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LAND USE CHARACTERIZATION IN PERI-URBAN AREAS OF KHULNA TOWARDS AN ECO-SUSTAINABLE METROPOLITAN REGION

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ABSTRACT

Khulna, the third most important city of Bangladesh will undergo rapid urbanization in near future owing to some significant driving forces like increase in urban population, construction of Padma Bridge etc. The goal of this study is to suggest a land use pattern for the peri urban areas of Khulna, which will have the potential to maintain the environmental balance and help to mitigate the probable associated environmental deterioration of the area. The Land Use Suitability Strategy Model (LUSSM) integrating Land Cover Analysis (LCA), and Fragmentation Analysis (FA) were applied in this study taking Digholia upazilla of Khulna as a case. The proposed land use suggests an increase in Connecting Green (greeneries between other land uses) type of land use as an environmental protection measure and promotes Natural Parks and Community Supported Agriculture (land use supporting local agricultural practice) considering the conservation of the existing natural resources and cultivation practice of the study area.

Keywords: *Fragmentation, Khulna, LUSSM, Land Cover, Peri urban*

1. INTRODUCTION

Cities in Asia are experiencing a rapid growth in urban population over the recent years. The United Nations (UN) (2011) has reported that about 45% of Asia's population lived in urban areas in 2011 and this figure is expected to increase to 64% by 2050. This implies that within the period of the next thirty years, an estimated 1.3 billion people will be absorbed into the urban areas (McGee, 2010). Housing this ever increasing urban population is always a major challenge and the consequence of this rapid and uncontrolled urbanization falls, almost inevitably on the peri urban areas (lands with transitional characteristics between the urban and rural fabric). Peri urban areas around the world are expanding at a rate which is four times the current rate expansion of the urban areas (0.5-0.6% per year) (Ferreira *et al.,* 2018). Again, a majority of the megacities of Asia having populations of more than 10 million are located in East, South East and South Asia (Kraas, 2007). Taking the case of Bangladesh, with the current trends of growth, Dhaka is anticipated to become the fourth largest city of the world by 2025, housing an enormous population of about 20 million (Barua *et al.,* 2012).

Similar to the case in Dhaka, Khulna, the third largest city of Bangladesh is also going through major urbanization process. Different studies over the recent years have shown that the Land Use Land Cover (LULC) of Khulna City and its adjoining areas is already at a dynamic state of change. Ahmed (2011) analyzed the Landsat satellite images of Khulna City of the years 1989, 1999 and 2009 and showed that the amount of water body, low land and fallow land were decreasing constantly while the amount of built up area was increasing rather quickly over time.

Although not a megacity, Khulna has the potential of growing into a one due to a number of important and influential factors. For instance, it is estimated that the population of the Structure Plan area of Khulna will be about 3.19 million by 2020 (Khulna Development Authority, 2002). New urban land will be required over the course of time to house this increasing population. To this end, Khulna Development Authority (KDA) mentions that within the Structure Plan (2001-2020) area at least 10 percent of land under the jurisdiction of Khulna City Corporation (KCC) and 95.50 percent of the area outside it are currently not urbanized (KDA, 2002). These areas have the potential to be used for future urban expansion and are hence prone to future LULC change. All these facts and figures clearly indicate that Khulna City is expanding at a significant rate and the effect of this expansion is bound to fall on the peripheral areas of the city. With this end in view, the current study strives to understand the land use dynamics of the peri urban areas of Khulna City and the factors driving them. Further, it tries to suggest an optimum land use pattern for these peri urban areas using a model named Land Use Suitability Strategy Model (LUSSM) (Greca *et al*., 2010) such that the suggested land use might be able to contribute towards the environmental sustainability of Khulna City.

There are a number of important socio-economic driving forces responsible for LULC change in Khulna. Sarker and Pia (2015) identified some of these factors based on their correlation and level of significance with four distinct LULC types namely- 'river', 'built-up and construction land', 'canal and artificial pond' and

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'vegetation'. They also summarize that increasing income level, average household size, house rent etc. factors have significant influence on the LULC change of Khulna City.

