APPLYING GIS AND REMOTE SENSING TO DETERMINE POTENTIAL DISTRIBUTION AREAS OF TURTLE IN NAM DONG NATURAL RESERVE, THANH HOA PROVINCE

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The study of Nam Dong Natural Reserve in Thanh Hoa province utilized remote sensing and GIS to assess potential turtle distribution across its 646.95 ha area, comprising lowland subtropical, lowland tropical, and rocky mountain forests. The reserve, rich in biodiversity, hosts species listed on both the Vietnam and IUCN Red Lists. Vegetation was classified into five types, with medium forest covering 74.34%, and elevation into five bands, with 50.02% in the 250-500m range. The study identified 31 turtles from four species, predominantly found in medium forest (65.52%) and the 82-250m elevation band (51.72%). Platysternon megacephalum favored stream habitats, while Cuora galbinifrons was less water-dependent. The habitat suitability map categorized the reserve into four levels: very suitable (57.48%), suitable (30.74%), less suitable (9.41%), and not suitable (2.37%). Cuora galbinifrons had the largest very suitable area (447.95 ha), while Platysternon megacephalum had the largest not suitable area (348.77 ha). Overall, the reserve provides favorable conditions for freshwater turtles, with substantial forest coverage and a dense river network.

Keywords: *GIS, Turtle species, endangered species, Nam Dong*

I.   Introduction

Tropical and subtropical forests are vital ecosystems, hosting rich biodiversity including numerous animal and plant species. These forests play crucial roles in human life and environmental health by providing resources such as wood and oxygen, regulating water, and serving as habitats for diverse fauna including valuable and rare species. Among these species are terrestrial turtles and tortoises.

Vietnam is a biodiversity hotspot, ranking 9th globally for turtle species richness with 32 species, 27 of which are freshwater and terrestrial, and 5 marine. However, the conservation status of Vietnamese turtles is precarious, with 85.1% of native freshwater and terrestrial species listed as Threatened on the IUCN Red List. Major threats to these species include habitat loss and overhunting for food, traditional medicine, and religious purposes. Vietnam's forest cover significantly decreased from 43% in 1945 to 36% in 1990. Although reforestation efforts since 1992 have increased forest cover, the quality of these forests remains poor. Much of the recovery involved homogenous tree plantations unsuitable for turtles, while natural forests remain fragmented and isolated. Trade, especially for the Chinese market, has also severely impacted turtle populations. IUCN assessments indicate that populations of most Vietnamese turtle species have declined by 50-90%. The Black-breasted leaf turtle (*Geoemyda spengleri*) is a key focus of conservation efforts. To protect these

turtles and their forest habitats, Vietnam has implemented numerous laws and regulations. Effective enforcement of these legal measures requires technological support.

Advancements in science and technology, particularly satellite imagery and GIS remote sensing, have revolutionized environmental research. These technologies enable efficient, large-scale data collection and analysis, aiding in natural resource management. High-resolution remote sensing images are particularly valuable for planning and managing natural resources. Geographic Information Systems (GIS) and remote sensing have emerged as essential instruments for wildlife conservation, particularly the analysis of species distribution. Researchers can now map habitats, track changes in the environment, and forecast possible distribution patterns thanks to these tools. For example, Ficetola et al. (2010) modelled the distribution of amphibians in the Mediterranean region using GIS and remote sensing, finding important regions for conservation. Similar to this, Tucker et al. (2018) used remote sensing to evaluate the sea turtle population distribution worldwide, identifying important nesting locations and migratory paths. Turner et al. (2003) provided evidence of the efficacy of employing satellite imagery to track changes in vegetation cover, which has a direct impact on the distribution of plant species. These illustrations demonstrate the increasing significance of remote sensing and GIS in biodiversity conservation efforts.

Remote sensing and GIS technology have been used in many research to map the habitats of different plant and animal species, which is important for conservation efforts. For instance, Elith et al. (2011) predicted the distribution of terrestrial animals in Australia using GIS-based models, which aided in identifying regions at danger of habitat degradation. In a similar vein, Nagendra et al. (2013) evaluated changes in India's forest cover using remote sensing, which gave important information about how these changes might affect the region's biodiversity. In a different study, Kumar et al. (2014) mapped the invasive plant species' distribution throughout the Himalayas using GIS, which helped guide management plans to save native ecosystems. Nam Dong Natural Reserve in central Vietnam, covering 646.95 hectares, is a protected area characterized by a limestone forest ecosystem. It supports high levels of endemic and rare fauna and flora. Investigations have identified 18 species listed in the Vietnam Redlist and IUCN Red List. The use of GIS and remote sensing to investigate species distribution in Nam Dong is yet mainly unexplored. There aren't many studies specifically utilizing these technologies to study turtles in this region, and there isn't much research using GIS to support other animal conservation initiatives in Nam Dong. This emphasizes the importance and originality of my study, which attempts to close a significant knowledge gap on the distribution of species in this area.

For these reasons, including the importance of GIS, the lack of studies on turtles in the research area, and the need for more focused conservation efforts, this study titled "Applying GIS and remote sensing to determine potential distribution area of Turtle in Nam Dong Natural Reserve, Thanh Hoa province" is conducted with the following objectives: 1) To develop vegetation, elevation, and stream maps of the study area; 2) To identify and rank the factors influencing the distribution of certain turtle species in the region; and 3) To create potential distribution maps for these turtle species within the study area. The research results will serve as an important scientific foundation for the effective and sustainable management, conservation, and development of turtle species in Nam Dong in the future.

II. Materials and methods

2.1. Study site

Nam Dong Natural Reserve is located in the northwest of Thanh Hoa Province, spanning Quan Hoa and Quan Son districts, approximately 155 km from Thanh Hoa City. Its geographical coordinates are 20°18'07" to 20°19'38" N and 104°52'8" to 104°53'26" E. The reserve features complex mountainous terrain with a dense network of rivers and streams, creating steep, rugged landscapes typical of karst ecosystems. The average elevation is 700-900 meters with slopes of 10-45°. The climate is influenced by the Northwest region, with average temperatures ranging from 23-25°C, and annual rainfall between 1,600-1,760 mm. Nam Dong covers 624.71 hectares of forest, maintaining 96.56% coverage, home to valuable conifer species. The forest includes tropical evergreen closed rainforests and tropical moist evergreen closed forests on limestone and earth mountains.

