ISSN 1608-7844

DOI: 10.54470/planplus.v11i1.4

Plan Plus, Volume-11, 2021 (41-58)

# ESTIMATION OF CARBON STORAGE CAPACITY OF DIFFERENT WARDS THROUGH MAJOR CARBON ABSORBING SINKS USING REMOTE SENSING AND GIS TECHNIQUES: A CASE STUDY ON KHULNA CITY, BANGLADESH

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## ABSTRACT

In recent decades, with the rapid growth of urbanization, the amount of carbon emission in urban areas has been globally accelerated. In this study, the carbon storage capacity of different small administrative regions (wards) of Khulna city has been estimated based on four major sinks types- trees, vegetations, soils, and water bodies. To estimate carbon storage capacity, the total coverage area of each of the sink's types has been estimated by Sentinel-II satellite image data of 2019 through supervised image classification of remote sensing techniques. A comparison of more carbon-absorbing capacities between the wards has been assessed through GIS techniques as well. Results show that the north-west part of Khulna city has some extent of carbon sinks. However, the lower portion in the southern part is congested with built-up areas and has a huge lacking of carbon sinks. The obtained amount of carbon about 9306992 kg, 7733698 kg, 7328298 kg, and 6030692 kg have been absorbed through respective trees, vegetations, soils, and water bodies which is about 31%, 25%, 24%, and 20% of total absorption, respectively. The result shows that carbon absorption capacity is very high in ward no. 3 whereas ward no. 1, 2, 4, 6, 9, 14, 16, and 31 are high carbon-absorbing wards. Ward no 8, 13, 15, 17, 18 and 24 are moderate, ward no 5, 10, 12, 21, 22, 25, 26, 27, 28, 29 and 30 are lower and ward no 7, 11, 19, 20 and 23 are very lower carbon-absorbing wards of Khulna city. The findings of this study opt to provide valuable insights amongst significant stakeholders, i.e., local people, urban planners, policy-makers, and non-government organizations regarding the emission and absorption of carbon.

**KEYWORDS**: Carbon Storage, Sinks Types, Storage Capacity, High Carbon Absorbing Wards.

## 1. INTRODUCTION

Globally, the urban population has been expanded rapidly in recent decades, with more than half of the people are now living in towns and cities (Seto et al., 2012). Urbanization is a major cause of worldwide land-use changes. However, this has been accompanied by high rates of land conversion to urban areas (Jiang et al., 2012). Several plans to alleviate the consequences of global environmental change propose large-scale plantations to minimize greenhouse emissions and improve carbon sequestration (Deng et al., 2017; Havlík et al., 2011; Yang et al., 2020). The estimate of the sequestration of carbon by plantations depends on how various management methods, disturbances, age and structure of stands on a landscape scale influence them

(Cao et al., 2018; Masera et al., 2003; Stockmann et al., 2013; Wang et al., 2013). Previous studies have traditionally been based on carbon storage figures of multiple tree species in homogeneous pedoclimatic conditions (Kanowski & Catterall, 2010; Laungani and Knops, 2009; Trum et al., 2011; Zhang & Wang, 2010). However, regional uncertainty associated with spatial variability can prevent accurate estimates of carbon storage (Houghton, 2005; Sierra et al., 2007; Weishampel et al., 2009) . Detailed awareness of carbon conservation by many plantations is limited to regional-scale assessment of the carbon balance.

The perspective on urban areas is often shifted towards the negative effects that they have on ecosystems, from local to global scale, and in fact, many aspects of global change have their origins there ( Grimm et al., 2008; Strohbach and Haase, 2012). For example, a high proportion of the greenhouse gas like carbon dioxide is emitted from urban areas with most emissions being related to the activities of urban dwellers that require fossil fuel, industrial production, excessive traffic, heating, or cement production, but also to the disturbance and alteration of soils and vegetation through urbanization (Churkina, 2012; van Bueren et al., 2012; Zhou and Wang, 2018). Therefore, many aspects of global changes, including carbon dioxide emissions, have been attributed to urban areas. Conversely, cities have been found to provide valuable ecosystem services such as carbon storage. In the public discourse over accountability and mitigation action against the threat of global climate change, carbon absorption through carbon sinks has become a major concern (Sohi, 2012).