Another influential factor to be considered as a driving force for LULC change in Khulna is the ongoing construction of Padma Multipurpose Bridge, which is by far, the largest infrastructure project of the country. The 6.15 kilometer long bridge over the mighty Padma River is expected to connect the comparatively less developed southern region of the country with the capital. Raihan and Khondker (2010**)** estimated the economic as well as welfare implications of Padma Bridge on the whole country in general and the south-western zone in particular. The results of their calculation suggest an equivalent annual growth rate of regional Gross Domestic Product (GDP) to be 1.66% over the next 31 years. According to a report on The Daily Star, experts involved in the Tk 28,793 crore mega project says that The Padma Bridge is expected to reduce the travel time between Dhaka-Khulna via Mawa Ferry Terminal from 13 hours to just three and a half hours when it goes into operation in 2018 (Azad and Byron, 2015). Based on the estimate of multiplier effects on the project investment The Daily Star in another of its reports suggests that the bridge will increase the GDP growth rate and the regional growth rate of the south-western zone by 1.2% and 3.5% respectively. It will also generate 743,000 person-years of additional employment, and thereby contributing 1.2% of the total labor market of Bangladesh. In short, the construction of this bridge will help generate employment opportunities and income through increased commercial activity in the southwest zone. Especially, Khulna Division which currently faces a poverty incidence higher than the national rate (46%) according to the household income, and expenditure survey conducted in 2005, will be benefitted enormously (Khan, 2016).

2. STUDY AREA

For the purpose of the study, a suitable peri-urban area of Khulna has to be chosen where the land use distribution can be applied. According to the Structure Plan of KDA (2001-2020), Khulna city is expanding linearly towards Khulna-Jessore highway which is giving birth to new prospective development areas for the city. These prospective areas have been taken into consideration in the structure plan as extended areas. The prospective areas are:

- Rupsha
- Digholia
- Noapara
- Phultala
- Daulatpur
- Batiaghata
- Khan Jahan Ali

These areas have less built up area than the KCC area, and mostly contain agricultural lands. To apply the land use distribution in the peri-urban area, only one area will be selected for the study purpose.

To determine the best suitable area among these prospective areas, it has to be determined which one of these areas has the highest potential to be considered as a peri-urban area. To determine that, some key variables were determined. A literature based approach was adopted in order to select the variables. The variables are mentioned in Table 1. In this case, the data of the each variable were normalized to the percentage of the total in each aspect. As there are 7 (seven) areas to be judged as the suitable study area, score ranging from 1 (one) to 7 (seven) were assigned for each variable.

Table 1: Variables for selecting the Study Area and scores obtained by Digholia

Sl. No.	Variable	Statistics for Digholia	
		Percentage Land Use	Score
1.	Percentage of Agricultural Land Use (Paul and McKenzie, 2013)	42.82	6
2.	Percentage of Built up Land Use (Hudalah *et al.,* 2007; Nogueira, 2010)	38.76	6
3.	Percentage of Water Body (Barua *et al.,* 2012)	13.38	6
4.	Percentage of Vacant Land (Nogueira, 2010)	3.21	6
5.	Percentage of Urban Green Space (Su *et al.,* 2014)	1.75	7
6.	Percentage of Circulation Network	4.31	1

(Source: KDA, 2002 and Author's Calculation)

For variable no. 1, 3, 4, 5 and 6, the score is ascending as the percentage increase. For variable no. 2, the score is descending as the percentage decrease. The score is calculated out of 32. After assigning the scores for each variable, the scores were aggregated. Digholia area, having 32 points, which is the highest among other areas, was selected as the study area. Digholia is mainly an upazilla situated at the north-eastern corner of the Khulna Metropolitan Area surrounded by Bhairab River. Total area coverage is 86.52 square kilometers. The total population of the area is approximately 1, 63,265 (Government of the Peoples' Republic of Bangladesh, 2016). Average population density is about 1,048 people per square kilometers (Bangladesh Bureau of Statistics, 2013). There is about 13,761 hectare of agricultural land in the area. The map of the Study area has been shown in Figure 1.

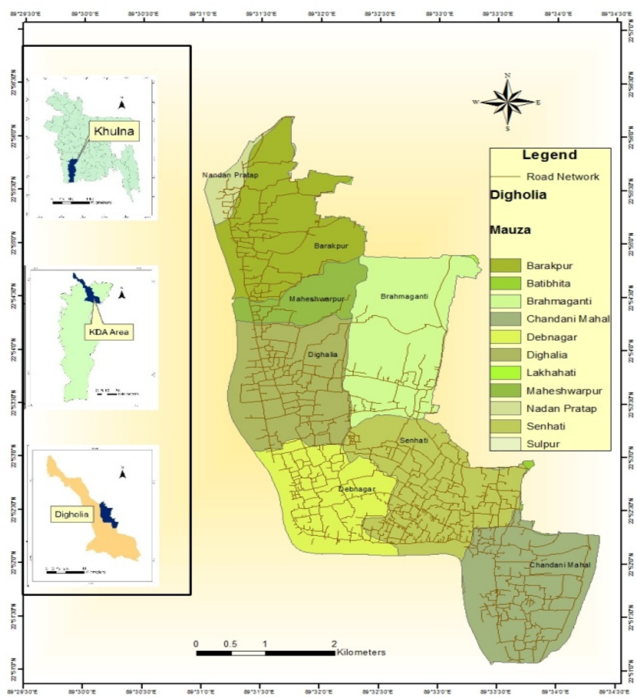

Figure 1: Map of the Study Area (prepared by the researchers)