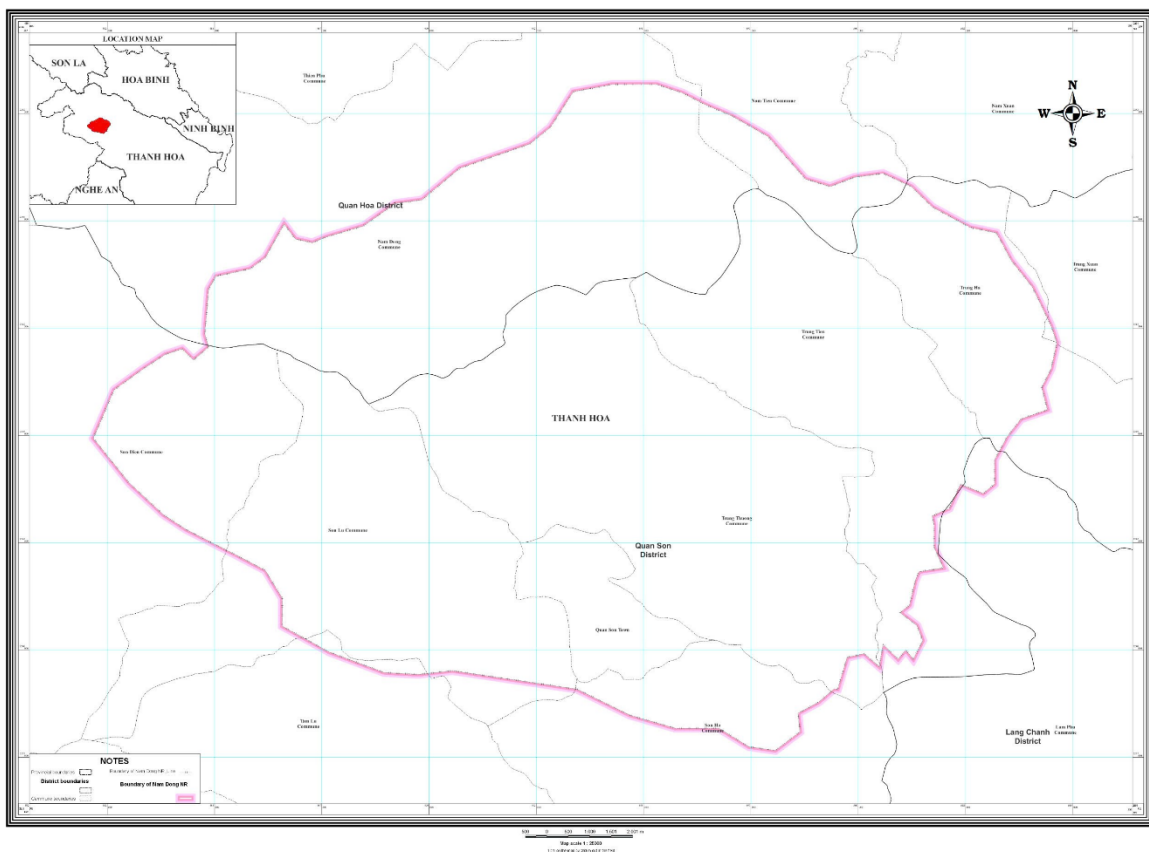**NAM DONG SPECIES AND HABITAT CONSERVATION AREA**

Fig 1. Map of geographical location of Nam Dong Natural Reserve

2.2. Materials

Study used Landsat 8 satellite image with a resolution of 30x30m to establish a map of current status, determination of biomass distribution and mangrove forest reserve in the study areas as shown in **Table 1**

Table 1. **Satellite image**

ID	Image codes	Resolution (m)
1	LC08_L1TP_127046_20190525_20190605_01_T1	30

Source: https://earthexplorer.usgs.gov

2.3. Methods

2.3.1. Investigating current status in Nam Dong Natural Reserve

2.3.1.1. Collecting documents related to the map

Paper maps, digital maps: Forest inventory map of the whole district provided by the Forest Protection Department of Quan Hoa District and Quan Son District.

2.3.1.2. Collecting related documents on forest status

The summary included annual reports from the People's Committee of Quan Hoa and Quan Son Districts, the statistical yearbook of Thanh Hoa Province, and reports on major programs and projects in the area. It also incorporated legal documents from the State, province, and district related to the study area. Additionally, it encompassed documents on local natural, economic, social, and human conditions, including hydrological climate data, survey results, land, population and labor statistics, socio-economic policies, and village history.

Based on the coordinates identified by GPS and remote sensing images, researching and developing forest resource status maps by ArcGIS software 10.4.1. Methods of interpreting and classifying landsat images according to the following diagram:
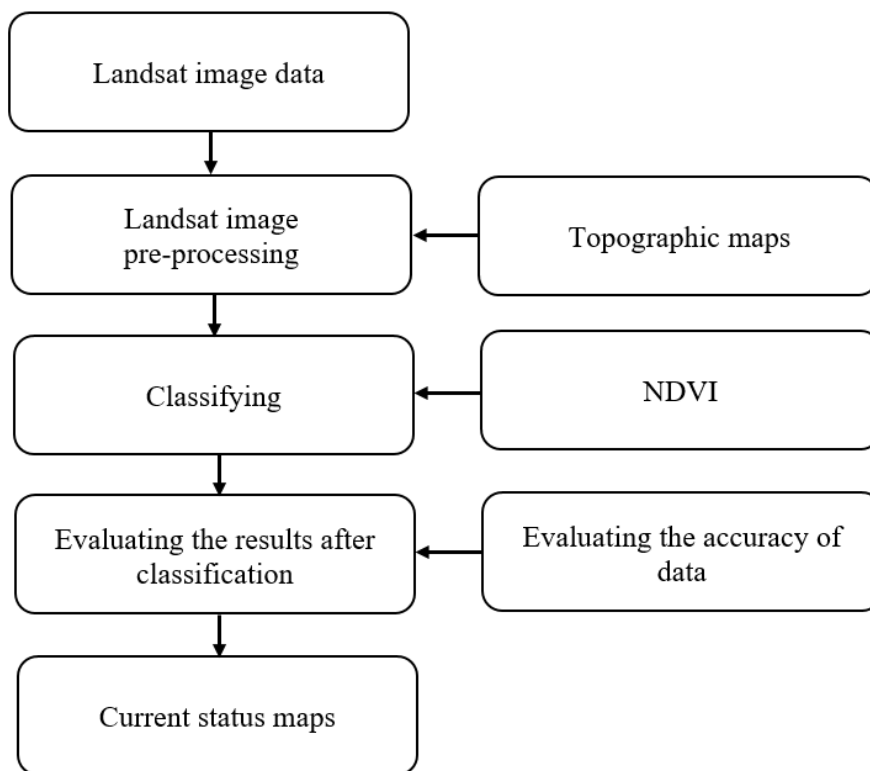

Fig 2. Steps to build the current status map in the study area

Step 1: Pre-processing Landsat remote sensing image:

Converting the numerical values (DN) on the image to the value of physicalradiation at the sensor by the formula:

$$L_\lambda = M_L \times Q_{cal} + A_L$$

Converting the values of physical radiation at the sensor to the values of reflection in the upper atmosphere of the object (object) by the formula:

$$\rho\lambda = (M_\rho Q_{cal} + A_\rho)/sin(\theta_{SE})$$

Step 2: Classifying images

Visual interpretation method

NDVI Vegetation Index

Formula: $NDVI = \frac{(NIR - Red)}{(NIR + Red)}$

Step 3: Evaluating accuracy and process images after classification

This research investigated 500 points for 5 subjects and used 40% of the survey points to evaluate the accuracy.

Post-Classification Accuracy: Used to evaluate the quality of the satellite image to be interpreted or to compare the reliability with the results of different methods in the classification of remote sensing images.

Post-Classification: After classifying, we need to carry out classifying procedures to create layers that can be mapped out by generalizing the information.

$Accuracy = \frac{Total\ Accurate\ points}{Total\ points} * 100\%$

Step 4: Create current status map

Conduct to divide to 5 objects: Rich forest, Medium forest, Poor forest, Shrub, Bare land and water.

2.3.2. Construct thematic maps of distribution of turtle by factors in Nam Dong Natural Reserve

2.3.2.1. Collect primary data

Step 1: Structure interview

A random sample of 50 households in surrounded Nam Dong Natural Reserve is selected in a survey. Questionnaires are prepared before going to the field to get information about: General information of interviewees (age, gender, education level, main income, etc.); their knowledge about distribution of turtle and forest type in local area.

Step 2: Semi-structure interview

Interviewing 15 staffs who work in Management board of Nam Dong Natureal Reserve by using checklist to get information and data on the issues: Current population, living standard of local communes; Local awareness about forest resources management. The role and level of local community participation in forest resources management in Natural Reserve.