In this study, the carbon storage capacity of different small administrative regions (wards) of Khulna city has been estimated based on four major sinks types- trees, vegetation, soils, and water bodies as major carbon storages which produce explicit carbon storage map. Spatial variability will be regarded and carbon storage variations dependent on sinks forms will be analyzed, allowing for a precise analysis of carbon storage inside the city boundary. As the bulk of carbon emissions can be attributed to urban areas, the policies and actions of the local authorities that administer towns and cities are central to meeting the required cuts ( Dhakal, 2010; Kennedy et al., 2011; Kennedy et al., 2010; Lankao, 2007). However, in order to achieve measurable reductions in the long-term, reliable baseline assessments of carbon stocks need to be available. Only then it can be established whether interventions such as tree planting strategies and land development policies can be advocated as effective tools that go some way to offsetting the emissions of urban inhabitants (Davies et al., 2013; Obersteiner et al., 2010). The goal of this paper is to investigate the carbon storage capacity of different small administrative regions (wards) of Khulna city based on four major sinks types- trees, vegetations, soils, and water bodies. In order to achieve the goal, two specific objectives have been considered which are: to assess the existing carbon absorption capacity of Khulna city based on the four major carbon sinks- tree, water bodies, vegetation and soil and to identify the higher carbon absorbing wards and select wards to take under action policy to increase the carbon absorption capacity.

## 2. LITERATURE REVIEW

Over the past decade, global climate change has become a topic of great international significance, and several reports on climate have showed that Bangladesh could be the worst target of global warming and subsequent sea-level rises. Bangladesh ratified the Framework Convention on Climate Change, which was signed at the United Nations Conference on Environment and Prosperity in June 1992, in response to environmental issues (Mahabub et al., 2007). A very limited proportion of global CO2 emissions are emitted by Bangladesh. Yet the country's carbon situation has shown that CO2 emissions have risen steadily. With the growing trend, CO2 emissions and per capita CO2 emissions in Bangladesh have risen. In 2011, the gross production of CO2 was measured at 57.07 million tons, which was 140.67 percent more than the 1991 emission of 15.94 million tons. This suggests an annual rise of 6.70 percent in CO2 emissions over the 1991-2011 timeframe (Sarkar et al., 2018).

According to the International Society of City and Regional Planners (ISOCARP), in the recent time the world is focusing on low carbon city and the carbon neutral city. Most of the developed countries already have made their vision for 2030 or 2050 from making their city as carbon free (Liang, 2010). So, as a developing country, we have to grow our concern on this vibrant issue. Because of our rapidly growing population, we are already moving towards this global problem. So, we have to think and made appropriate policy and actions based on our existing resources from now for the future.

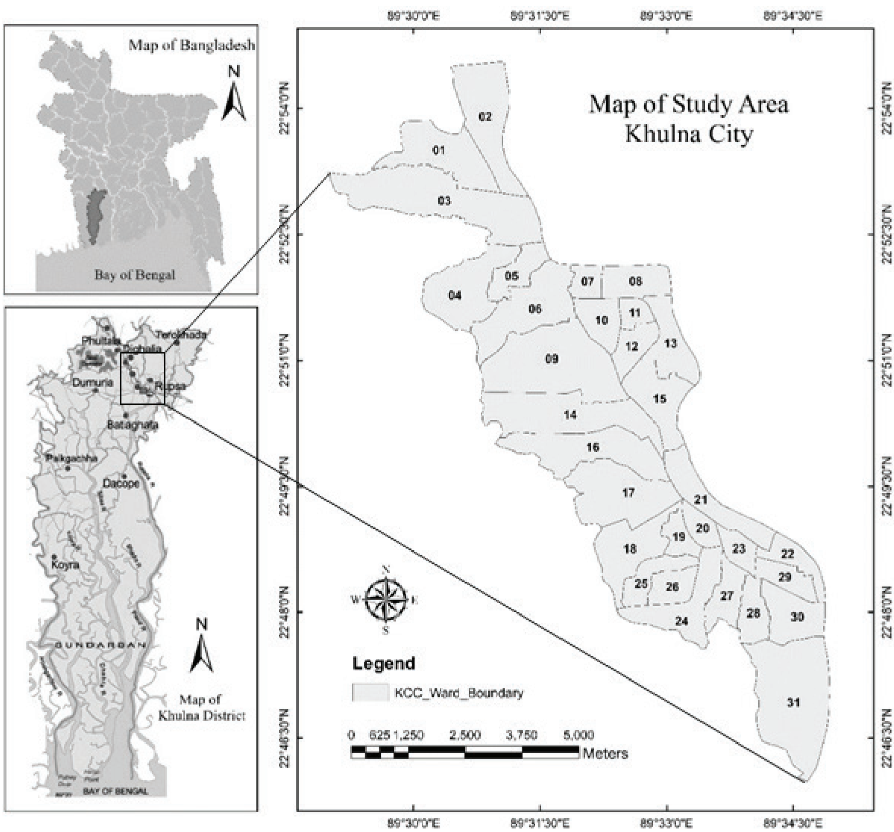
A carbon sink is an artificial or natural reservoir that accumulates and stores atmospheric carbon (Ali et al., 2018). Sequestration is known as the mechanism by which carbon sinks extract carbon dioxide (CO2) from the atmosphere (Peng et al., 2008). The Kyoto Protocol, which encourages research, has expanded general understanding of the importance of CO2 sinks. Their usage as a form of mitigation for carbon. The three primary carbon traps are trees, water bodies and soils, as these take a large volume of CO2 from the atmosphere (Batjes, 2019). Carbon stocks in forests, bodies of water bodies and soils which change in two ways, owing, on the one hand, to changes in their area and, on the other hand, to changes in stock concentration in the current area (Kaipainen et al., 2004). Several plans to alleviate the consequences of global environmental change propose large-scale plantations to minimize greenhouse emissions and improve carbon sequestration (Wang & Huang, 2020). Policymakers are profoundly mindful that, by fixing, storing and emitting large volumes of carbon from the environment, world forests play a vital role in the global carbon cycle (Murray et al., 2000). One of the main problems in environmental studies on transition is the global and regional carbon cycle. It is not only statistically relevant to estimate the size of carbon sinks and their spatial and temporal trends, but also to target widespread public interest because it is closely linked to the ambitious Kyoto Protocol aimed at reducing atmospheric fossil fuel emissions (Roulet, 2000).

