Delineating fringe by rough-set theoretic approach: a case study on Barasat city, India

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Abstract. In the process of rapid land use change, the city compels the urbanized area to sprawl and engulf the surrounding landscape. A region which was once rural gets converted into fringe and ultimately incorporated within the urban built-up. Uncontrolled structural change of a city by the inclusion of non-urban landscape within the urban areas is responsible for environmental degradation. Prevention of environmental dilapidation, demands the proper demarcation of fringe. The concept of ‘fringe’ suffers from a problem of not having any universally accepted definition and methodology of demarcation. In this study, attempts have been made to delineate the fringe, happens to develop within the administrative boundary of a monocentric city of Barasat, India, based on i) the land use diversity and ii) social behavior of the populace. The land use diversity is computed by using the Shannon Diversity Index (SDI) which is used to define the global diversity threshold for fringe demarcation. Social behavior of the residents has been used for estimating the accuracy of this crisp classification of core and fringe. The result shows that because of the fuzziness in nature, the change over from core to fringe is characteristically zonal i.e. it extends for a distinct region where this transition is visible in the form of mixed land use and social behaviour. This gives birth to a boundary area instead of a precise boundary line that could be termed as “possible fringe.”

Key words: Fringe delineation, Rough set theory, Land use diversity, Social diversity, Shannon Diversity Index (SDI)

1. Introduction

In the process of rapid land use, a region that once was rural comes in close contact with the growing town and becomes a transitional area and acquires the character of the fringe. It's the most sensitive, dynamic and swiftly changing area during the urbanization. The urban areas slowly overtake this fringe area, forcing the fringe to migrate out of the city centre. Uncontrolled structural change of a city by integrating non-urban landscape into urban areas is responsible for various environmental and social degradations. In addition to the direct assimilation of land, process of converting urban fringe and rural land to urban land uses causes destruction of open space, natural vegetation and loss of farm lands. Fringe often suffers from inadequate service & social infrastructure, landfills, waste dumping, unmixing of residents. Prevention of these dilapidation, demands the proper demarcation of fringe. The term 'fringe' suffers from a problem of not having any widely agreed definition and demarcation methodology. Gaplin's pioneering study on the conversion process of 'rural' to 'urban' laid the foundation for future studies on fringe [1]. T. L. Smith's used the term “urban fringe” to define it as the “built-up area just outside the corporate limit of the city while studying population composition and changes in Louisiana [2]. Fringe as the mixture of urban landscape and farmland was defined by Salter [3]. Wehrwein has defined the fringe as ‘an area of transition between well-recognized urban land uses and the area devoted to agriculture’ [4]. Fringe is neither completely urban nor solely rural. It is the region where all sorts of offhand developments take place. Kurtz and Eicher conceptualized that the
rural-urban fringe or simple fringe exists outside the city's legal limits [5]. But fringe may not always dependent on the administrative boundaries. The urbanism of a city may be practised beyond the administrative limits of the city or people may practice rural lifestyle within the city boundary [6]. Allen (2003) says that rural-urban features can co-exist within the cities and fringe may develop within the administrative limit of a city [6].

Thus, understanding land use and land use conversion can be the best method of fringe identification [4]. Pryor has stressed on the social and demographic behaviour, along with the pattern of land use for demarcation and the depicted urban-rural fringe as the transition zone between the rural hinterlands and the city's continuing urban areas [7]. Pryor has classified fringe into urban fringe and rural fringe [8]. The region that is contagious to the urban fringe can be described as "rural fringe" with lower population density, a higher proportion of agricultural activities [8]. According to Carter, the area with distinctive characteristics, which is only partially assimilated to the urban complex and still partly rural, is called the fringe [9]. Ramchandran designated fringe in Indian contest as an area starting from a point near the city where agricultural land appears and extends up to the villages with distinct land use [10]. Adell considered fringe where the urban meets the rural [11]. In the analysis of central Brazil, urban fringe was described as 'informal settlements' since it is not included either strictly in the urban or rural categories [12]. Fringe is also referred as a juxtaposition of activities that were previously considered incompatible [13]. With low density dispersed patterns of settlements, greenery, agricultural land and natural water bodies, fringe is situated along the outer boundary of the built-up zone [14].

The belt of fringe does not remain static; it is under continuous pressure of urban development [13]. The city's dynamic nature compels the urbanized region to expand and embrace the surrounding landscape [15]. Because of this dynamic nature, it is difficult to delimit the urban fringe through definite criteria [16]. For the study of the fringe in Orlando and Florida land use intensity and its changing pattern has been considered as the major factors [17].