Step 3: Establish transects
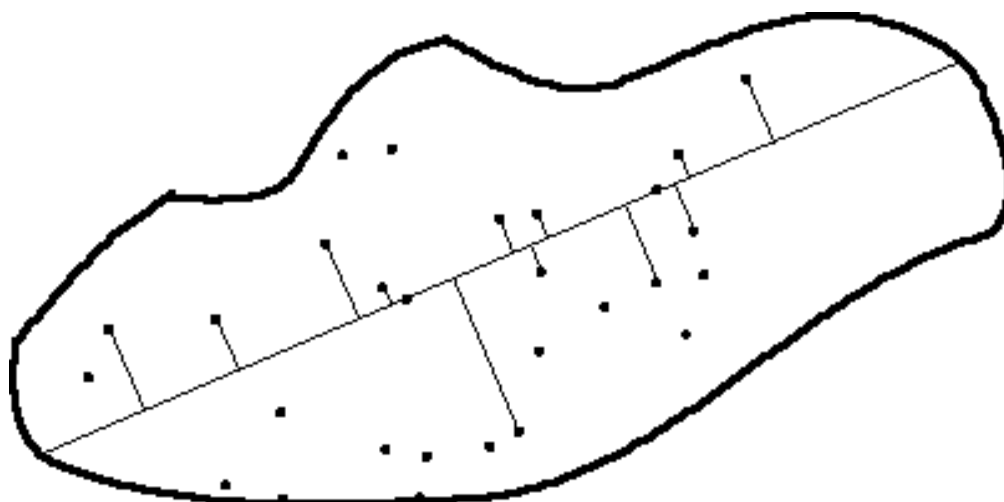
Fig Ошибка! Текст указанного стиля в документе отсутствует.**. Transect method**

The investigation process involved using GPS to determine the direction of travel and the length of each transect. The collected data was meticulously recorded in a data sheet, which includes details such as transect number, time, location, topography, and coordinates. The data sheet captured essential information including the transect number, species name, quantity, distance (in meters), and any additional notes.

Field surveys were carried out during a period of 2 years in Nam Dong Nature Reserve. Ten line transects were established with a length of 3.5 – 21km in Lo and Bau villages (Nam Dong commune), Na Ho village (Son Dien commune), Phe and Kham villages (Tam Thanh commune), Bin village (Son Lu commune), Bang village (Trung Thuong commune), each line transect was marked the start and end points.

Step 4: Data analysis

Using Excel and SPSS software, descriptive statistics were used to the quantitative data that had been obtained in order to create charts and graphs. This procedure involved identifying the distribution of turtles in the research region and categorizing the forest structure.

2.3.2.2. Construct thematic maps of distribution of turtle by factors

To conduct thematic maps of distribution of turtle by factors, we use map of current status in part 2.3.1 and overlay the distribution of tutles.

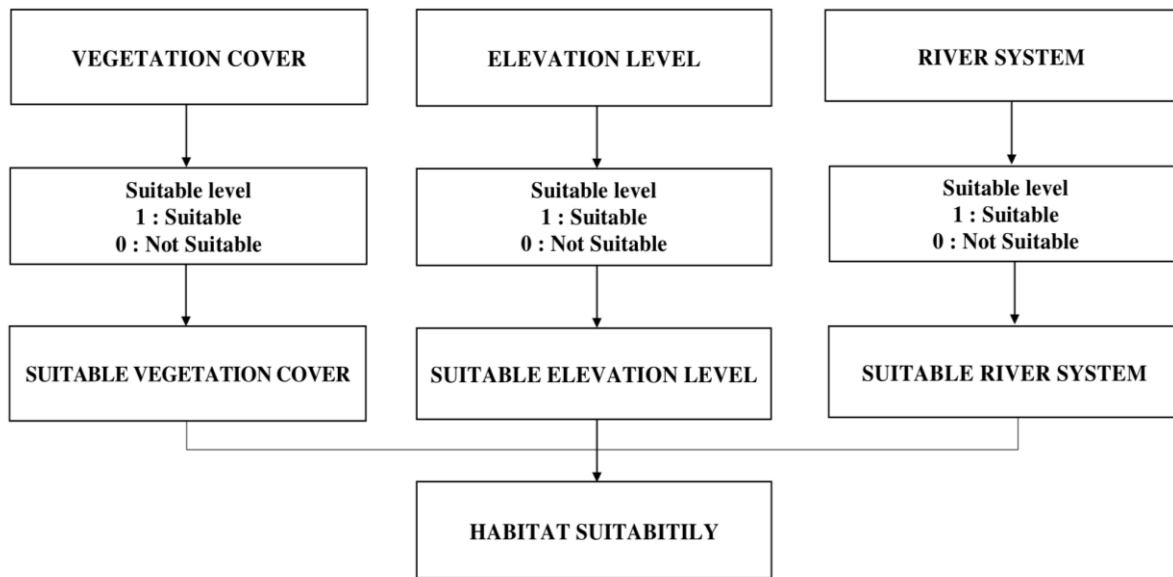### *2.3.3. Conduct suitable habitat map of turtle in Nam Dong Natural Reserve*

Fig 4. Process create maps of habitat suitability of turtle in Nam Dong Natural Reserve

We continue using current status map to create map of habitat suitability of turtle in Nam Dong Natural Reserve. Following the steps in **figure 4,** we find the area that it is suitable with total species and each species. After that, we plus 3 layers of 3 factors to get final map. All calculations and analyses were performed using ArcGIS software.

II.   Results and discussion
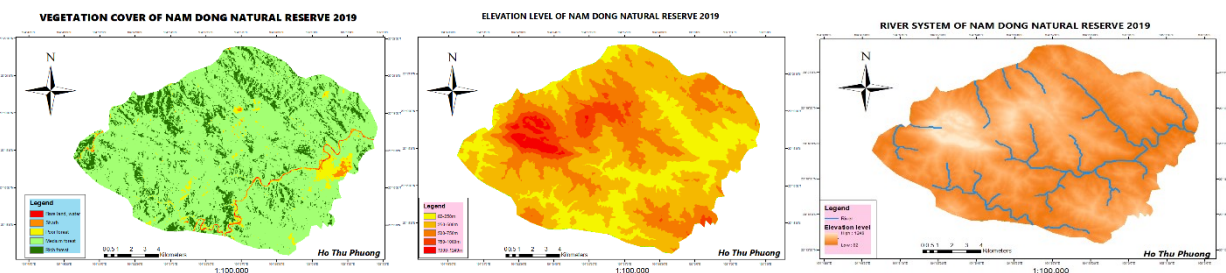## 3.1. Vegetation map, elevation and river system of Nam Dong Natural Reserve

Fig 5. Current status map of Nam Dong Natural Reserve

Basing on NDVI results, we can recognize that light green has the largest area – Medium forest (492.84 ha) accounting for 74.34% the total study area. It runs o.3 – 0.6 in NDVI value classification table. The second order – dark green is Rich forest (64.54 ha) accounting for 10.73%. The lower order is Poor forest (yellow) having 48.7 ha about 8.65%. The smallest area is orange – Shrub accounting for 2.81%. The higher percentage as Bare land, water having 22.24 ha (3.47%).

Using this DEM, we conducted current status map of elevation level in Nam Dong Natural Reserve. The study area is located quite high form 82m to 1249m. According to Figure 5, we can see that the largest area is light orange band 250 – 500m (323.48 ha) accounting for 50.02% total study area. Band 1000 – 1249m is the smallest area having 12.93 ha on total area (2.11%). Besides, yellow area presents for band 82 – 250m (124.39 ha) accounting for 20.13%. And there is 1 main river flowing through

Nam Dong Natural Reserve. This is Luong river – the first order stream of Ma river. River system is quite thick with second and third order from main stream.