Two wide-ranging techniques are ground measurement and remote sensing. The physical field measuring method is the most common method implemented at the project level. For small-scale project fields, this is a low-cost and realistic strategy. Remote sensing is useful for obtaining area forecasts for various forms of land cover and divisions of land use. In addition, remote sensing can help locate and classify relatively homogeneous areas that can direct sampling (Chauhan et al., 2004). Remote sensing is a technique which has tremendous potential to track improvements in the area and carbon reserves in the long term. For large projects, remote sensing methods are now widely being used and will also apply for small-scale projects (DeFries et al., 2007).

## 3. MATERIALS AND METHODS

### 3.1 Study area

Khulna city has been selected as the study area in this research (Map-1). It is the third-largest city in Bangladesh, which is in the south-western part of Bangladesh at 22°49′0″N and 89°33′0″E. It covers a total area of 59.57 sq.-km and has about 1.3 million populations (BBS, 2014). The population density of Khulna city is increasing day by day, resulting in rapid urban sprawl on the city fringes. This urban sprawl is correlated with increased energy use and causes pollutions (Johnson, 2001). Different anthropogenic activities and the rapid expansion of commercial areas and increased industrial activities are making Khulna city environmentally polluted day by day with an increasing amount of $CO^2$ in the atmosphere.




Map 1: Study Area

### 3.2 Satellite image processing and classification

For this study, Sentinel-II satellite data of the year of 2019 has been used. Having the image geo-referenced and geometrically rectified, image clipping has been performed and subset from the full image based on a frame covering the study area. These preprocessing tasks allowed to export the classification and land cover information from satellite image. Using reference images, e.g. Google Earths, Google Maps, training samples have been gathered as signatures for each class. The training points were proportionally distributed to each cover type with at least 20 points per sinks type. From the supervised classification methods in ERDAS IMAGINE 2014, the Para-ML classification algorithm was used to produce the land cover maps which combine parallelepiped and maximum likelihood classification methods using a decision rule to evaluate each pixel. The parallelepiped classification is based on a set of lower and upper threshold reflectance determined for a signature on each band. To be assigned to a particular class, a pixel must exhibit reflectance within this reflectance range for every band considered. Pixels that are assigned to over one class are then passed to the maximum likelihood decision rule for assignment to a single class. Then the area of each sink's types (trees, vegetation, soils, and water bodies) have been calculated (Dorendorf, 2014).

### 3.3 Calculating carbon storage

Since the goal of this study is to assess the existing carbon storage capacity of Khulna city, carbon storage factors (kg C/sq. m) of respective storages have been considered for trees, vegetation, soils, and water bodies (Dorendorf, 2014). The carbon storage of Khulna city has been calculated by using Equation (1):

$$CS = \sum_{i=1}^{n} CSi \quad \dots\dots\dots\dots\dots\dots (1)$$

Where, CS is the total carbon storage of the Khulna city; i is the individual storage category; n is the total number of storage categories (here, n = 4 in this study- i) trees, ii) vegetation, iii) soils, and iv) water bodies. Then, CSi is calculated using Equation (2):

$$CSi = \sum ASi \times Ei \dots\dots\dots\dots\dots\dots (2)$$

Where ASi is the total existing area of individual storage type; Ei is the equivalence factor. Integrating Equations (1) and (2), CS is calculated using Equation (3):

$$CS = \sum_{i=1}^{n} \left( \sum ASi \times Ei \right) \quad \dots\dots\dots\dots\dots\dots (3)$$

By using these equations, the exiting carbon storage of Khulna city has been calculated and carbon storage intensities map has been prepared.

