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Quantification of Green Carbon Changes in Relation with LULC Changes using Remote Sensing - GIS Technology in Kuantan River Basin

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ABSTRACT

Land use land cover changes (LULCC) is a process that is influenced by anthropogenic effect. The growth of population is increasing, which leads to a demand on metropolitan regions. However, these urbanization and development are significant contributors to the expansion of LULCC conflict at an alarming rate to fulfil the human needs. LULCC has derived huge effects towards the environment which is biomass and green carbon changes. LULCC has caused vegetation covers of the land being degraded which reducing the total biomass of the area and implemented to that, the carbon stock for the area is increasing causing climate change and global warming. Therefore, the estimation of total carbon is important to be conducted. The existing map of LULCC is not update, the inventories information about the total carbon in Kuantan is not well covered, people in this region are lack of awareness about the harmful of carbon in the air, and conventional method is hard to be applied for carbon estimation are the problems that have derived for this study to be conducted. This study is focused on quantification of total carbon in Kuantan district to raise the awareness towards the local communities about the danger of high amount of carbon. The objective of this study is to classify LULC types in Kuantan district using geospatial artificial intelligent (GeoAI) approach on satellite images, to relate soil types, vegetation index and satellite – based total biomass in Kuantan River basin and to map green carbon changes in Kuantan based on quantified biomass using remote sensing – GIS technology. Therefore, this study is focused on Kuantan district to quantify the total biomass and carbon in this area by using selected multispectral satellites images with high spatial resolution Landsat 8 OLI, and Landsat 5 TM.

1. Introduction

Green carbon emissions into the environment are increasing these days as the situation worsens. The biggest concern is the Malaysian atmosphere, as it tends to accumulate a high amount of carbon dioxide (CO_2). It has derived negative effects towards the environment such as climate changes issue and global warming. Extreme weather conditions are linked to climate change that led to the rising

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of sea surface temperature and increase the wind speeds in tropical storms which cause unusual amount of rainfall [1] The climate change issue is resulting flood tragedy and flash flood [2] that always occur in Pahang involving Kuantan city. Kuantan, which is located in the eastern part of Peninsular Malaysia, has a huge green corridor. The city is one of the most rapidly urbanizing cities in Peninsular Malaysia with high number of populations. A tremendous landuse change has been actively occurring in Kuantan within three decades ago. A rigorous urban development, agricultural activities, and expansion of the industrial area in Kuantan have had a significant impact and changed the existing forestry area, which stores huge amounts of carbon. Therefore, this area is suitable for this study. This study is an indication of the Malaysian government's commitment to achieve a carbon-neutral nation by 2050, as announced by Malaysia's 9th Prime Minister, Ismail Sabri Yaakob [3].

Malaysia is facing rapid development where most activities that related to any development is held in forest. The growth of demands for residentials, commercial buildings, industrial as well as for institutions are rising parallel to the increasing of human population in this country. According to Department of Statistic Malaysia 2021, the size population in Malaysia during year 2021 has reached 32.7 million. A Land Use Land Cover Changes (LULCC) has driven many effects on natural ecosystems such as biomass changes and green carbon changes [2] Biomass is the total of quantity organisms such as plants, animals and microorganisms that live as well as dead materials which in the form of vegetation for instance trees, shrubs, and leaves [5]. The conversion of forest has greatly impacted towards the loss of biological diversity such as flora and fauna which lead to biomass being decreased. The reduction of total biomass causes carbon changes in such a particular area as it can affect forest structure, ecology, and composition [6]. Based on Intergovernmental Panel on Climate Change (IPCC) report [7,8] indicated that LULCC is the main cause of fluctuation of carbon storage in the ecosystem. Carbon should be quantified to estimate its contribution to global climate change and environmental [9]. Therefore, it is essential to quantify the carbon changes to determine the scale impacts of LULCC and human activities towards the ecosystem. The existing map of LULCC is not update, the inventories information about the total carbon in Kuantan is not well covered, people in this region are lack of awareness about the harmful of carbon in the air, and conventional method is hard to be applied for carbon estimation are the problems that have derived for this study to be conducted.

Remote Sensing and Geographical Information System (GIS) technology is used in mapping and quantifying the carbon changes and biomass. The usage of remote sensing is very convenient since it is used images from satellite [10,11]. Therefore, this study is focused on quantification of total carbon in Kuantan district to raise the awareness towards the local communities about the danger of high amount of carbon. The objective of this study is to classify LULC types in Kuantan district using geospatial artificial intelligent (GeoAI) approach on satellite images, to relate vegetation index and satellite-based total biomass in Kuantan River basin and to map green carbon changes in Kuantan based on quantified biomass using remote sensing- GIS technology. The technology manages to ease monitoring carbon changes and capture images at the forest area in Kuantan. The remotely sensed image that is commonly used for carbon monitoring study consists of passive optical remote sensing imagery including Landsat 8 OLI, and Landsat 5 TM. GIS has been implemented into the information infrastructure of all metropolises. This system is capable of capturing, storing, manipulating, analyzing, managing, and presenting all forms of geographic data [12]. GIS and remote sensing have many positive impacts on quantification of green carbon changes in Kuantan district. Moreover, this study is directly supporting the agendas of the 17 Sustainable Development Goals (SDGs) by following agenda: (i) sustainable cities and communities (Goal 11th), (ii) climate action (Goal 13th), and (iii) life on land (Goal 15th).