3.2. Distribution of Turtle by factors
3.2.1. Distribution of Turtle by vegetation cover

There are 4 species that the study concerned about observed in different types of vegetation cover. Distribution of turtle by vegetation cover is showed in figure 7.
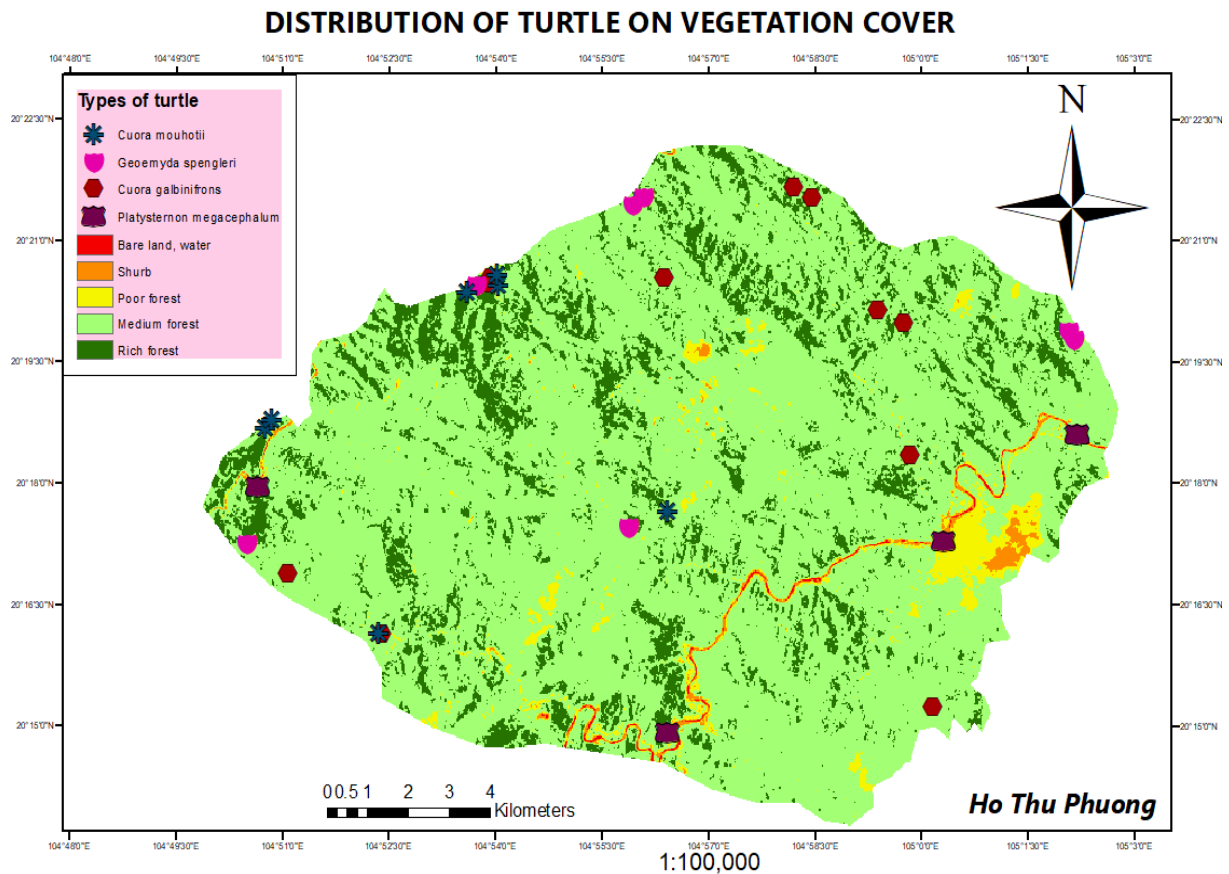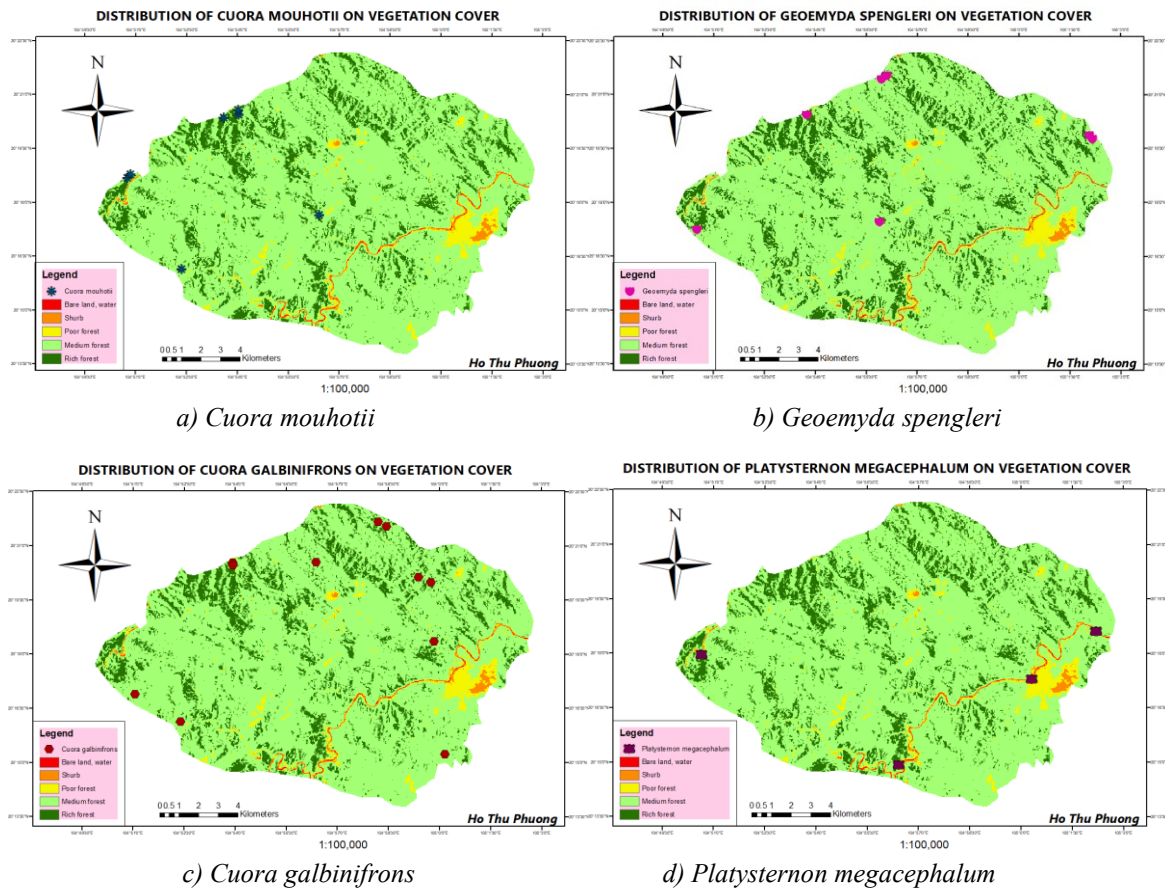

Fig 6. Map of distribution of turtle by vegetation cover in the study area

The map of distribution for each species by vegetation in Nam dong Natural Reserve was as following:

a) Cuora mouhotii

b) Geoemyda spengleri

c) Cuora galbinifrons

d) Platysternon megacephalum

Fig 7. Map of distribution of each species by vegetation cover

Particularly, we conducted map of distribution for each turtle species. The first is *Cuora mouhotii* with 7 individuals found. This species was found in two forest types including Medium forest with 5 individuals and Rich forest with 2 individuals. The forest cover at the location that *Geoemyda spengleri* ranged from 70%-90% (mean =76.4 ± 7.4 %, median = 75%), thus showing that this species inhabits dense forest patches. The next species is *Cuora galbinifrons* – the highest number of individuals. There are 11 individuals found in woodlands and evergreen forest between sun and shade. In Medium forest, we observed 8 individuals; 2 individuals were in Rich forest and only 1 individual was in Poor forest. The lowest number of individuals belongs to *Platysternon megacephalum* accounting for 13.97% total found turtle. They were found near the stream and on the rock near that.