Table 2: Table showing land use types in Digholia with percentages

Land Use Type	Percentage
Agriculture	42.82
Circulation Network	4.31
Commercial	0.78
Community Service	0.34
Education and Research	0.82
Government Services	0.12
Manufacturing and Processing Activity	1.94
Miscellaneous	0.01
Mixed Use	0.36
Non-Government Services	0.01
Recreation Facilities	0.09
Residential	**29.71**
Restricted Area	0.17
Service Activity	0.17
Transport and Communication	0.01
Urban Green Space	1.75
Vacant Land	3.21
Waterbody	13.38

Source: (KDA, 2002)

The land use map collected from KDA shows that the selected study area has 18 (eighteen) types of land use. Table 1 show these land use types and the percentage of land that falls under each category. A majority portion of the study area is used for agricultural purpose (42.8%) (KDA, 2002). This indicates a greater dependency of the population of the study area on agriculture and related activities.

3. METHODOLOGY

In this study, a method named LUSSM (Greca *et al.,* 2010) has been used to determine the required evapotranspiration area for peri-urban areas to support the environment of nearby metropolitan region. This method has adopted land cover analysis and fragmentation analysis to determine the eco-sustainable land use pattern for a region.

3.1 Land Use Determination

The first step of the methodology is to determine the land use characteristics of the study area. The land use map of *Digholia* area is already prepared by KDA. It was validated via reconnaissance survey, and Google Earth Maps. In the land use map of KDA, residential area is typically delineated without any further detailing or classification. For this study sub-categories within the residential land use were identified in order to get a better understanding of the urban fabric for the Land Cover Analysis (Greca *et al.,* 2010). The residential area was sub-divided in several categories: Multi-storied building, historical compact urban settlements, and detached houses. The task was completed both via field observation, and by placing the residential land use patches on Google Earth Image to cross check as well as to fix up the categories.

Another type of land use that was differentiated is the open space. This category was divided into woods and shrubs, public and private gardens, playgrounds and abandoned farmlands. The delineation of this category was also done using the above mentioned method.

3.2 Land Cover Analysis (LCA)

Land use characterization does not always provide exact scenario of the existing land cover condition of the study area (Gill *et al.,* 2008). A land use type may consist of different types of land cover components. For example, in a land use map of a city, there is demarked an area for a university. The university has some playgrounds, ponds and some open spaces which the land use map has totally avoided in its demarcation. A land cover analysis of that area will provide a clear scenario of how many components there are.

Visual interpretation of the study area was conducted using Unsupervised Image Classification named Maximum Likelihood Classification. This type of image classification process worked best with the Google Earth image used for this study. This allowed to determine different land cover types in which a pixel with the maximum likelihood is classified into the corresponding class. A geographic sampling was performed because 20 land cover classes were generated based on unsupervised classification which resulted in different classes for the same types of land covers based on slight differences in their colors. For instance, a farmland with newly planted crops shows a different color in the image compared to that shown by a farmland with crops ready for harvest and hence was identified as two different classes. For the study, 4 (four) types of land cover were determined. They are: built up area, vegetation, farmland and open spaces and, water body (Ahmed, 2011; Sarker and Uddin, 2016).

In the next stage, land cover composition for each land use type was conducted. This was conducted via Geographic Sampling Strategy (Gill *et al.,* 2008; Akbari and Taha, 2003; Tappan *et al.,* 2004) as mapping every single detail is time consuming. For the purpose, the land use map was overlaid over a 100×100 meter cells, and using GIS tools, random sampling was done. In this case, a sample of cells was generated for each land use type. Different size of the sample is also required here. Confidence level and interval were fixed respectively at 95% and 5%. Based on these assumptions, about 193 out of 374 cells were taken as sample size for the study. The equation for determining sample size is:

$$\boldsymbol{n} = \frac{\boldsymbol{N}}{\boldsymbol{1+Ne^2}} \text{ (Gupta and Kapoor, 2002)} \quad (1)$$

Here, n= sample size; N= Population (total no. of cells under consideration); and e= standard error.

Land cover surfaces was manually identified and digitized for each sampled cell. For the purpose, high resolution Google Earth image was used. After that, the percentage of land cover types for each land use category was determined. It was used for further mathematical calculation.