1.1 Land Use Land Cover Changes (LULCC) Mapping Approaches

Land use refers to the type of usage of the land while land cover indicates to the vegetation, water bodyor any infrastructure is available in the land area. LULCC has played a vital role in global issues due to disturbances that are made from human or natural disasters. The land cover is frequently influenced by land usage. In this context, change was defined as a change in the appearance of the surface of landscape component, which was only regarded to occur if the surface appeared differently on few separate occasions [13]. Most major metropolitan regions face the problem of urban sprawls and loss of naturalvegetation cover. LULCC are mostly pressured due to increasing of population and economic necessities whichhas caused great problems on sustainable development. Therefore, some approaches are taken to map the LULCCsuch as conventional method which was used before the technological based mapping method is used in recent studies in global.

1.2 Conventional Method

Geophysical survey is the method that is used in mapping conventionally to produce the detail of image or map of the area. It is a technique that required ground – based physical sensing techniques that required the observer to go to the field site and have physical monitoring to see the real condition of the site. Traditional mapping methods such as ground truthing, surveying, and other approaches that rely on field surveys and on-site human-made observations are generally reliable, but they are time-consuming and expensive [14-17]. The conventional approaches were used in the pre- remote sensing era for LULC mapping, forest inventory, and LULC modifications [18]. The conventional methods are unable to capture the exact LULCC characteristics and dynamics effectively [19]. This type of method needs to be done frequently to achieve reliable data. This necessitates the collection of land cover samples and ground-truth data, which are required to assign each class based on the spectral data ofsatellite photos or derived transformation images. Ground-truth integration needs more work resources to conduct the survey.

1.3 Technological-Based Mapping

Nowadays, the development of mapping methods is using geoinformation cartography and geoinformation systemsto create the maps instead of using analog methods [20]. For mapping and change analysis, traditional sources have been replaced with remotely sensed data because it is more accurate, cost- effective, time-efficient, and able to cover a larger region [18]. The usage of GIS software in the field will bring drastic changes in the scope of work based on performance and accuracy [20]. GIS and remote sensing techniques have been well developed, the applications of remote sensing on urbanization research are becoming quite common, as remote sensing techniques are more affordable and technologically reliable. Opposed to conventional method, remotely sensed data may be saved in a digital formatthat can be instantly copied, taken to another location, or analyzed by a human. Thus, this project helps in enhancing the usage of these technologies. The technology of remote sensing offers a very practical and economical method to study vegetation cover changes [21]. It manages to process over a large scale of studies with large spatial temporal coverage [5]. It provides an efficient monitoring of vegetation cover changes and canopy density stratification which aids in field inventory. Besides, these technologies are producing accurate data to estimate biomass of the forest and time saving and less labour usage which make this technology cheaper than the conventional method [22,23]. As a result, remotely sensed datasets were used for LULC mapping and evaluation, and they showed to be more fruitful, economical, and handy, with the potential to store data for a longer period.

1.4 Remote Sensing Data in Mapping Green Carbon Changes

Remote sensing is the most accurate method because it provides a solution to environment destruction, time consuming and expensive cost. Remote sensing is the process of collecting data from a distance about an object, location, or phenomena and evaluating it using devices without coming to the area that is being studied [24]. Besides that, is a technology captures spatial variability in the qualities of interest by providing a synoptic overview of the surface region of interest. It is able to acquire information on areas of interestthat are difficult to access or unreachable. Evaluation of total carbon of vegetation is important to allow the understanding of the carbon sequestration capacity of the forestry area. It has common database functions such as query and statistical analysis, which are integrated with maps using GIS technology. It provides tools to visualize, overlay data layer and query the databases. Basically, GIS is a system for gathering, analyzing, and managing data and properties that are geographically related to the earth. It has become an essential tool that have been utilized nowadays, to generate various type of maps and to obtain remote sensing information which are used in real cases related to the environment. As urban development has expanded, GIS can fulfil the need to gain the data that is needed for constructing the development [25]. LULCC is one of the most common national issues that occur in most countries. GIS software also has been applied to quantify green carbon changes becauseit has a lot of advantages. Besides, GIS software is more effective than using conventional method in terms of cost, time, and manpower to quantify the green carbon changes in relation LULCC. The use of remote sensing, GIS, and modeling to investigate the status of carbon sequestration and its future dynamics is intriguingand has the potential to be a novel way to solve ecological assessment problems. The data may detect and record spatial variability, spatial distributions, and spatial patterns in forests, as well as track their evolution through time [26].

