 to 2021 [16] and Flood and Storm Prevention Report of RachGia City from 2011 to 2021 [17].

5. Location of study area

RachGia city is located in the center of KienGiang Province, looking over the RachGia bay of Eastern sea, the city has a total of 12 public entities: 11 wards and the commune of PhiThong. Natural area is measured at 103,54 km^2. The city is equipped with the national highway No. 80, 61, and the seaside corridor road. This is a coastal city, until 2020 the percentage of civilian's permanent, semi-permanent houses reached about 90%. RachGia city also has the dense network of canals including the water supply mains such as RachSoi, RachGia – LongXuyen and RachGia – HaTien canals. In recent years, due to the effects of climate change which cause the saline intrusion, inundation, river bank erosion, coastline appear more and more frequently, especially the rising of saline intrusion, which is more seriously in the dry season leading to the saline contamination in the water sources from rivers and reservoirs [18].

6. Results and discussions

6.1. Natural conditions – slope of surface terrain

The analysis to choose urban construction land is necessary, because the identifying most potential and appropriate zone to develop urban spatial plays a very important role. The slope is one of the first factors of the evaluation criteria for selecting urban construction land. The analysis and evaluation of construction land is based on the results of calculating the slope. According to regulations and standards ([19,20]) land for construction of houses and public buildings or industrial construction, for areas with a slope of less than 0.4% is a favorable area for construction. To calculate the slope, the study was based on the digital elevation model to build the slope. Looking at the results, the city has a flat and low topography, with a small slope below 0.5%. With the slope criteria in the regulation of selecting urban construction land, the whole RachGia city satisfy the slope requirements in construction (Fig. 2).

6.2. The effects of climate change

6.2.1. Housing damages

For an overview of the damage caused by tornadoes and typhoons, a map of damaged homes is sketched in every ward from 2011 to 2016. During this time, more than 120 houses had been collapsed due to thunderstorms and heavy rain in the whole city. According to

2012 statistics [21], RachGia city has a total of 44 733 permanent and semi-permanent houses. The above analysis shows that PhiThong commune and VinhThong ward have the highest rate of houses damaged by natural disasters of 2.56%, whereas the wards of VinhThanh, VinhBao andVinh Lac are not affected (Fig. 3). Fig. 4 shows that in 2012 the number of damaged houses was over 60, in 2014 the number of damaged houses decreased, but in the last two years (2015, 2016) the number of damaged houses increased, which reflects the increasing of extreme weather intensity.

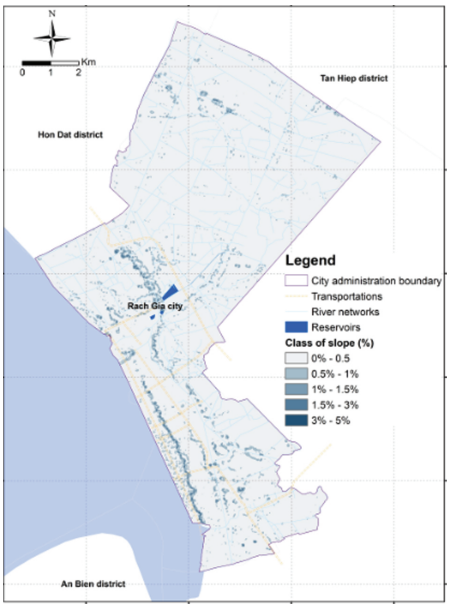

Fig. 2. Slope map of study area

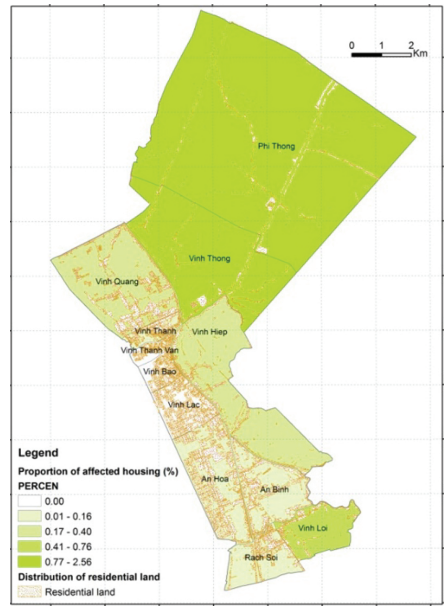

Fig. 3. Affected housing allocation map with public entities boundaries

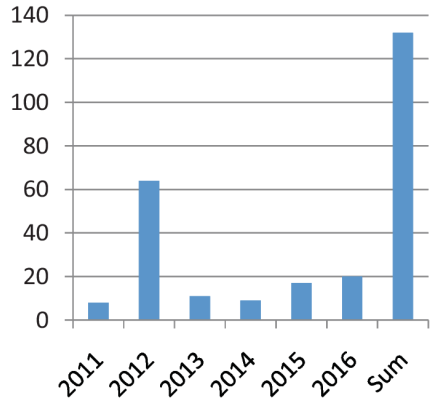

Fig. 4. Yearly records of affected housing in the period 2011–2016

6.2.2. Flooding

The reasons which cause flooding to the area are: heavy rain, high tides and the combination of both rain and high tide. The flooded areas were calculated based on the hydraulic hydrological model. This data helps in identifying urban areas affected by flooding. The analysis results show that flooding areas are mainly located in central urban zones. The zoning of frequently flooded urban areas has determined the urban flooded urban area to be around 150 hectares, accounting for nearly 10% of the urban residential land area (Fig. 5 and Fig. 6 together with Table 1).