3.3 Fragmentation Analysis (FA)

When a contiguous ecosystem is divided into patches it's known as fragmentation (Greca *et al*., 2010). A patch consists of an area that has relatively homogeneous conditions in comparison with other patches (Forman, 1995). A patch category is typically represented by a class. For land use types, fragmentation was evaluated for all the patches. In this study, the geographical unit for fragmentation metrics is the single Peri-Urban Patch. Two patch composition metrics (Rutledge, 2003) was calculated in this study:

- Patch Area (PA) (McGarigal and Marks, 1995)
- Number of patches (NP) within 200m radius from each patch

PA is the measure of the area for each patch. Larger patches are less fragmented and smaller patches are highly fragmented. The two metrics are then aggregated to get a unique fragmentation score:

$$FR = (1 - PA\_) + (NP\_) \tag{2}$$

Here, FR (Greca *et al.,* 2010) is the degree of fragmentation for each patch. PA_ (McGarigal and Marks, 1995) and NP_ (Turner, 1989) are the normalized values of PA and NP in a 0 to 1 scale.

$$PA\_ = \frac{PA}{PA_{max}} \tag{3}$$

$$NP\_ = \frac{NP}{NP_{max}} \tag{4}$$

PA_{max} and NP_{max} are the maximum values in the study area. All the scores were considered to be relative among different patches within the study area.

3.4 Land Use Suitability Strategy Model (LUSSM)

In this stage, a suitable land use percentage for *Digholia* area was determined. In this study, for identifying a land use pattern that is suitable for providing environmental support and services to the main city (Khulna), a model called LUSSM was used (Greca *et al.,* 2010). Here, LCA and FA were used in the proposed model for defining a two dimension matrix which combines evapotranspiration and fragmentation degrees.

When the two matrices were combined, the data will intersect at various points. The evapotranspiration and fragmentation values were divided into several classes of equal intervals. In the matrix, the intercepting values were assigned a land use type. For example, a land with high evapotranspiration value but with low level of fragmentation can be used for environmental protection purpose as there is high level of vegetation cover and ecological integrity. On the other hand, where the evapotranspiration and fragmentation value is high, it indicates that there are small fragmented patches and can be used for local green services.

Table 2: Percentage (%) of various types of surfaces by land use types

Land use type	Built up area	Water body	Evapotranspiring surface
Agriculture	4.11	30.67	65.22
Circulation Network	3.37	29.55	67.07
Commercial	15.91	13.75	70.34
Community Service	16.96	13.08	69.96
Education and Research	11.37	20.00	68.62
Govt. services	15.49	24.19	60.32
Manufacturing and Processing Activity	7.11	18.90	73.99
Miscellaneous	6.88	30.57	62.55
Mixed	8.63	24.83	66.54
Non govt. Services	11.98	22.31	65.71
Recreation	8.24	29.53	62.22
Residential	15.76	24.32	59.92
Restricted	8.63	24.83	66.54
Service	4.01	32.48	63.50
Transport and Communication	8.14	16.28	75.58
Urban Green Space	0.43	32.17	67.41
Vacant Land	2.57	31.49	65.94
Water body	0.79	70.62	28.59

4. ANALYSIS AND INTERPRETATION

4.1 Land Cover Analysis (LCA)

The four distinct land cover types were analyzed to find out the percentage of impervious surface/built up area, water body and evapo-transpiring surface within each of the 18 land use types of the study area. The results are summarized in Table 2. Noteworthy, here is the fact that the land cover analysis and all the other analyses done henceforth were performed in order to determine the contribution of various land cover types to Evapotranspiration. Evapotranspiration means the combination of evaporation and transpiration by plants. Hence the areas under the land cover types of ‘Vegetation’ and ’Farmland and Open spaces’ have been considered as the ‘Evapo-transpiring Surfaces.’

Figure 2 shows the percentage of evapotranspiring surfaces under each land use types based on the values from Table 2. The values have been mapped after classifying them into four equal intervals from Level A (low) to Level D (high). Land uses like residential and recreational areas are in Level A; agriculture, urban green and vacant lands in Level B; commercial, community services etc. in Level C and Transport and Communication, Manufacturing and Processing Activity falls in Level D. These results can be utilized in further decision making processes including suggestion of new land uses as well as preservation and conservation measures.