1.5 Advantages of Geo - Spatial Technology Usage for Mapping

Since geospatial technology has been widely used for carbon changes monitoring, it has changes rather thanconventional method. It is because remote sensing GIS technology does require less manpower in handling the tool-based [27]. When less manpower is being used, therefore the budget to undergo the project to generate the needed mapping is lower to because the cost of workers can be cut and save. According to [28], geospatial technology usage is found to be cost efficient because the cost of the ground surveyscan be reduced by using satellite images as the alternatives. Remote sensing data such as satellite images are preferable because it is free access satellite and function detect most vegetation accurately [29]. A previous study also stated that the advancement in sensor technology has led to cheaper or freely availabledata with optimal spectral properties suitable for urban planning and monitoring [30]. Hence, it is required to shift towards the adoption of newly launched, freely available, and cost-effective multispectral sensors such as Landsat 8 OLI, Landsat 5 TM in urban ecosystem services quantification. Thus, GIS technology is a suitable method to be utilized for any scales of project without worry the cost and budget. Table 1 shows the advantages of carbon changes monitoring using geospatial technology.

1.5.1 Duration

GIS technology is more time saving rather than the conventional method and that is the reason why this techniqueis chosen for this project. This technology is time saving because it does not require the work to be done manually [31]. The user can easily access the maps in the remote sensing GIS –

technology every time needed. The data is easily transferred and process to be integrated into the form required. Remote sensing is able to gather information at short intervals of time over vast areas [32]. Besides that, the process of the data is fast, so the user does not need to wait to gain the results since the results can be obtained ina short period of time.

1.5.2 Accuracy

Images satellite from Landsat 8 OLI, and Landsat 5 TM will develop high accuracy and reliable data to monitorand the observation during mapping process such as for LULCC and carbon mapping. The integration of Landsat 8 data provides in a worldwide average revisit interval of roughly three days. It allows surface monitoring with cloud-free observations in some locations and agricultural product development at medium spatial resolution [33], thus the images produced are clear. According to United States Geological Survey (USGS),the availability of Landsat data is proposed an accuracy level of 85% as the minimum requirement for LULCC mapping with Landsat data [34]. Based on previous studies, GIS data has better potential to improve the results in terms of its consistency and accuracy [35]. It manages to detect any changes and integrate for analyzing the mapping such as LULCC. This system has advanced functions of spatial statistical analysis such as hotspots and it can collect data over large-scale regions in short periods. The images picked up from afar are simple to track down and suitable to be used to map LULCC and green carbon changes.

Table 1
Monitoring of carbon changes using geospatial method

Author	Year	Title	Advantages
Avtar, R., Kumar, P., Oono, A., Saraswat, C., Dorji, S., and Hlaing, Z.	2016	Potential application of remote sensing inmonitoring ecosystemservices of forests, mangroves, and urban areas	• create maps, derived information, visualize scenarios, present powerful ideas, and develop effective solutions. • generate of various thematic maps in forestry sector such as forest types.
Giri R. K.K.V. and Mandla V. R.	2017	Study and Evaluation of Carbon SequestrationUsing Remote Sensingand GIS: A Review on Various Techniques	• provide the utilities to handle attribute data, location,and topology in spatial analyses. • Information about a remote area.
Issa S., Dahy B., Ksiksi T. and Saleous N.	2020	A Review of TerrestrialCarbon AssessmentMethods Using Geo- Spatial Technologies with Emphasis on Arid Lands	• Most time-efficient and cost-effective approaches in mapping vegetation, biomass quantification and assessing carbon stock.
Lamb, R. L., Ma, L., Sahajpal, R., Edmonds, J., Hultman, N. E., Dubayah, R. O., Kennedy, J., and Hurtt, G. C.	2021	Geospatial assessment of the economic opportunity for reforestation inMaryland, USA	• 3D structure information on vegetation acquired from LiDAR remote sensing has provided by far the most accurate forest estimates across broad geographical extents.
Omali T.U.	2022	Monitoring theEcological Component of Sustainable Development Goalsusing GeospatialInformation Tools.	• Remote sensing is the only cost-effective technology that can provide data at a global scale. • Improve in evaluating, modelling, monitoring, and reports in relation to global concerns.

2. Methodology

The methodology of this study using the data gathered from various sources. The three-phases method for this study includes Machine Learning (ML) and Deep Learning (DL) which involves primary on the optical satellite images with different image specifications. The methodology is included the processes such as filed visit for identifying LULCC at real site, measure DBH tree height, data collection using satellite, data processing, spatial analysis, verification, and the last one is map generation to fulfil the study purposes. Figure 1 shows the general flowchart of the methodology of this study.