3.2.2. Distribution of Turtle by elevation level

There are 5 bands of elevation level corresponding for distribution of turtle in Nam Dong Natural Reserve. The result is following in figure 8.
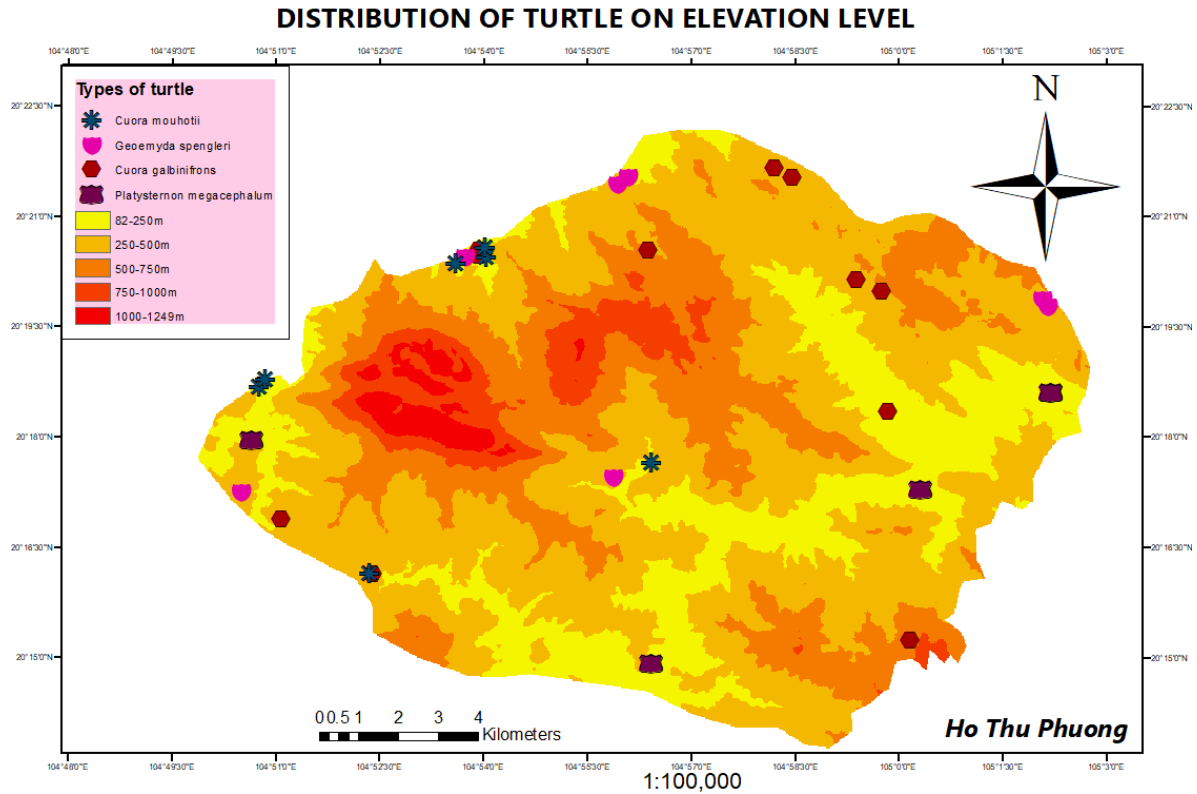

Fig 8. Map of distribution of the various turtle species by elevation level in the study area

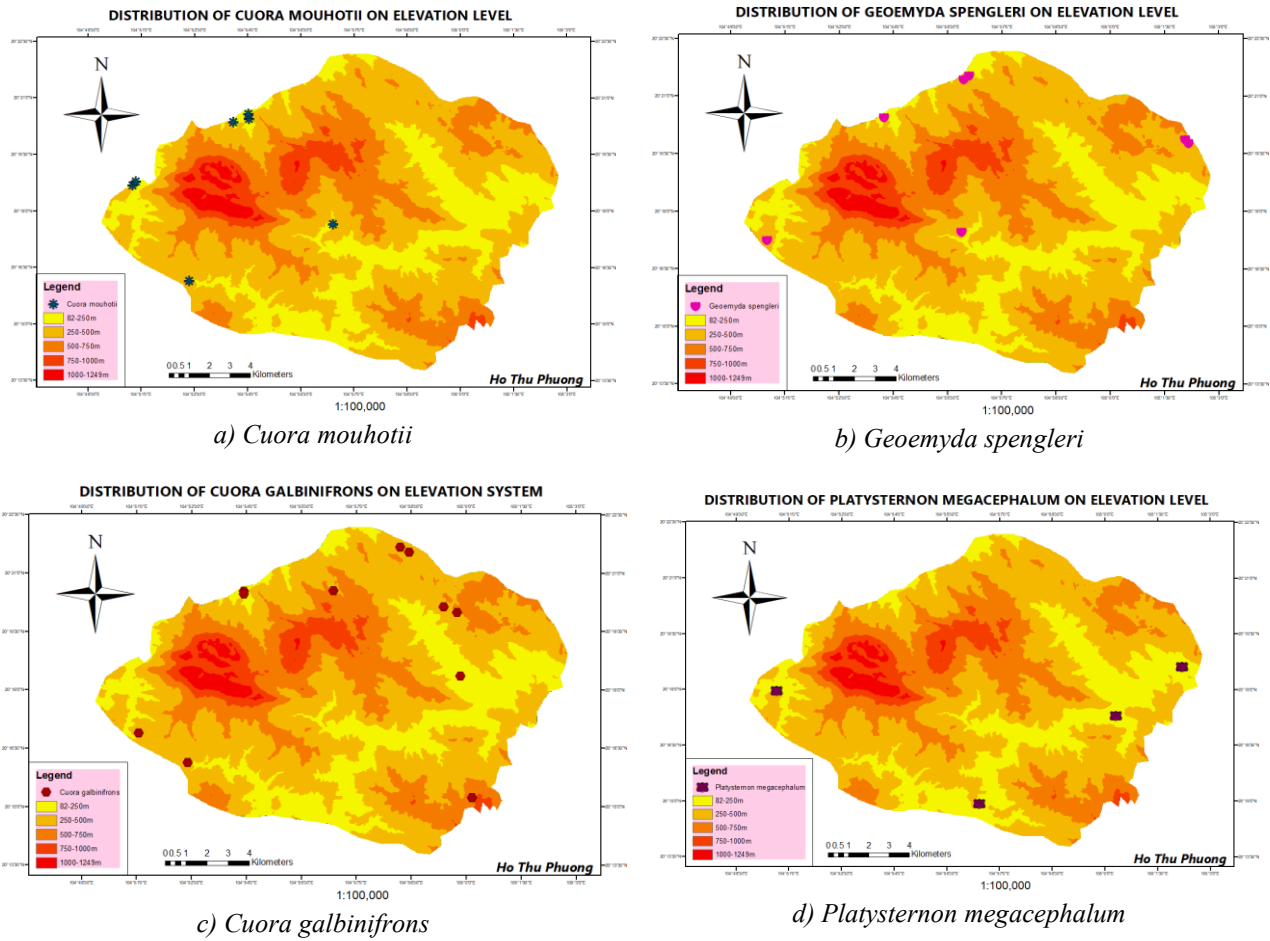The map of distribution for each species by elevation level in Nam Dong Natural Reserve was as following:

a) Cuora mouhotii

b) Geoemyda spengleri

c) Cuora galbinifrons

d) Platysternon megacephalum

Fig 9. Map of distribution of each species by elevation level

Based on the figure 9, we can see that this species just appeared in two lowest band 82 – 250m and 250 – 500m. There is only one individual observed in light orange area (band 250 – 500m). We found 6 remainder individuals in band 82 – 250m. In brief, we observed 7 turtle individuals in the height less than 500m – the favourite place for Cuora mouhotii.