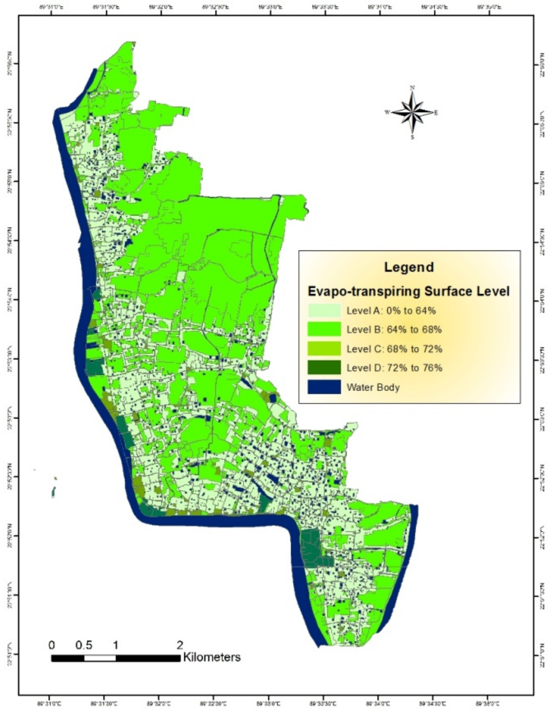

Figure 2: Percentage of Evapotranspiring Surfaces

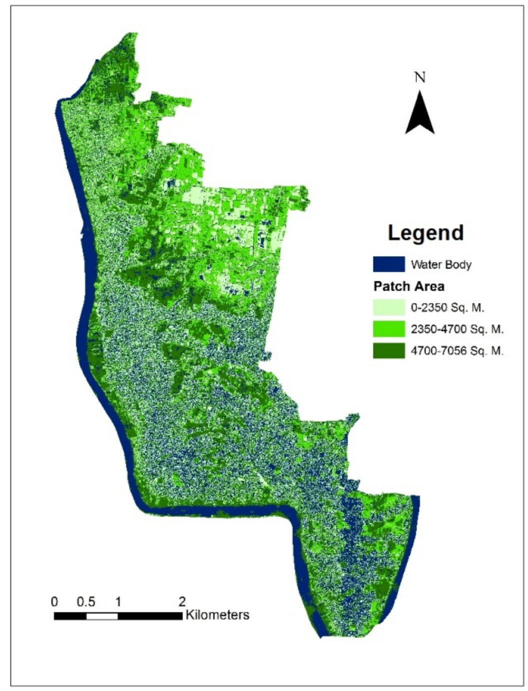

Figure 3: Map of Patch Area (PA) metric

4.2 Fragmentation Analysis (FA)

The fragmentation analysis should be conducted based on two patch composition matrices as mentioned in the methodology.

1. Patch Area (PA)
2. Number of Patches (NP) within 200 m radius of each patch

Since the study area is not too large, NP was calculated with a radius of 200m of each patch. Figure 3 shows the PA values for a total of 76, 08,695 patches. The PA values range from almost 0 sq. m to 7056 sq. m. The map shows the small patches distributed over the entire study area, from the residential and recreational areas on the south-west to the agricultural lands towards the north-east. Majority of the patches are of areas between 2350 and 4700 sq. m. This indicates that the patch areas are smaller in the residential areas due to high concentration of dwelling units, but the amount of fragmentation is relatively low. On the other hand, Figure 4 illustrates the map of NP values which suggest a medium to high level of fragmentation in the southern and south-western region of the study area. This is again due to the presence of large number of dwelling units in that region. Again, the NP values are low to medium in the north-eastern and central regions showing comparatively lower degree of fragmentation there. The NP value ranges from 51 to 228.

The Fragmentation Degree (FR) values are presented in Figure 5 after grouping them into three classes of equal intervals, viz. Level 1 (low), Level 2 (medium) and Level 3 (high). The map shows a huge amount of Level 3 fragmentation throughout the study area, especially along the western and south-western region of the study area which are mainly used for residential, Govt. service, and recreational etc. purposes. However, the majority of the study area (37.75%) including the agricultural lands in the central and north-eastern region consists of Level 1 fragmentation, followed by Level 3 fragmentation (32.61%) which are also characterized by large to medium patch areas and medium to low NP values. In short, these values indicate that the level of fragmentation is not much high in the study area. This is due to the fact that a large portion of the study area is covered with agricultural lands and manufacturing and processing activity.