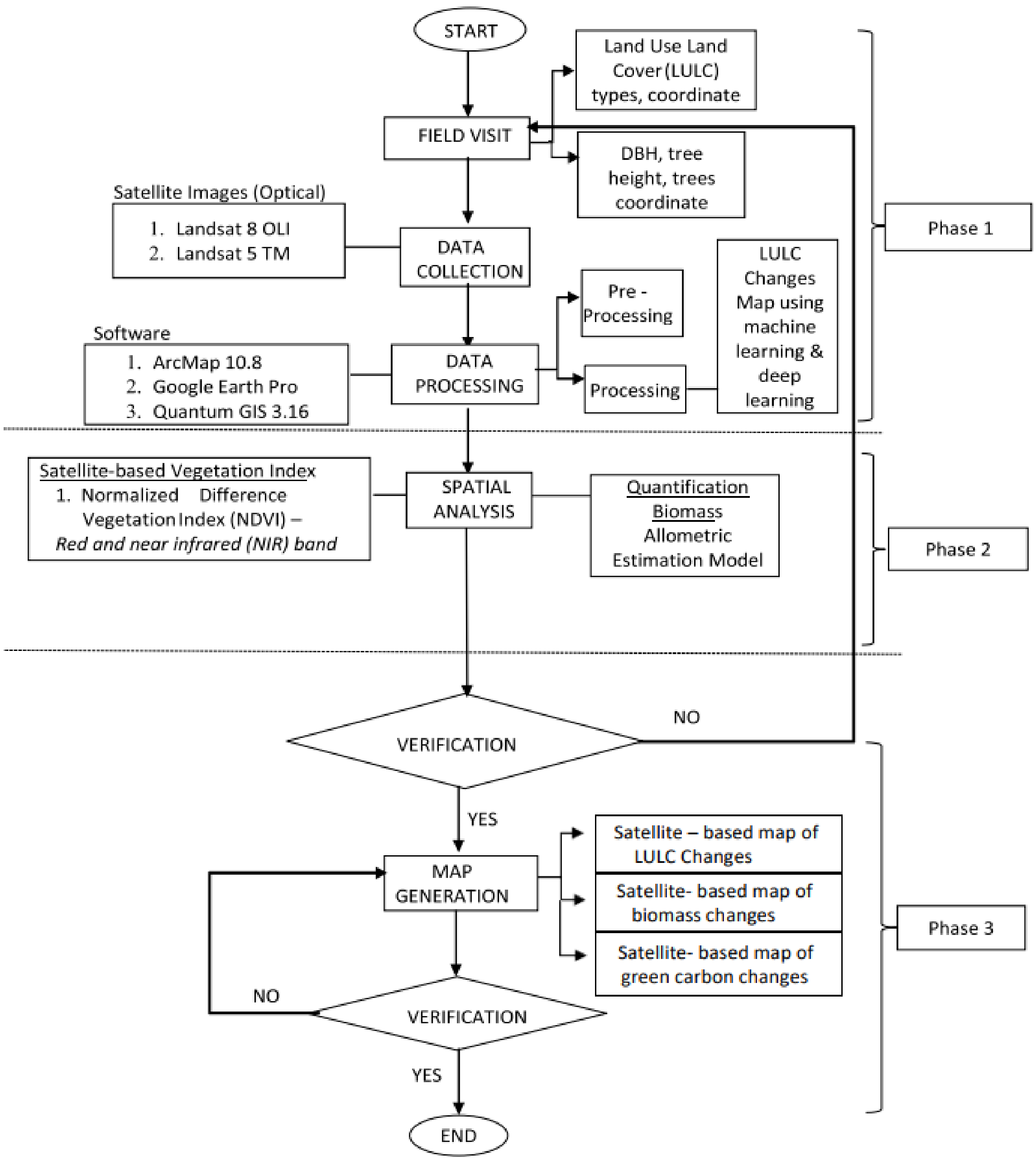


Fig. 1. Flow chart of methodology

2.1 LULCC Mapping Using Geospatial Artificial Intelligent (GeoAI) Approach on Satellite Images

The data collected were focused on 20 years interval from year 2002 to 2022 using QGIS and satellite image wereobtained from USGS Earth Explore. This study focused on a 20 years interval which start from year 2002,however year 2012 cannot be included because there were no great quality satellite images found. The satellite captured a lot of clouds images this year which could obstruct the data processing. Therefore, year 2013 is chosen for this study. There are two approaches that were used in developing LULCC mapping which are Machine Learning and Deep Learning. Machine learning techniques offer a suitable automated mechanism to detect these patterns by learning models. Machine Learning techniques have been applied to forest pattern recognition [36]. In contrast, deep learning contains a variety of methods, including neural networks, hierarchical probabilistic models, and many specific unsupervised and supervised feature-learning algorithms [37].