Table-1: Values of Absorption Factors

| Sink Type | Values of Absorption Factors (kgCO2/Sq. m) | Sources |
|---|---|---|
| Tree | 1.66 | (Nowak & Crane, 2002; Dorendorf, 2014) |
| Water bodies | 1.28 | (Taylor et al., 2019) |
| Vegetation | 0.67 | (Bardhan et al., 2007) |
| Soil | 0.83 | (Bardhan et al., 2007) |

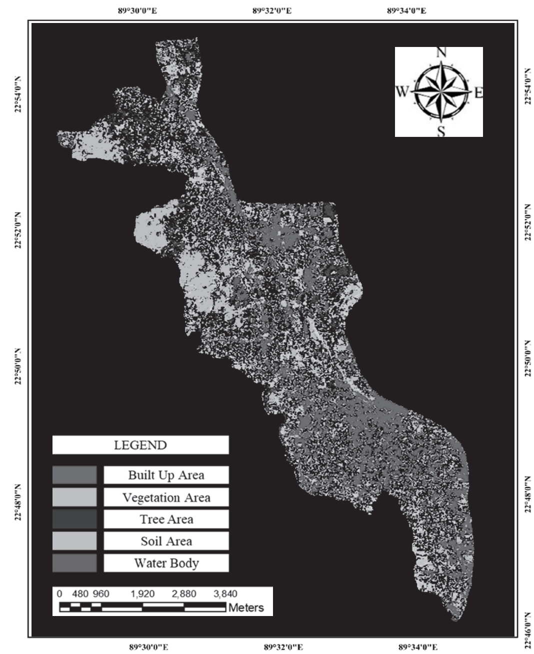
*Source: Author, 2021*

**4. RESULT AND DISCUSSION**

In this paper, we have come up with several findings those show the precise information regarding the estimation of carbon storage capacity and its absorption. This section sums up the major findings of the study.

**4.1 Existing landuse classification of Khulna city**

Major four types of carbon sinks (tree, vegetation, soil and water bodies) have been classified here through supervised image classification (Map-2). From the findings, the north-west part of Khulna city has some extent of carbon sinks. However, the lower portion at the southern part is highly congested with built-up area, which has a huge lack of carbon sinks.




Map 2: Existing landuse classification of Khulna city

Figure 01 shows the existing areas of classified groups. Interestingly, the built-up area has the largest share of space than the other group. It is alarming for future as the amount of major carbon sink's area is negligible in present time which has been decreasing day by day. As a result, carbon absorption capacity of the overall city is insignificant, which will be a challenging matter with the rapidly changing climatic condition.

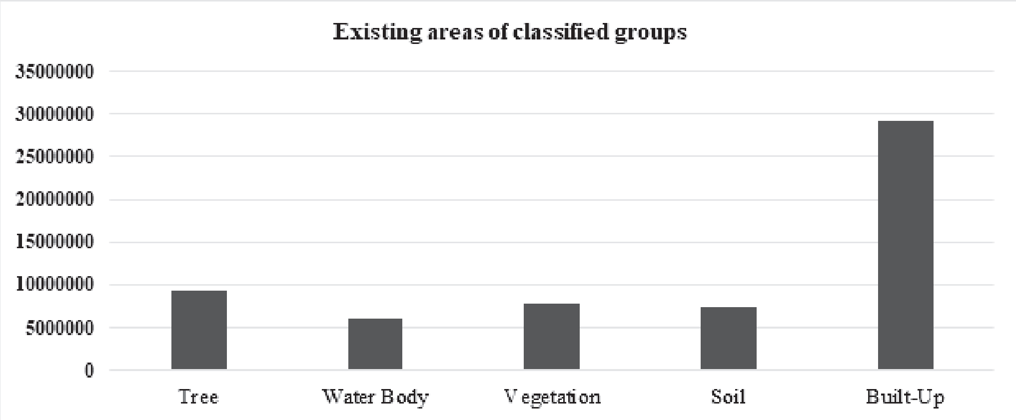



Figure-1: Existing areas of classified groups
*Source: Author, 2021*

The pie diagram shows the percentage of existing carbon sink areas, which are - tree area is about 31%, water bodies body is 20%, vegetation area is 25% and soil area is 24%. The percentage for each sinks area is very insufficient comparing with the total amount of carbon, producing each month from different landuse types within the city.

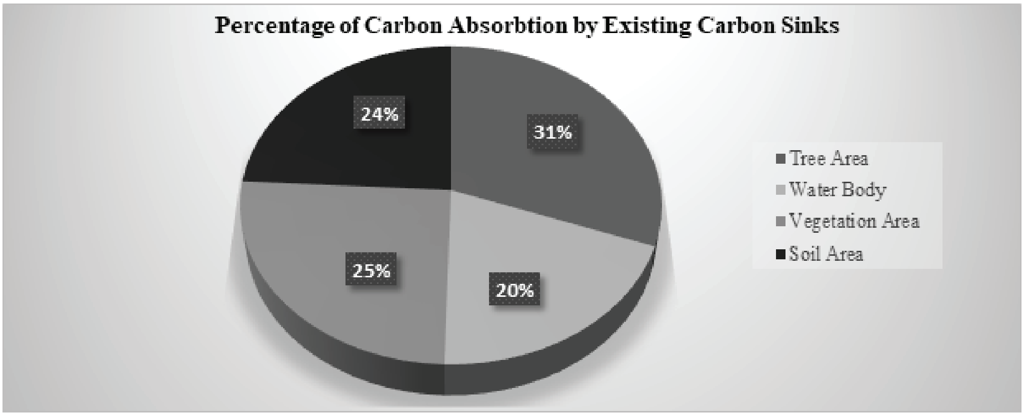



Figure- 2: Carbon Absorption Percentage by Existing Carbon Sinks
*Source: Author, 2021*