3.2.3. Distribution of Turtle by river system

Depending on the field survey, quantity of turtles we found near river system was quite a few. The result of general distribution for turtle by river system in Nam Dong Natural Reserve is showed in figure 10.
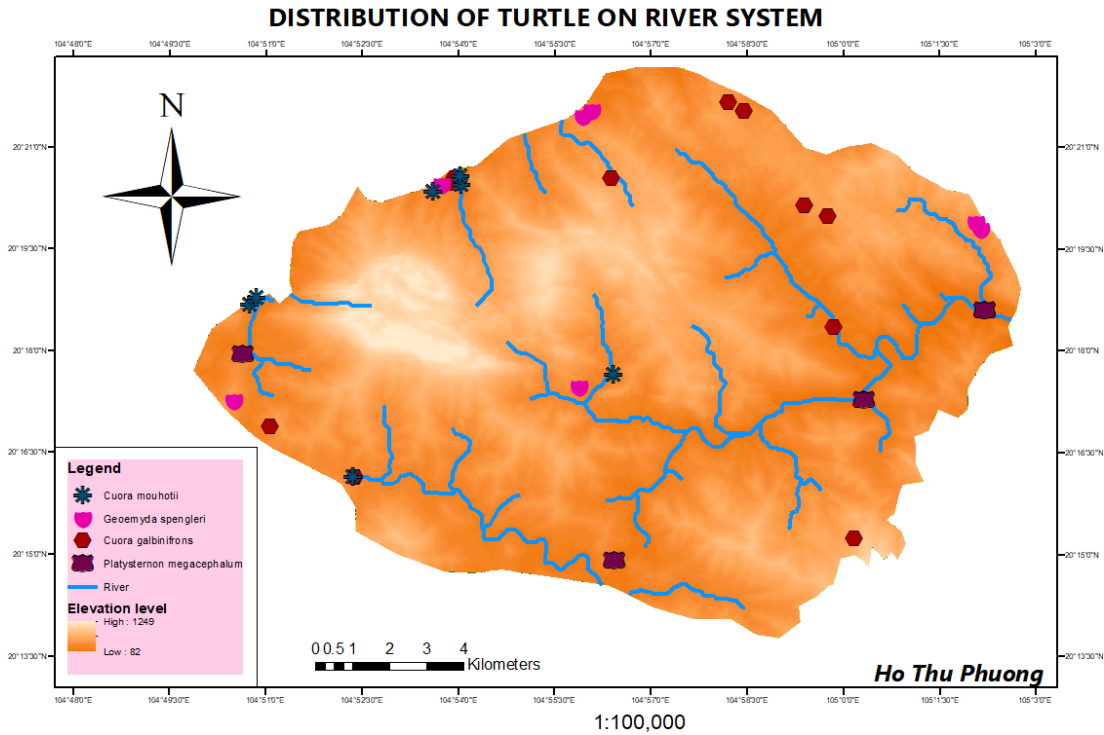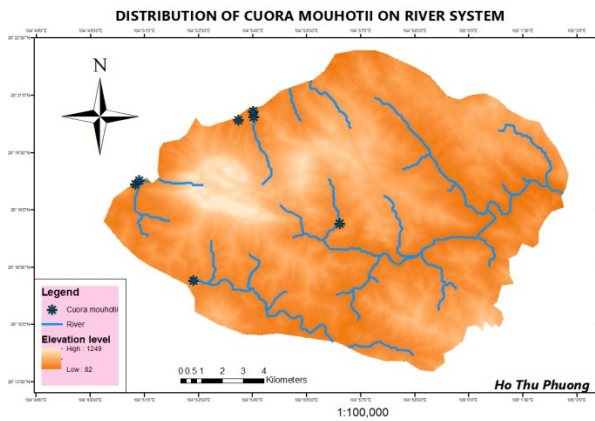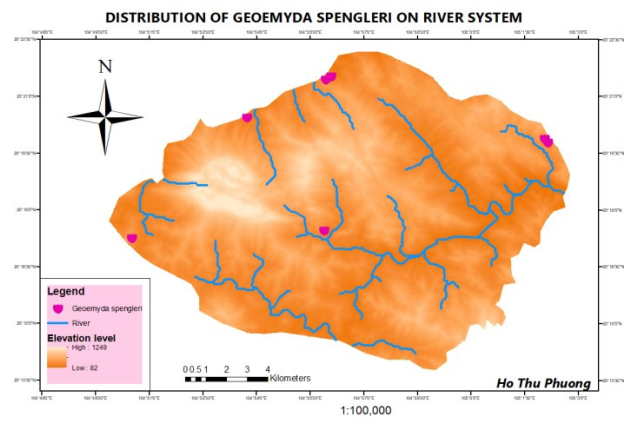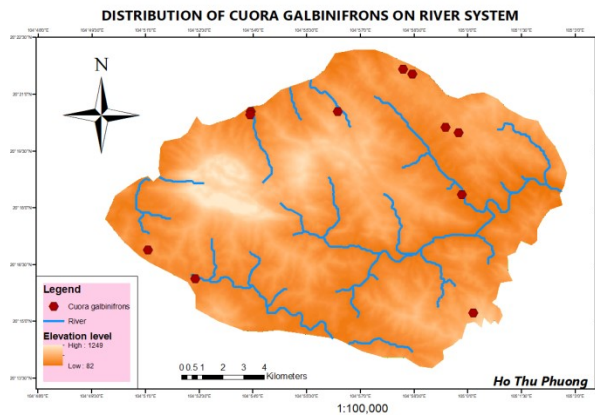
Fig 10. Map of distribution of turtle by river system in the study area
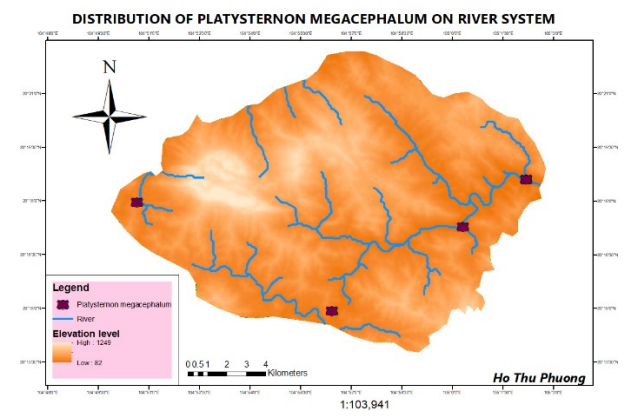

a) Cuora mouhotii

b) Geoemyda spengleri

c) Cuora galbinifrons

d) Platysternon megacephalum

Fig11. Map of distribution of each species by river system

We recognize that distribution of turtle by river system in Nam Dong Natural Reserve is unequal. Depending on elevation level, the distance of each individual to the river was really different. Some

of them in the map, we can see with the same distance but, they were at the different height. River system where is the favourite habitat for fresh water turtle is quite thick. There are some individuals observed inside river system – small streams.