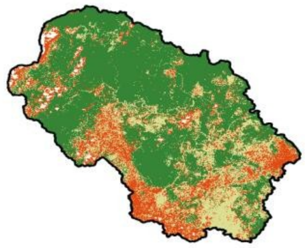
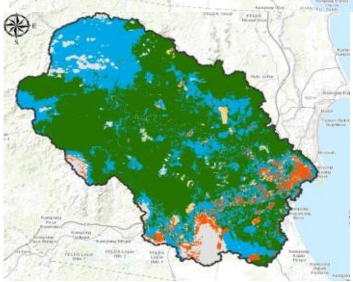
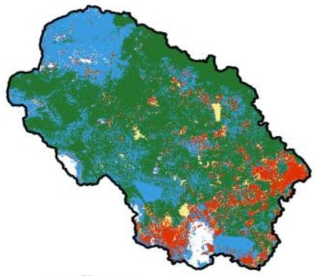
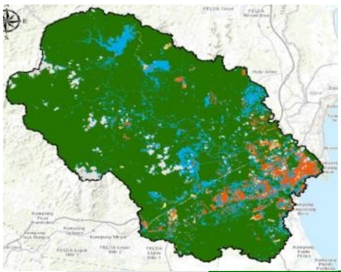
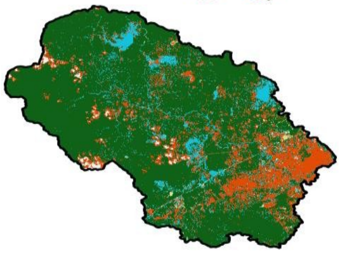
Machine learning algorithm namely Maximum Likelihood was applied on the Landsat and Sentinel-2 image to extract landuse information from different years. It extracts spectral, textural, and spatial features from Landsat and Sentinel imagery for each pixel in Kuantan. Using a set of training pixel, the trained classification models applied to the entire Landsat and Sentinel imagery covering the Kuantan River Basin. The models will classify each pixel in the imagery into predefined land use classes and green carbon classes based on their spectral and spatial characteristics. Meanwhile, deep learning classification namely Convolutional Neural Networks (CNN) on Landsat and Sentinel imagery offer advanced capabilities. The algorithm extracted spectral bands from Landsat and Sentinel imagery for each pixel in the study area. Optionally, it performs data augmentation techniques such as rotation, scaling, and flipping to increase the diversity of the training dataset. The algorithm trained the deep learning model using the extracted spectral bands as input and the labeled training samples as targets. CNNs consist of multiple layers, including convolutional layers. These layers apply filters (also known as kernels) to input images to extract features such as edges, textures, and patterns. Activation functions introduce non-linearity into the network, allowing CNNs to learn complex relationships between input features (pixel) and output classes. Fully connected layers connect every neuron in one layer to every neuron in the next layer, allowing the network to learn high-level features and make predictions. Total LULC derived from machine learning and deep learning process is the basis for the quantification of green biomass and thus carbon changes in KRB.

3. Results

3.1 Satellite Image Processing for Landuse Mapping

Both machine learning and deep learning approaches have shown that vegetation has covered most of the area of river basin. The pattern of mapping from year 2002 to year 2022 shows that the river basin has the highest vegetation or forest in year 2002, then, year 2022 andlastly year 2013 accordingly since the map in year 2002 is greener than the rest years. Table 2 shows the comparison outcome of the mapping. LULCC types are distinguished by different colours according to its type of land use as presented in the legend. According to Table 2, LULCC of Kuantan River basin has been identified into five main classes which are forestor vegetation, built-up area, water body, open area including cloud detected from the satellite images. Each classification is represented by various colours followed by its types. The comparison between these two approaches of producing LULCC maps can be seen in Table 2. Deep learning has shown a better result than machine learning where the deep learning approach distinguish clearer mapping production of LULC. The images from deep learning are sharper and better quality of classification for LULC.

Table 2
Machine Learning and Deep Learning of LULCC Mapping from year 2002 to 2022

Year	Machine Learning	Deep Learning
2002		
2013		
2022		

Legend	Cloud	Forest/Vegetation	Built-up area	Water body	Open area

The forest area can be determined by obtaining the amount of area of vegetation from LULCC mapping. The area of forest from year 2002 to year 2022 are tabulated in Figure 2 as well as its area changes of 10 years interval. Based on Figure 2 below, the forest area in Kuantan River basin in 2002 is about 68,259.01517 ha and decreased about 47,858.46031 ha which the forest covered 20,400.55 ha only in year 2013. However, the forest area in year 2022 has risen to 24,399.53 ha from the forest area in 2013 which the forest has covered about44,800.09 ha in this year. The reduction of forest area in 2013 was due to fulfilling the demands and need of urbanization of Kuantan city, thus most of the forest were being degraded to construct the development area. Forest covered area in 2013 is lesser than 2022 due to opening of main dam in Kuantan River basin. Nevertheless,the increment of forest or vegetation in 2022 is due to realization of the vision from Majlis Bandaraya Kuantan(MBK) in making Kuantan city as sustainable and liveable city aligned with agenda of Sustainable Development Goals (SDG) where MBK encourages citizen to plant trees through *"1Pokok, 1Rakyat Pahang"* programme [38]. The effort from MBK has produced a good impact on environment and growth of vegetation in this area.