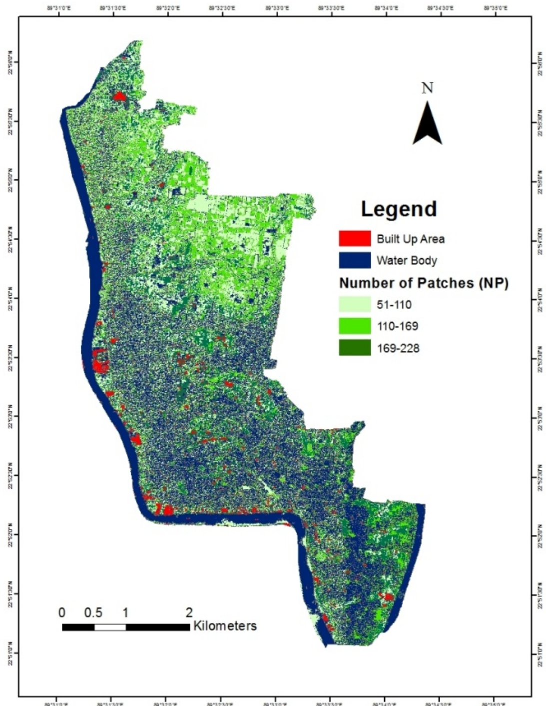

Figure 4: Map of Number of Patch (NP) metric

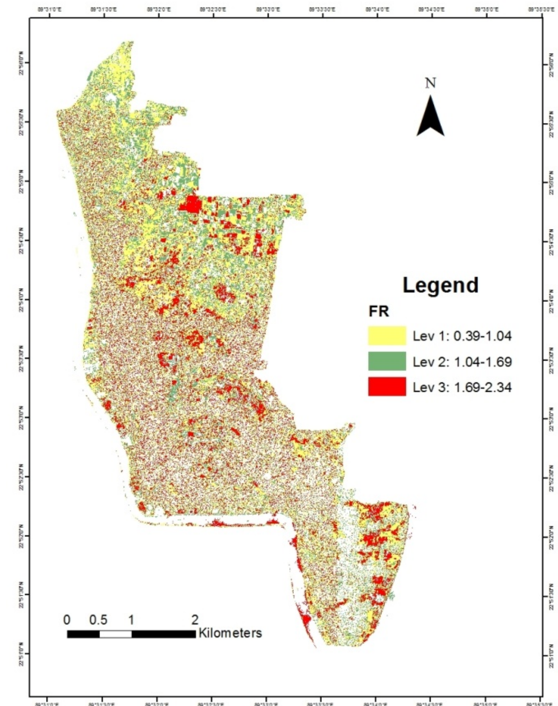

Figure 5: Map of Fragmentation Degree (FR) metric

4.3 Land Use Suitability Strategy Model (LUSSM)

Appropriate allocation of land use with prior concern to deriving maximum socio-economic as well as environmental benefits by utilization of limited resources is one of the primary objects of urban and regional planning. Hence, new land use should be suggested after considering a number of alternative options and selecting the most suitable one based on verified results. In the present study, a suitability model named LUSSM has been adopted to suggest the most appropriate land use option for *Dhigholia Upazilla*. Results of LCA and FA was used to generate a two dimensional matrix consisting of evapotranspiration and fragmentation degrees, both of whose values are classified into equal intervals.

Through rigorous literature review and field research, Greca *et al.* (2010) also suggested seven Prospective Land Uses (PLUs) for each of the patches within the study area that intersects with their respective classes of evapotranspiration and fragmentation values. These seven PLUs have been grouped into four broader classes based on various strategic purposes namely, environmental protection, leisure, local green services and urban agriculture.

The seven PLUs for LUSSM are mentioned below:

1. Natural Parks
2. Connecting Green
3. Agricultural Parks
4. Community Supported Agriculture (CSA)
5. Allotment Gardens
6. Urban Green Spaces
7. Small Gardens and Playgrounds

The seven PLUs are also well justified for the PUAs of Bangladesh. For instance, Community Supported Agriculture (CSA) can be seen in the PUAs in the form of agricultural product processing factories and other related services. About 1.94% of the land use of the study area, *Digholia* is attributed to 'Manufacturing and Processing Activities' (KDA, 2002), which can be considered as a form of CSA in Bangladesh. Again, Urban Green spaces and Parks and Playgrounds can be easily found in the metropolitan as well as suburban context of Bangladesh. Hence, the seven PLUs have been considered for this study too.

The two dimensional matrix shown in Fig. 6 suggests the Degree of Fragmentation divided into three increasing classes (Level 1 to Level 3) and the Degree of Evapotranspiration divided into four increasing classes (Level A to Level D). The squares inside the matrix indicate the new PLUs for each of the intersecting classes and the colors of the squares refers to the categories of strategic purposes.