### 4.2 Ward Wise Carbon Absorption

Spatial variation of carbon sinks and their capacity for the storage carbon of Khulna city have been analyzed based on four different major types of carbon sinks. Based on the amount of existing carbon sinks, the following map (Map-9) shows the more carbon absorbing wards. From the findings it can be illustrated that at present tree is the most dominant carbon source in Khulna city as it has an absorption capacity of 15511653 kg carbon per year, and then the other contributors' water bodies, soil and vegetations has 7729337, 6106915 and 5155799 kg carbon per year, respectively. Where carbon absorption capacity is very high only in ward no. 3. Ward no. 1, 2, 4, 6, 9, 14, 16 and 31 are high carbon absorbing ward. As well as, ward no. 8, 13, 15, 17, 18 and 24 are moderate, ward no. 5, 10, 12, 21, 22, 25, 26, 27, 28, 29 and 30 are lower and ward no. 7, 11, 19, 20 and 23 are very lower carbon absorbing wards.

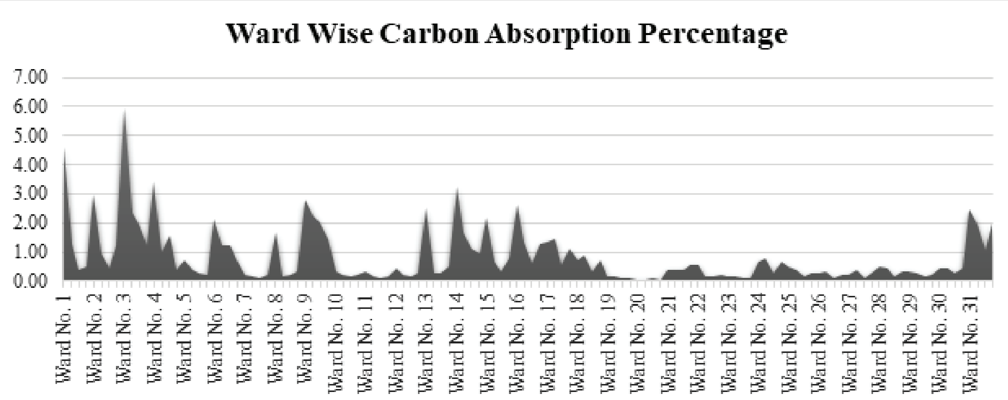



Figure 3: Ward Wise Carbon Absorption Percentage of Khulna city
*Source: Author*

Table-2: Ward Wise Carbon Absorption Capacity and Percentage

| Ward No. | Sink Type | Area (sq. meter) | Area % | Sink Wise Absorption | Absorption % |
|---|---|---|---|---|---|
| Ward No. 1 | Tree | 953299 | 3.14 | 1588832 | 4.60 |
| | Water bodies | 351099 | 1.15 | 449992 | 1.30 |
| | Vegetation | 204600 | 0.67 | 136400 | 0.40 |
| | Soil | 202500 | 0.67 | 168750 | 0.49 |
| Ward No. 2 | Tree | 614099 | 2.02 | 1023499 | 2.97 |
| | Water bodies | 253400 | 0.83 | 324774 | 0.94 |
| | Vegetation | 225500 | 0.74 | 150333 | 0.44 |
| | Soil | 497099 | 1.64 | 414249 | 1.20 |
| Ward No. 3 | Tree | 1232399 | 4.05 | 2053999 | 5.95 |
| | Water bodies | 638999 | 2.10 | 818984 | 2.37 |
| | Vegetation | 1010999 | 3.33 | 673999 | 1.95 |
| | Soil | 514201 | 1.69 | 428501 | 1.24 |
| Ward No. 4 | Tree | 704598 | 2.32 | 1174331 | 3.40 |
| | Water bodies | 263500 | 0.87 | 337719 | 0.98 |