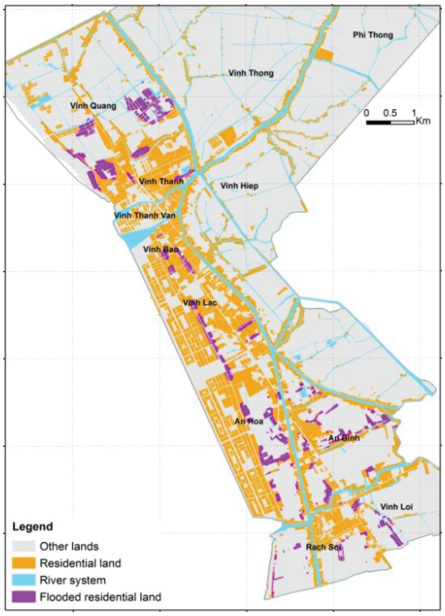

Fig. 5. Flooding map of study area

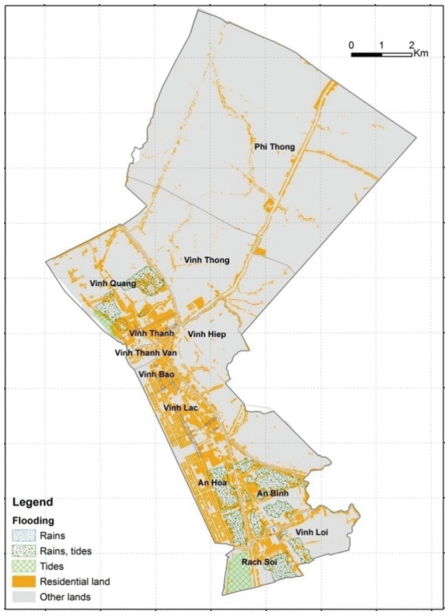

Fig. 6. Flooding areas map due to heavy rain and tides

6.2.3. Saline intrusion

According to the report of the Southern Institute of Water Resources Research on "Forecasting saline water intrusion in the Mekong Delta", the salinity measured on the river at 0.3 g/l affected the intake of water used for irrigation and domestic water supply (Fig. 7). In fact as shown on Fig. 8, the level of salinity measured and surveyed in RachGia area in the dry season was from 1 g/l to 4 g/l, there were even times when the salinity level reached over 10 g/l.

The water supply network of RachGia city consists of a reservoir system with a total volume of about 600,000 m^3 and a 3.2 km length of water channels, so it cannot meet the demand when the water supply is saline for a long period (the reservoir system can sustain about seven days of production). Due to the high salinity of underground aquifers, surface

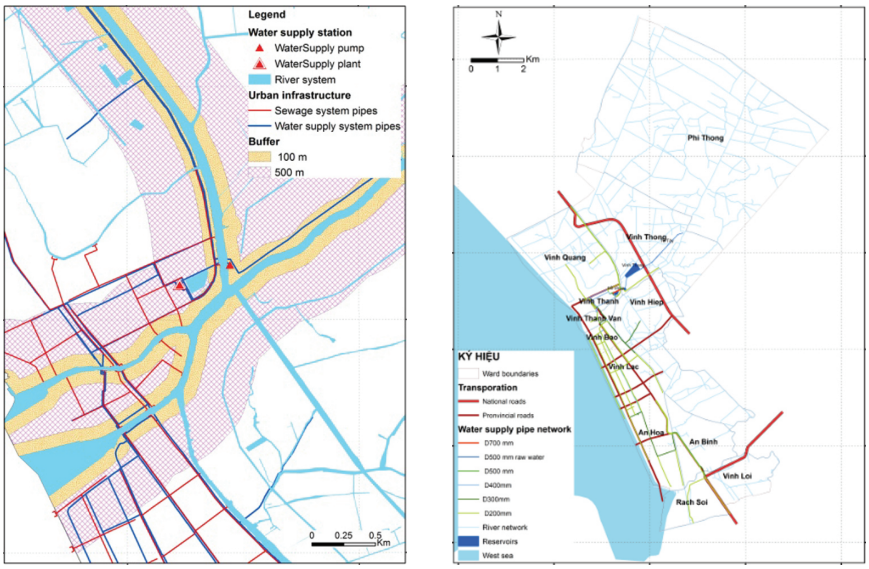

Fig. 7. Affected urban infrastructures by salinity intrusion

Fig. 8. Saline intrusion map of RachGia city

water is the main source of supply. The reservoirs get water from the canals. Based on the survey results, the current effect of saline intrusion on urban water supply infrastructure of RachGia city is significant. The results of the data overlay show that the water supply system is under the high influence of saline intrusion.

7. Conclusions and recommendations

Based on the application of GIS, the database system for researching and assessing the impact of climate change on the urban infrastructure of RachGia city, the information layers were built and thematic maps were established. Maps of identifying affected areas, impacts, etc., will be data for subsequent analyzes of climate change vulnerability to urban infrastructure. This result is confirmed by studies showing sensitive areas that need special attention when managing land use, as well as water conservation measures such as delineation of surrounding reservoir protection areas. Protected areas established around the city artificial lake must allow decision makers to regulate domestic, industrial and agricultural activities and monitor land use or manage to avoid pollution being made to this resource which is important for the regional population. In particular, this can be a reference data in the plan to build more water reservoirs for the city or pollution management and prevention works. With the prospect of saline intrusion in the river routes, the authorities need to build sluice gates to prevent saline intrusion, in combination with regulating drainage. This paper's outcomes demonstrate the thematic layers necessary to complete in order to optimize the decision-making process on the theme of urban management [10].

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