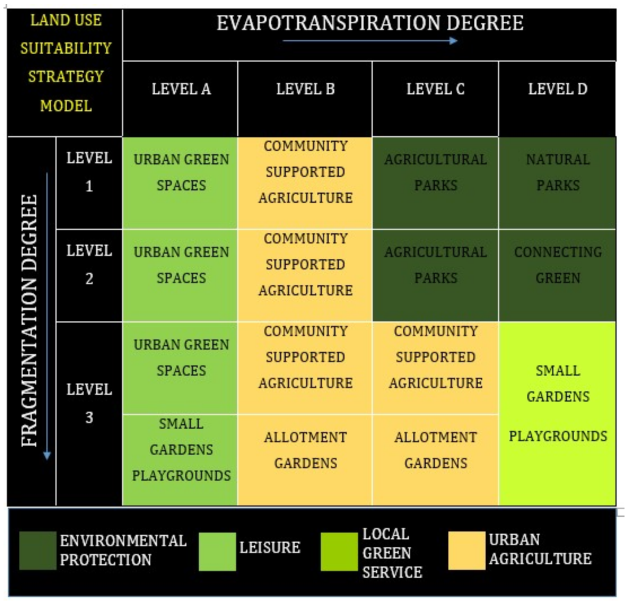

Figure 6: The Matrix used for addressing peri urban land use by LUSSM, (Modified from: Greca *et al.,* 2010)

All the other suggested PLUs except those for the intersection of Fragmentation Degrees of Level 3 and Evapotranspiration Degree of Level A to Level C are understandably distinct. This exception occurs in order to take the concept of residential proximity into account. For instance, in areas with low level of evapotranspiration (Level A) combined with highest level of fragmentation like those within the residential zone, small gardens and playgrounds can be suggested as an alternate option to urban green spaces. Again, in case of medium to high level of evapotranspiration (Level B-C) with highest level of fragmentation (Level 3), allotment gardens can be suggested instead of CSA. However, when the degrees of both evapotranspiration and fragmentation is the highest, (Level D and Level 3 respectively), the only suggested PLU should be small gardens and playgrounds such that the existing level of evapotranspiration is not hampered due to the proposed layout.

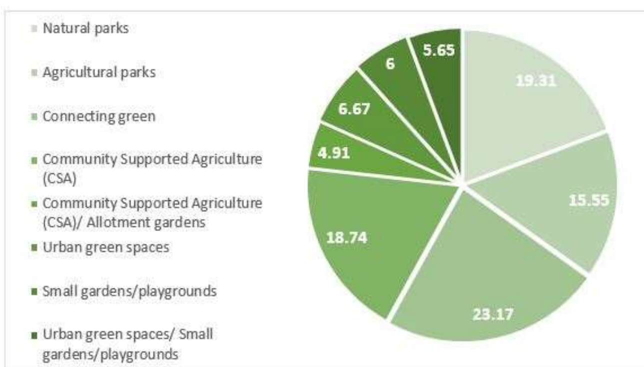

Figure 7: Proposed suitable land use percentage for Digholia under the 7 (seven) PLUs

4.4 Suitable Land Use Map Preparation

According to the LUSSM, a suitable land use map (Fig. 8) for *Digholia Upazilla* was prepared with the values of the degrees of evapotranspiration and fragmentation and the corresponding suggested PLUs from the matrix. The proposed land use percentages for different PLUs according to the map is represented in Figure 7. The results show an increased emphasis on connecting green (23.17%) or in other words, greeneries between built up or other land uses, followed by natural parks (19.31%). This suggestion seems valid considering the fact that almost 56% of the study area is currently under use as agricultural land and another 26.5 % for residential purpose. Compared to that the amount urban green spaces in Digholia is negligible (0.09%) (KDA, 2002). Hence the proposed land use suggests an increase in connecting green type of land use as an environmental protection measure and promotes natural parks and CSA type of land uses considering the conservation of the existing natural resources and cultivation practice of the study area. More emphasis on Connecting Green type of land use also seems valid from the consideration that the amount of built up area within the study area will increase in future and hence, networks of continuous or discontinuous natural or semi natural state areas with greenery will be required around and between developed patches. Because of the agricultural nature of the study area and the existence of manufacturing and processing activities therein CSA is highly recommended.