3.3. The suitable habitat map of turtle in Nam Dong Natural Reserve

Suitable habitat map of turtle was built from 03 factors: vegetation cover, elevation level and river system. From field survey results, reference materials and interviewing experts, influenced factors were divided as following:

- Vegetation cover: suitable is medium forest, not suitable is other
- Elevation level: suitable is 82 – 600m band, not suitable is > 600m
- River system: suitable is surrounding 1200m, not suitable is >1200m

Total process to create suitable habitat map for turtle was built as following figure 12 on software ArcGIS 10.4.1.
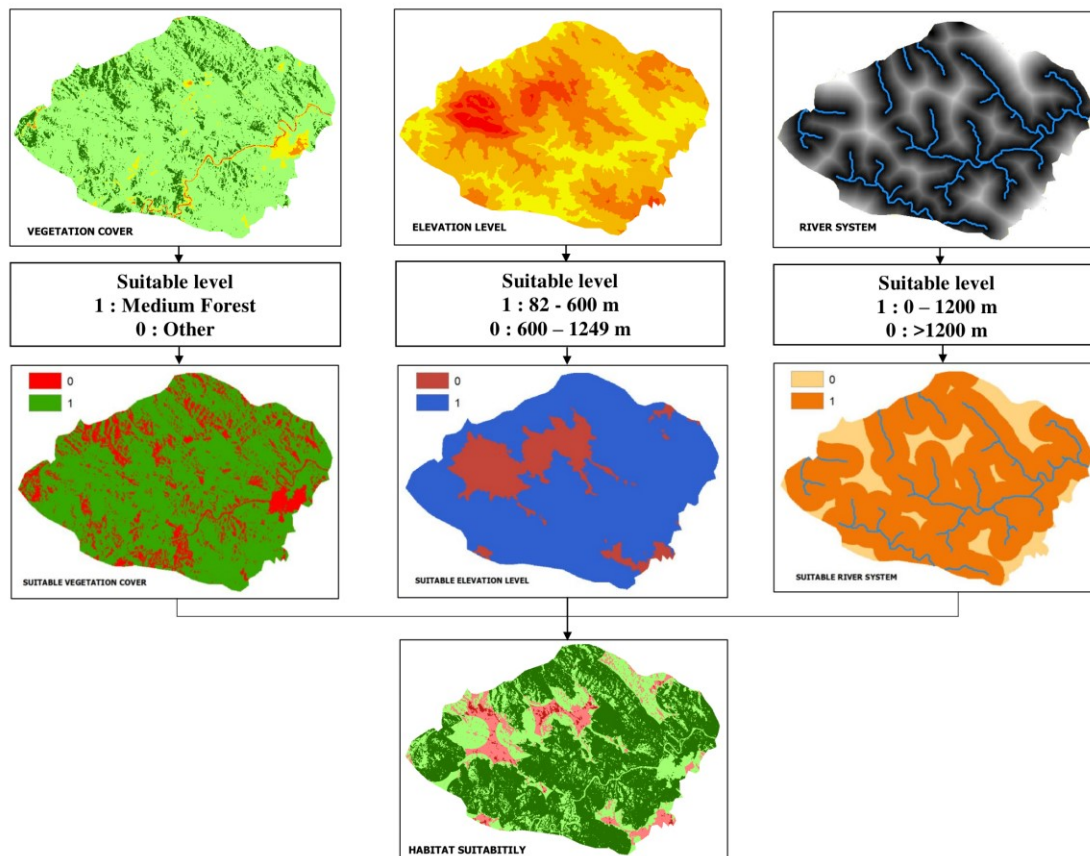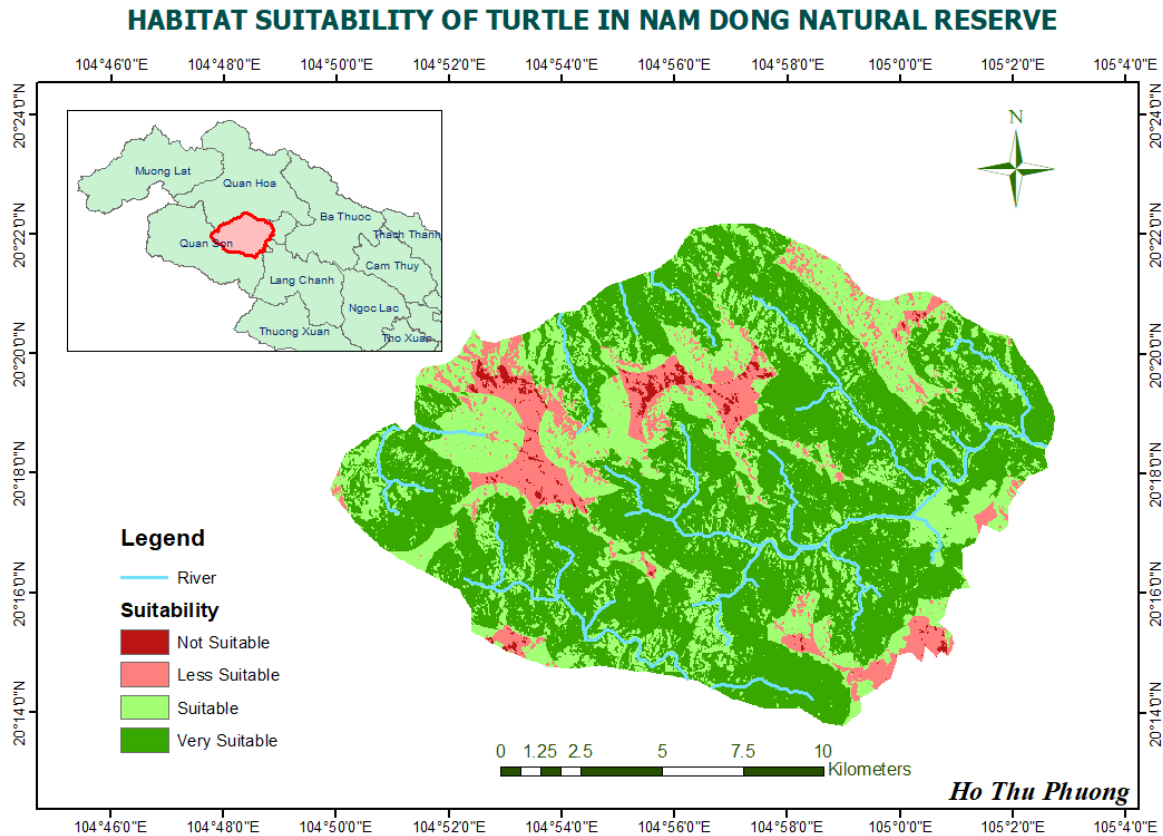