Normalized Difference Vegetation Index (NDVI) is a measure of the state of plant health according to how the plant reflects light at certain frequencies. As indicated in Figure 3, it shows Normal Differences Vegetation Index (NDVI) mapping where the positive values indicated the sparse vegetation to dense green vegetation. NDVI produced high resolution of images. The NDVI differentiated the vegetation fromother land cover types. Besides that, vegetated visualized the abnormal changes growth in the images. NDVI has various spectral bands in surface material reflectivity offer a key mechanism for understanding details in remotelysensed pictures, the greener area from the map in Figure 3 shows it has high NDVI value which means the area has greater density of trees while blue area shows lesser vegetations

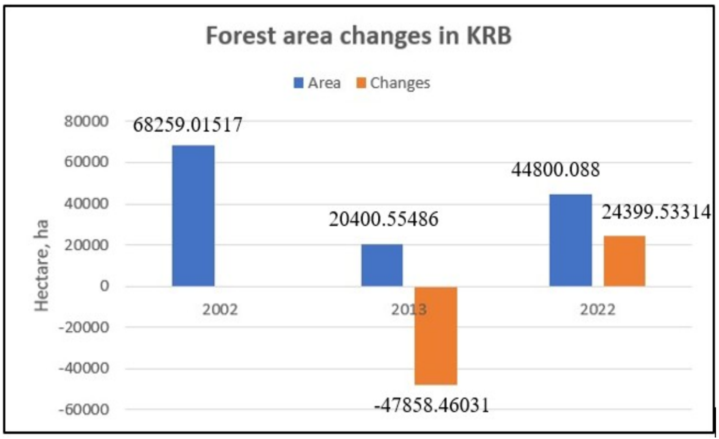


Fig. 2. Forest area changes in Kuantan River basin

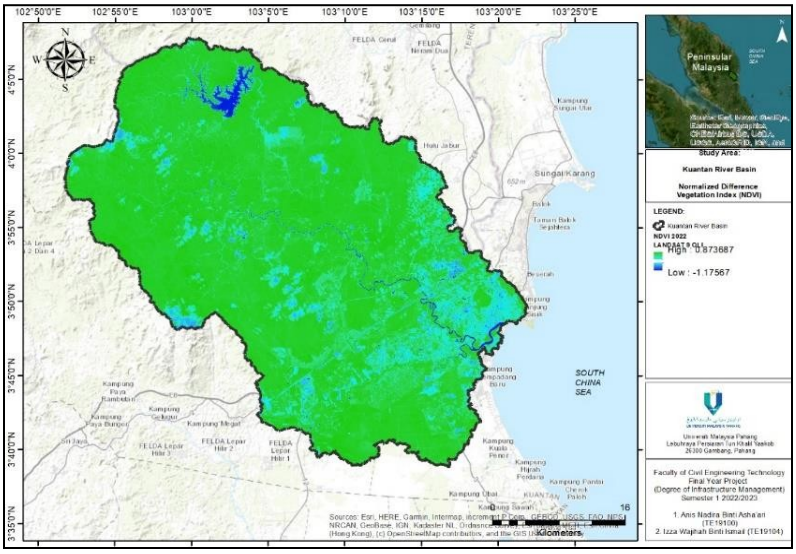


Fig. 3. Normalized Difference Vegetation Index (NDVI)

3.2 Total of Above Ground Biomass (TAGB) and Quantification of Green Carbon Changes

The reduction of forestry area in KRB from 2002 to 2013 poses numerous environmental, social, and economic challenges. Deforestation can lead to loss of biodiversity, soil erosion, water pollution, and increased greenhouse gas emissions, contributing to climate change. Furthermore, forest loss can negatively impact indigenous communities and local economies that depend on forest resources for their livelihoods. Prior to quantification of the carbon changes, Total Aboveground Biomass (TAGB) is estimated. TAGB was calculated using Allometric Estimation Model which based on diameter at breast height (DBH) and height data [39]. Figure 4 indicates the regression model of total aboveground biomass in Kuantan River basin. From the result shown in Figure 4, it stipulates that Sg. Lembing area has the highest TAGB value and thedifference of TAGB value with other location site is huge. This high biomass value specifies that Sg. Lembing area has many aged forest trees which important for environment and ecosystem to face the challenge of global climate change.