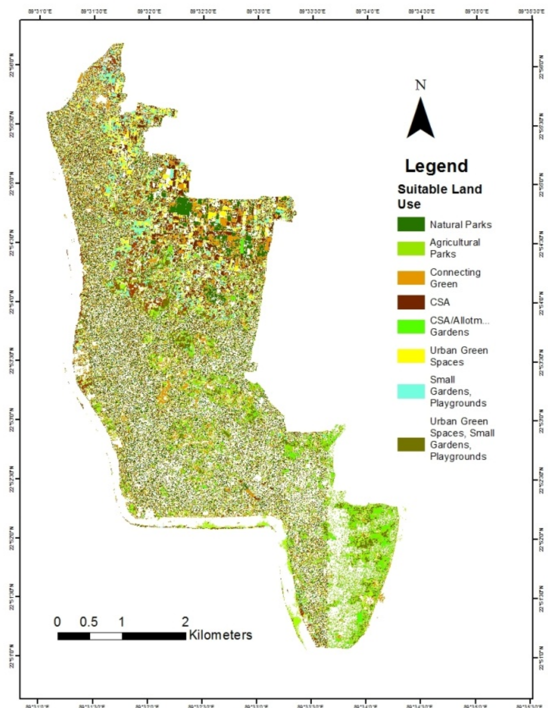

Figure 8: Map of Proposed Land use for Digholia Upazilla using LUSSM

It is required that, at least 25% of the total area of a city should consist of green spaces which may consists open spaces, natural parks, vegetation or agricultural lands. The total percentage of greenery available in Khulna city is about 50% (Sarker and Pia, 2015), according to the data available from 2014. That may look like a promising statistics for a growing city like Khulna. But, as discussed in the introductory portion of this paper, the amounts of greenery is decreasing due to increase in population and have the probability to decrease more in the upcoming years. Most of the evapo-transpiring surfaces are left as unused with no definite purpose. This unused land, if properly managed and protected against haphazard growth, can contribute towards effectively increasing the sustainability of the City (Khulna) with respect to ecological values and food production support. With the rapid urbanization in Khulna, densification will eventually follow and hence the concept of Compact Cities will be applicable in the not so distant future. Hedblom *et al*. (2017) points out peri urban areas as a very important contributor to the increasing need of public green spaces and ecosystem service providers in urban areas. They further argued that sustainable cities of the future must take into account the crucial services that peri urban areas provide to the urban dwellers. On this note, if the suggested land use is applied in the concerned study area, it will ensure that every fragment of land will be utilized properly. The respective authority won't have to facilitate for additional open spaces and the agricultural lands will remain protected. The protection of agricultural lands will ensure that the respective area is facilitated by adequate amount of food as well as the additional amount can be transferred to the main city. The higher amount of evapo-transpiring surface will help to maintain the ecology to remain in a sound state and the level of the groundwater will have less chance of degradation.

5. CONCLUSION

From application perspective this study is a unique approach for Bangladesh. With proper collaboration with the existing policies, laws and legislations, the proposed land use can be very beneficial for the environmental health of the region. Thus the work is replicable for any area with environmental prospects.

Generally, the study area adopted here has larger amount of evapo-transpiring surface compared to other areas in Khulna city. But most of these lands are unused or misused in one way or another. The urban areas are increasing in an unplanned manner. New manufacturing areas have been constructed along with the increase in population in the area. But, there is less concern about the environmental aspect. If the unused or misused parts of the study area can be studied with appropriate quantitative data and can be brought in front of proper authority then it would be helpful for both the dwellers and their environment. Using the Land Cover Analysis (LCA) and Fragmentation Analysis (FA) can provide useful information and quantitative data and can provide a method for decision making process to adapt with the changes in the environment.

The areas where the amount of built up areas is high it is probable that the patch fragment will also be higher. Higher fragmentation level provides less opportunity for green spaces which deteriorates human health as well as unique species in that area in the long run. Evaluating the evapo-transpiring patches by means of fragmentation analysis can be very helpful for determining land use characteristics. It can be understood from the study that, high level of fragmentation causes discontinuation of green spaces and thus lands are left unused or misused. These small parts of land where no big initiatives can be taken are suitable for use as small gardens, community supported agriculture or small playgrounds for children. This method identifies these small patches of land and suitable land use can be suggested for health and environmental safeguard.

On the other hand, less fragmented areas means the patches are uninterrupted which can be used for large land use like agricultural parks or natural parks. In other words, integrity of ecological functions can be assured by the compactness and size of patches that guarantee minor interference from human activities.

The FA in the study area has shown that the amount of less fragmented areas is highest which validates the fact that the high amount of evapo-transpiring surface in the area. The southern part of the study area is comparatively densely populated and has diverse land cover which has resulted in higher fragmentation in that area.

The higher amount of evapotranspiring surface in an area is definitely an asset for the respective area. Proper allotment of land use in that area ensures environmental safety and improvement in public health. For example, small fragments of lands are often found beside residential plots or beside any other built structures. Policy measures that suggest appropriate land uses for these fragmented lands (such as the one suggested in this study) can result in a better environmental management of the area under consideration. If the respective authorities like KDA take this study into consideration, it will definitely change the environmental scenario of the area.

Further study can be initiated if the land data can be more accurately acquired. During the study, retrieving some data was time consuming and in some cases required big calculation. This is especially relevant in those planning systems that do have limited criteria specifically targeted to evapotranspiring surface and unused and misuse of land and that consider them as generic farmlands or undefined urban green spaces which resembles our planning system.

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