Table-2: Ward Wise Carbon Absorption Capacity and Percentage (continued)

| Ward No. | Sink Type | Area (sq. meter) | Area % | Sink Wise Absorption | Absorption % |
|---|---|---|---|---|---|
| | Vegetation | 808498 | 2.66 | 538999 | 1.56 |
| | Soil | 151600 | 0.50 | 126333 | 0.37 |
| Ward No. 5 | Tree | 152200 | 0.50 | 253666 | 0.74 |
| | Water bodies | 103900 | 0.34 | 133165 | 0.39 |
| | Vegetation | 126900 | 0.42 | 84600 | 0.25 |
| | Soil | 99100 | 0.33 | 82583 | 0.24 |
| Ward No. 6 | Tree | 442499 | 1.46 | 737499 | 2.14 |
| | Water bodies | 333399 | 1.10 | 427306 | 1.24 |
| | Vegetation | 634500 | 2.09 | 423000 | 1.23 |
| | Soil | 293699 | 0.97 | 244750 | 0.71 |
| Ward No. 7 | Tree | 45200 | 0.15 | 75333 | 0.22 |
| | Water bodies | 36400 | 0.12 | 46653 | 0.14 |
| | Vegetation | 61600 | 0.20 | 41067 | 0.12 |
| | Soil | 78500 | 0.26 | 65417 | 0.19 |
| Ward No. 8 | Tree | 341000 | 1.12 | 568334 | 1.65 |
| | Water bodies | 43800 | 0.14 | 56137 | 0.16 |
| | Vegetation | 124900 | 0.41 | 83267 | 0.24 |
| | Soil | 141400 | 0.47 | 117833 | 0.34 |
| Ward No. 9 | Tree | 577099 | 1.90 | 961831 | 2.79 |
| | Water bodies | 603799 | 1.99 | 773869 | 2.24 |
| | Vegetation | 1039600 | 3.42 | 693067 | 2.01 |
| | Soil | 609901 | 2.01 | 508251 | 1.47 |
| Ward No. 10 | Tree | 63900 | 0.21 | 106500 | 0.31 |
| | Water bodies | 55200 | 0.18 | 70748 | 0.21 |
| | Vegetation | 93900 | 0.31 | 62600 | 0.18 |
| | Soil | 95300 | 0.31 | 79417 | 0.23 |
| Ward No. 11 | Tree | 63400 | 0.21 | 105667 | 0.31 |
| | Water bodies | 37500 | 0.12 | 48062 | 0.14 |
| | Vegetation | 60500 | 0.20 | 40333 | 0.12 |
| | Soil | 69500 | 0.23 | 57917 | 0.17 |
| Ward No. 12 | Tree | 96100 | 0.32 | 160167 | 0.46 |
| | Water bodies | 61500 | 0.20 | 78823 | 0.23 |
| | Vegetation | 94800 | 0.31 | 63200 | 0.18 |
| | Soil | 123200 | 0.41 | 102667 | 0.30 |
| Ward No. 13 | Tree | 522499 | 1.72 | 870832 | 2.52 |
| | Water bodies | 72600 | 0.24 | 93049 | 0.27 |
| | Vegetation | 130600 | 0.43 | 87067 | 0.25 |
| | Soil | 208300 | 0.69 | 173583 | 0.50 |
| Ward No. 14 | Tree | 670600 | 2.21 | 1117666 | 3.24 |
| | Water bodies | 451399 | 1.48 | 578543 | 1.68 |

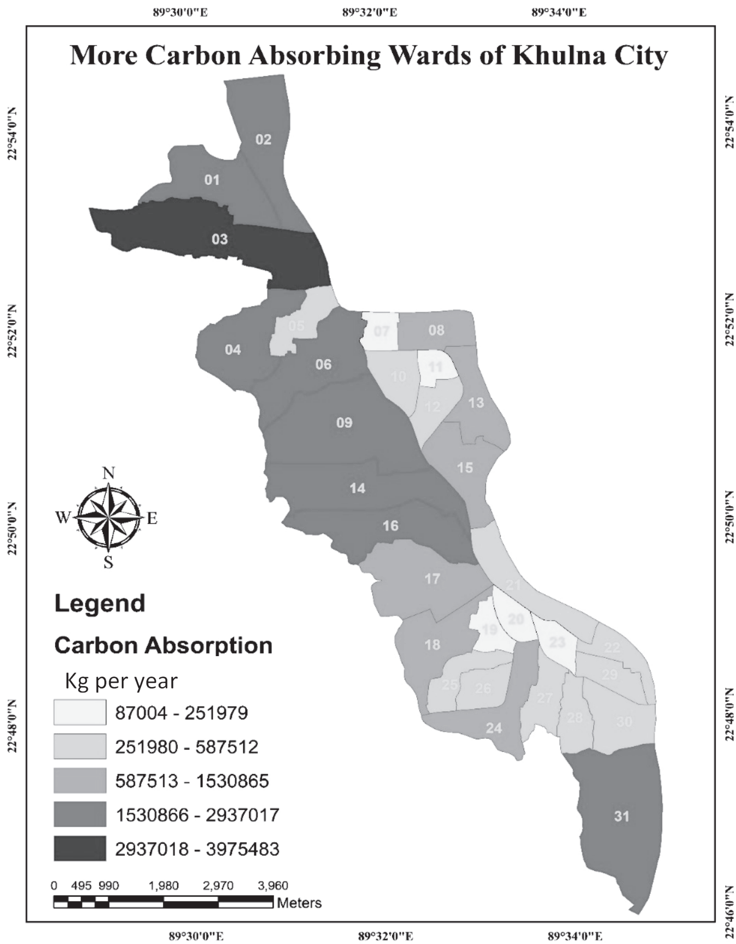
Table-2: Ward Wise Carbon Absorption Capacity and Percentage (continued)