In Figure 5, the biomass of Kuantan River basin is mapped where the greener area shows that the high number of biomass while the blue area is with low amount of biomass. Figure 5 also indicates that Sg. Lembing area has greater total of biomass while around Bandar Kuantan is found to have lesser total biomass. It is because Sg.Lembing area is a revitalized heritage area of tourism attraction where it still preserves the old trees to retain the uniqueness. While Bandar Kuantan is facing rapid urbanization due to new development such as malls, schools, and other commercial buildings.

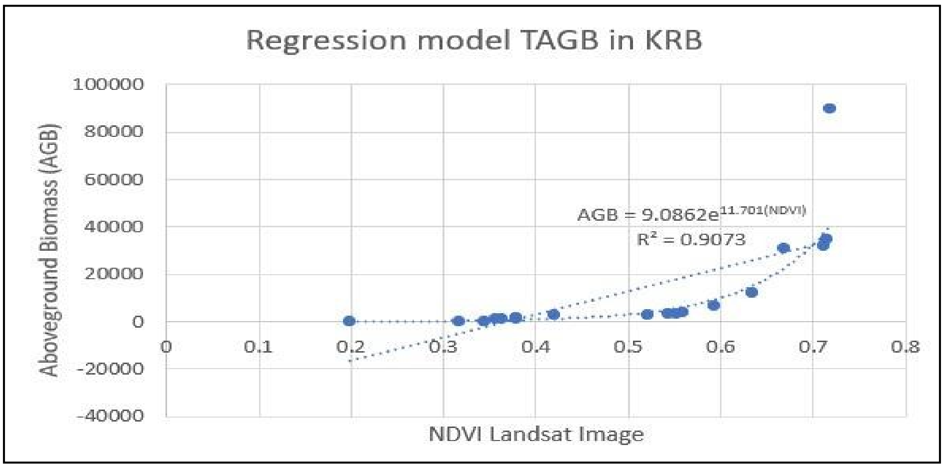


Fig. 4. Regression Model Total Above Ground Biomass in Kuantan River Basin

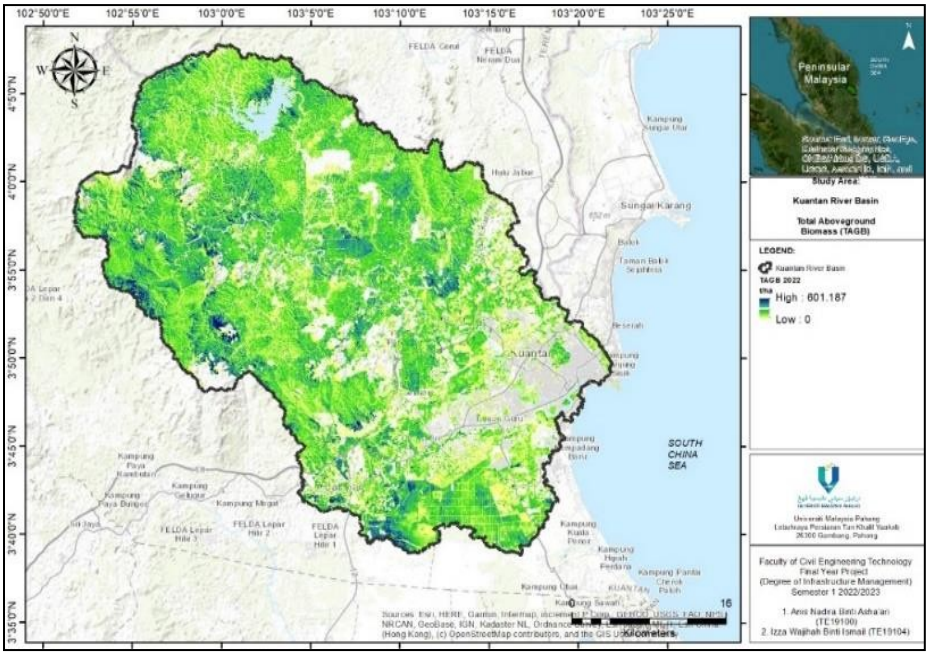


Fig. 5. Total Aboveground Biomass (TAGB)

By using biomass estimation value, the carbon of the area is generated in Table 3. Table 3 presents the quantification of green carbon changes from the year 2002 to 2002 of Kuantan River basin. According to the result, Kuantan River basin has the highest total of biomass in the year 2002 which means the area of case study has the highest number of vegetation or forest in that year. The amount of biomass decreased in year 2013 and increase again in year 2022. From the biomass estimation, the carbon in the area is managed to obtain where the highest carbon identified in year 2002 following year 2022 and 2013, respectively. The total of carbon and carbon changes is presented in Figure 6. The quantification of green carbon changes is drop from the year 2002 to year 2013 and rise again between year 2013 to year 2022 which show huge recovery and good impact from MBK town planning implementation of realization. In fact, the increment of forestry area in KRB from 2013 to

2022 signifies a positive trend towards forest conservation and ecosystem restoration efforts in the region. It reflects a collective commitment to safeguarding natural resources and fostering resilient ecosystems for the benefit of present and future generations. It can be concluded that, the greater the biomass value of the area, the greater the carbon stock in that region.