Fig 12. Process to create suitable habitat map for turtle in the study area

Fig 13. Suitable habitat map for turtle in the study area

Nam Dong Nature Reserve features a lowland subtropical forest ecosystem above 700 meters, with mixed needle-leaved and broad-leaved trees, and a dense river system, making it suitable for freshwater turtles, including the four species of interest in the study. The study identified 381.7 ha (57.48%) as highly suitable, 200.55 ha (30.74%) as suitable, 58.23 ha (9.41%) as less suitable, and 6.47 ha (2.37%) as not suitable for turtles. The reserve provides good forest cover and a dense river system, but threats include habitat destruction, deforestation, and overexploitation for food, traditional medicine, and the pet trade, particularly in China where the species is bred in captivity on a small scale.
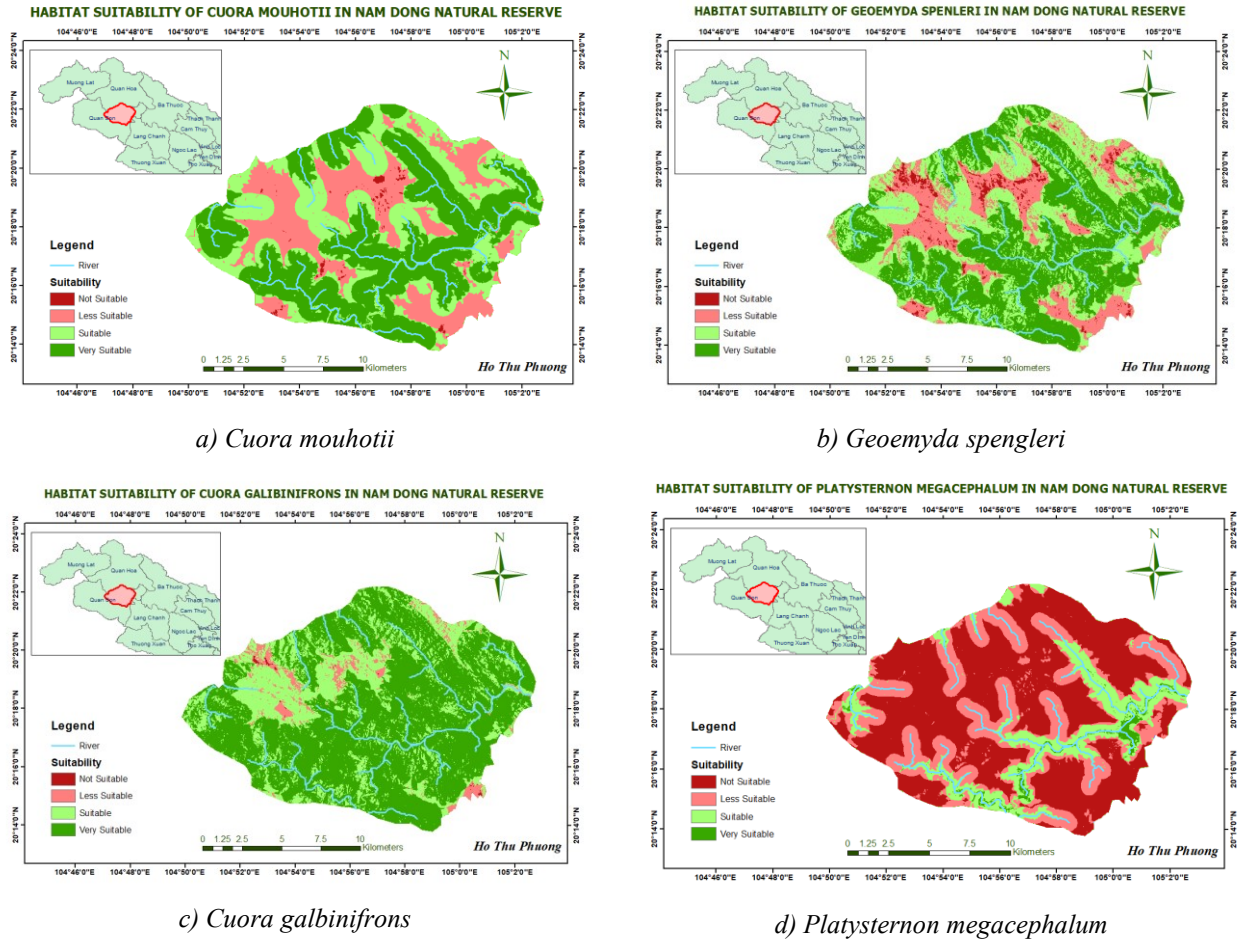
a) Cuora mouhotii

b) Geoemyda spengleri

c) Cuora galbinifrons

d) Platysternon megacephalum

Fig 14. Suitable habitat map for each species in the study area

Cuora mouhotii is listed as endangered by the IUCN, with its population in steep decline, particularly in Vietnam, due to capture for food and pets, and legal export. Major threats include deforestation and hunting. In Nam Dong Natural Reserve, the habitat is quite suitable for Cuora mouhotii. According to figure 5.16, the most suitable area covers 290.47 ha (44.91%), while 194.09 ha (30%) is suitable, 158.44 ha (24.49%) is less suitable, and 3.95 ha (0.61%) is not suitable. Overall, the topography of Nam Dong Natural Reserve provides a good habitat for Cuora mouhotii.

According to figure 5.18, the largest and best area for *Geoemyda spengleri* in Nam Dong Natural Reserve is about 300.13 ha (46.39%). The suitable area is 220.28 ha (34.05%), while the less suitable area is 110.95 ha (17.15%). The not suitable area is the smallest at 15.59 ha. Despite having a larger not suitable area than *Cuora mouhotii*, Nam Dong Natural Reserve remains a commendable habitat for *Geoemyda spengleri*.

Due to having the highest number of individuals found during the field trip, the potential distribution of *Cuora galbinifrons* is larger than that of others. The very suitable area reaches 69.24% (447.95 ha), accounting for nearly three-quarters of the total area of Nam Dong Natural Reserve. The suitable area is 174.48 ha (26.97%), and the less suitable area is 23.61 ha (3.65%). The not suitable area is minimal at 0.91 ha (0.14%). This species is the most common turtle in the area, and nearly all of the study area is suitable for its survival, despite being one of the most endangered turtle species globally according to the IUCN (2018).

Platysternon megacephalum, one of the four species studied, favors water the most. According to figure 15, individuals are typically found within 500m of river systems. This species can live in poor forest, shrub, and bare land, with an elevation range of 82-250m being suitable. Unlike the other three species, the largest area identified on the map (figure 5.22) is not suitable, covering 348.77 ha (53.91%). The very suitable area is the smallest, at 14.82 ha (2.28%). The suitable area covers 98.14 ha (15.17%), while the less suitable area is 185.22 ha. Despite being the rarest turtle species in terms of habitat suitability, Nam Dong Natural Reserve is still a good place for Platysternon megacephalum due to its significant forest reserves

IV. Conclusion

Nam Dong Natural Reserve in Thanh Hoa province was studied for potential turtle distribution using remote sensing and GIS. The reserve, spanning 646.95 ha, comprises three main ecosystems: lowland subtropical forest above 700m, lowland tropical forest below 700m, and tropical forest on rocky mountains. The area boasts diverse flora and fauna, including species listed in the Vietnam Red List and the IUCN Red List. Vegetation cover was classified into five types, with 74.34% being medium forest. Elevation was divided into five bands, with the majority (50.02%) in the 250-500m range. The reserve also features a thick river system.

The study found 31 individual turtles of four species in the reserve: *Cuora mouhotii, Cuora galbinifrons, Geoemyda spengleri,* and *Platysternon megacephalum*. Turtles were mostly found in medium forest (65.52%) and the 82-250m elevation band (51.72%). *Platysternon megacephalum* favored water habitats, with most individuals found near streams. *Cuora galbinifrons* was less dependent on water, with some individuals found far from rivers. The study highlights the reserve's intermittent and large stream networks as potential habitats for rare freshwater turtles.

The final habitat suitability map categorized areas into four levels: very suitable (57.48%), suitable (30.74%), less suitable (9.41%), and not suitable (2.37%). For *Cuora mouhotii*, the most suitable area was 290.47 ha. *Geoemyda spengleri* had a very suitable area of 300.13 ha. *Cuora galbinifrons* had the largest very suitable area at 447.95 ha. Conversely, *Platysternon megacephalum* had the largest not suitable area at 348.77 ha. Overall, Nam Dong Natural Reserve provides good habitat conditions with significant forest reserves and a thick river system, suitable for freshwater turtles.

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