| Ward No. | Sink Type | Area (sq. meter) | Area % | Sink Wise Absorption | Absorption % |
|---|---|---|---|---|---|
| | Vegetation | 577200 | 1.90 | 384800 | 1.12 |
| | Soil | 391899 | 1.29 | 326582 | 0.95 |
| Ward No. 15 | Tree | 456099 | 1.50 | 760166 | 2.20 |
| | Water bodies | 179900 | 0.59 | 230572 | 0.67 |
| | Vegetation | 162700 | 0.54 | 108467 | 0.31 |
| | Soil | 318701 | 1.05 | 265584 | 0.77 |
| Ward No. 16 | Tree | 548300 | 1.80 | 913834 | 2.65 |
| | Water bodies | 363199 | 1.19 | 465500 | 1.35 |
| | Vegetation | 327701 | 1.08 | 218467 | 0.63 |
| | Soil | 527899 | 1.74 | 439916 | 1.27 |
| Ward No. 17 | Tree | 273700 | 0.90 | 456166 | 1.32 |
| | Water bodies | 391000 | 1.29 | 501132 | 1.45 |
| | Vegetation | 274101 | 0.90 | 182734 | 0.53 |
| | Soil | 469000 | 1.54 | 390834 | 1.13 |
| Ward No. 18 | Tree | 151900 | 0.50 | 253167 | 0.73 |
| | Water bodies | 233200 | 0.77 | 298885 | 0.87 |
| | Vegetation | 155300 | 0.51 | 103533 | 0.30 |
| | Soil | 303800 | 1.00 | 253167 | 0.73 |
| Ward No. 19 | Tree | 31300 | 0.10 | 52167 | 0.15 |
| | Water bodies | 42900 | 0.14 | 54984 | 0.16 |
| | Vegetation | 57000 | 0.19 | 38000 | 0.11 |
| | Soil | 48500 | 0.16 | 40417 | 0.12 |
| Ward No. 20 | Tree | 12100 | 0.04 | 20167 | 0.06 |
| | Water bodies | 19600 | 0.06 | 25121 | 0.07 |
| | Vegetation | 39200 | 0.13 | 26133 | 0.08 |
| | Soil | 18700 | 0.06 | 15583 | 0.05 |
| Ward No. 21 | Tree | 85000 | 0.28 | 141667 | 0.41 |
| | Water bodies | 97500 | 0.32 | 124962 | 0.36 |
| | Vegetation | 195200 | 0.64 | 130133 | 0.38 |
| | Soil | 228900 | 0.75 | 190750 | 0.55 |
| Ward No. 22 | Tree | 116700 | 0.38 | 194500 | 0.56 |
| | Water bodies | 43300 | 0.14 | 55496 | 0.16 |
| | Vegetation | 76300 | 0.25 | 50867 | 0.15 |
| | Soil | 88400 | 0.29 | 73667 | 0.21 |
| Ward No. 23 | Tree | 36600 | 0.12 | 61000 | 0.18 |
| | Water bodies | 35500 | 0.12 | 45499 | 0.13 |
| | Vegetation | 54600 | 0.18 | 36400 | 0.11 |
| | Soil | 32900 | 0.11 | 27417 | 0.08 |
| Ward No. 24 | Tree | 134500 | 0.44 | 224166 | 0.65 |
| | Water bodies | 203300 | 0.67 | 260563 | 0.76 |

Table-2: Ward Wise Carbon Absorption Capacity and Percentage (continued)