By quantifying the green carbon changes, this study has assisted the local authorities in helping them to provide appropriate policies for improving the efficiency of the land use that manage to minimize the risk of green carbonchanges. This research is significant as the inventories or collected data that can be reviewed by any parties for referencing the total carbon changes that occur in Kuantan areas. The data can be used for any usages in assistingthe development of this city in future by practicing methods that is environmentally friendly. The maps are significance as hazard records to ensure every development made is rational and the most optimal way [40]. As the total of the biomass and green carbon changes in Kuantan area obtained in this study, therefore the local authorities can use the data for decision – making process for development planning of Kuantan city to provide a comfort and safe to the livelihoods and nature of that region. By monitoring the green carbon changes in the selected vegetation area, the responsible authorities can practice the mitigations and preventive measures inreducing the climate change effect and global warming due to LULCC in local levels [41]. The illegal logging activity needs to be vanished by harnessing the laws and adding more obligations for the license specifically for this activity.

Table 3
Biomass estimation and carbon changes

Year	Area (ha)	Changes (ha)	Biomass (Gigatonne/ha, Gt/ha)	Carbon (CGt/ha)	Changes (CGt/ha)
2002	68259.01517		1250.05628	625.0281381	
2013	20400.55486	-47858.46031	373.604008	186.8020039	-438.2261342
2022	44800.088	24399.53314	820.443	410.2215	223.4194961

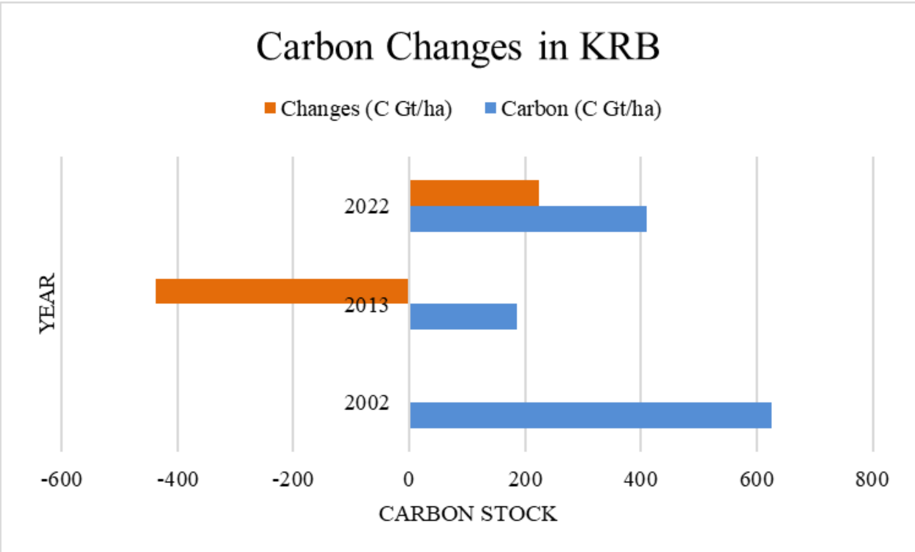


Fig. 6. Carbon Changes in Kuantan River Basin

4. Conclusions

This study has quantified the green carbon changes in relation to LULCC in the Kuantan River basin. All objectives of the study have been achieved. The result shows that the greater the amount of vegetation, the greater the number of biomasses and the greater the total carbon stock. The year 2002 had the highest total carbon stock since the Kuantan River basin was dense with vegetation and no heavy developments were discovered in 2002. The opening of dams and more development areas within ten years to 2013 has caused the destruction of forest and vegetation, which led to a decrease in total carbon stock in 2013. In this modern globalization era, the encouragement from Kuantan City Council (MBK) to increase awareness of the importance of forests in Kuantan has been impressively effective. Many programs are conducted to conserve the forest, which helps to increase the biomass and carbon stock of the forest in 2022. Besides that, this study also enhances the use of mapping and monitoring carbon changes in forested areas by utilizing remote sensing, and GIS is much more convenient than the traditional method because it is very easy to handle. In the future, high spatial resolution and commercialized satellite images are recommended because of the higher accuracy offered in the results of satellite-based LULC mapping using the GeoAI approach.

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