| Ward No. | Sink Type | Area (sq. meter) | Area % | Sink Wise Absorption | Absorption % |
|---|---|---|---|---|---|
| | Vegetation | 129400 | 0.43 | 86267 | 0.25 |
| | Soil | 271099 | 0.89 | 225916 | 0.65 |
| Ward No. 25 | Tree | 101500 | 0.33 | 169167 | 0.49 |
| | Water bodies | 98900 | 0.33 | 126757 | 0.37 |
| | Vegetation | 87300 | 0.29 | 58200 | 0.17 |
| | Soil | 121200 | 0.40 | 101000 | 0.29 |
| Ward No. 26 | Tree | 61200 | 0.20 | 102000 | 0.30 |
| | Water bodies | 94600 | 0.31 | 121245 | 0.35 |
| | Vegetation | 65700 | 0.22 | 43800 | 0.13 |
| | Soil | 91800 | 0.30 | 76500 | 0.22 |
| Ward No. 27 | Tree | 43100 | 0.14 | 71833 | 0.21 |
| | Water bodies | 99300 | 0.33 | 127269 | 0.37 |
| | Vegetation | 60400 | 0.20 | 40267 | 0.12 |
| | Soil | 109800 | 0.36 | 91500 | 0.27 |
| Ward No. 28 | Tree | 103600 | 0.34 | 172667 | 0.50 |
| | Water bodies | 116900 | 0.38 | 149827 | 0.43 |
| | Vegetation | 83300 | 0.27 | 55533 | 0.16 |
| | Soil | 136600 | 0.45 | 113833 | 0.33 |
| Ward No. 29 | Tree | 73000 | 0.24 | 121666 | 0.35 |
| | Water bodies | 67100 | 0.22 | 86000 | 0.25 |
| | Vegetation | 90000 | 0.30 | 60000 | 0.17 |
| | Soil | 78800 | 0.26 | 65667 | 0.19 |
| Ward No. 30 | Tree | 94900 | 0.31 | 158167 | 0.46 |
| | Water bodies | 116400 | 0.38 | 149186 | 0.43 |
| | Vegetation | 141400 | 0.47 | 94267 | 0.27 |
| | Soil | 178800 | 0.59 | 149000 | 0.43 |
| Ward No. 31 | Tree | 504600 | 1.66 | 840999 | 2.44 |
| | Water bodies | 521600 | 1.72 | 668518 | 1.94 |
| | Vegetation | 540000 | 1.78 | 360000 | 1.04 |
| | Soil | 827201 | 2.72 | 689334 | 2.00 |

*Source: Author, 2021*




Map 3: More Carbon Absorbing Wards of Khulna city

### 4.3 Accuracy Assessment

#### *4.3.1 Kappa Statistics*

Kappa statistics have been computed for the classified map to measure the accuracy of the results. The resulting classification of land cover map of 2019 had a Kappa statistic of 80%. Kappa accounts for all elements of the confusion matrix and excludes the agreement that occurs by chance. It provides a more rigorous assessment of classification accuracy. The Kappa coefficient has been calculated according to the formula given by (Thomas et al., 2003) in ERDAS IMAGINE.

Table-3: Values of Conditional Kappa for Each Categorical Class

| Class Name | Kappa |
|---|---|
| Tree | 0.7622 |
| Soil | 0.6920 |
| Vegetation | 0.7721 |
| Water bodies | 0.7937 |
| Built-up | 0.9103 |

*Source: Author, 2021*

Table-4: Accuracy Assessment of Image Classification

| Class Name | Reference Totals | Classified Totals | Number Correct | Producers Accuracy | Users Accuracy |
|---|---|---|---|---|---|
| Tree | 49 | 52 | 42 | 85.71% | 80.77% |
| Soil | 33 | 41 | 30 | 90.91% | 73.17% |
| Vegetation | 47 | 43 | 35 | 74.47% | 81.40% |
| Water bodies | 37 | 34 | 28 | 75.68% | 82.35% |
| Built-up | 90 | 86 | 81 | 90.00% | 94.19% |
| Totals | 256 | 256 | 216 | | |

*Source: Author, 2021*

In accuracy assessment, kappa coefficient of all classes is about 0.7977 and the overall classification accuracy is 84.38%, which showed a better overall classification.

**5.CONCLUSION**

Urban-area carbon sinks play an important role in reducing the levels of ambient carbon dioxide. Due to accelerated growth rates, increased proportions of big trees, and potential secondary effects of decreased building energy usage and consequent carbon emissions from power plants, urban forestry, farmland, water bodies and bare soil have a higher influence. The findings reveal that the southern part (lower part) of Khulna City is extremely congested with built-up regions with a massive lack of carbon sinks. In Khulna city, highest amount of carbon has been absorbed by trees and vegetation which is approximately 56% together. Among 31 wards of Khulna city, only 8 wards have high carbon absorption capacity while others are moderate to low carbon absorbing wards. However, some of the pollution savings produced by urban carbon sinks can be replaced by urban carbon emissions. The estimates given in this paper are based on restricted field and secondary data, as they refine from national to regional and state estimates, they become more unpredictable. To better enhance carbon accounting and other functions of urban forest environments, further field observations are required in urban areas. In addition, a study needs to develop improved absorption potential calculations for urban carbon sinks, boost estimates of decomposition and maintenance emissions of sinks, and analyze the effects of other urban carbon sinks on urban carbon storage and flux. In order to create management strategies and national policy that will dramatically enhance environmental sustainability and human health around the country, a deeper understanding and accounting of urban environments can be used.

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