From the socio-economic viewpoints, fringe interface has also presented several peculiarities. The social composition of fringe is highly heterogeneous and subject to change over time. Small farmers, migrants, industrialists and urban middle-class residents can all coexist in the fringe area. They often have different and sometimes conflicting interests, practices and perceptions. Thus the study of the social behaviour also used as criteria for delineating the fringe belt. In America, the occupational and social structure was used to define fringe [18]. The preferences of home buyers were used to assess the location of the fringe in the Columbus metropolitan area of Ohio [19]. Integrated remote sensing and GIS techniques can use both land use change information, demographic and socio-economic data together to delineate the fringe.

In this study attempts have been made to delineate the fringe, happens to develop within the administrative boundary of a monocentric city, based on the land use and social characteristics. Barasat Municipality of West Bengal has been selected as the study area for demonstrating the work. The rural-urban dichotomies in the city indicate the existence of fringe within the framework of the administrative boundary of Barasat. There have been significant differences in the behavioural pattern found in dress, habits, literacy occupation and livelihood earning of the residents of the inner part and the outer part of the city. The study has attempted to differentiate fringe, core and possible core based on diversities. Shannon Diversity Index value is used as the primary indicator for delineating the boundary of fringe in the study area. The core is the continuous built-up area (urban core) or unbroken rural landscape (rural core). Fringe is the perfect mixture of both urban and rural environment. Possible fringe is the fuzzy unclassified boundary zone between core and fringe. The inclusion and exclusion rule of possible fringe would be careful field observation dependent. Part of this work has been adapted from author’s previous work [20].

This paper is organized into five sections. The initial part is the review of existing literature of fringe study and available methodologies of fringe delineation. The next part is the description of the study area. The third part deals with the proposed methodology of fringe identification, followed by the advanced methods of fringe delineation. The last section discussed about the detail analysis of the implementation of the proposed methodologies, conclusion concludes the paper.
2. **Study area**

As an urban area in the vicinity of the Kolkata agglomeration, the municipality of Barasat, a city of class I, situated under the jurisdiction of the Kolkata Metropolitan Development Authority (KMDA) (figure 1).

The Municipality of Barasat was chosen as a case study for this research work. Since it became the District Headquarters of North 24 Parganas District in 1986, its importance has widened and has been affected by rapid and continuous urban developments. It currently has around 300,000 inhabitants with a population density of 8216 per square kilometer (as of 2011). It is shocking to note that the population growth rate in Barasat between 1991 and 2001 was 125.5 per cent, which is much higher than the urban population growth in West Bengal and India. Rapid urbanization, rural and agricultural practices within the city, migration from neighboring Bangladesh since partitioning has given this study area a heterogeneous character and ideal for this study.

![Location map of the study area](image.png)

**Figure 1.** Location map of the study area

3. **Background concept**

3.1. **Shannon diversity index**

Available socioeconomic statistics can clearly identify rural and urban areas, but will not be able to provide any identity pattern for the demarcation of fringe. Land use pattern and its quantified evenness in distribution within a landscape can be an indicative factor of fringe identification. Both rural and urban
core will have homogenous nature of land use. As the transitional area encompasses mixed fragmented land use, there always will be an increasing tendency of heterogeneity.

A diversity index (DI) is a quantitative measure that reflects number of different types in a dataset (#N) and evenness of their distribution.

\[
\text{DI} \propto \#N
\]

\[
\text{DI} \propto \text{Evenness of the distribution}
\]

From a range of diversity index Shannon Diversity Index (SDI) has been selected. SDI has been widely used for measuring biodiversity and also used recently for identifying degree of disorder in landscape and consequent fringe demarcation [21]. The lowest possible value of the index is zero which stands for no diversity and higher the index value, higher is the diversity. Shannon diversity index when used in land use studies, the interests are relative abundance of different land use in a particular area. The formula is:

\[
SDI = -\sum_{i=1}^{m} (P_i \ln P_i)
\]

Where \( P_i \) is the proportion of land use present in land use type \( i \) which is proportional to the total number of land use types calculated in an area and \( \ln P_i \) is the natural logarithm of the \( P_i \) value.

The Shannon Diversity Index is also used to measure the social entropy. Social diversity index describes the extent to which the social behavior of the residents is diverse. There are three major factors (health behavior, education level and occupation) for which the social diversity has been calculated for the venue. These categories are further described in the appendix section. By averaging these values across the social neighborhood the final social diversity is derived.

3.2. Rough set:

3.2.1. Information system. Datasets can be represented as table. Objects of the dataset are represented by the rows of the table. Whereas, attributes of the dataset are represented by table columns. For each object, each attribute will have some value. This table is known as an information system. Formally information system \( I= (U, A) \), where \( U \) denotes set of objects and \( A \) denotes set of attributes. Such that \( a: U \rightarrow Va \forall a \in A \). Where \( Va \) denotes value set of a.

Example of an information system is given below in table 1:

| Table 1. An example information system |
|----------------------------------------|
|                                        |
| Fertilizer used (‘000 tones) | Rice production (MT) |
| X1                | 4000             | 139   |
| X2                | 4000             | 110   |
| X3                | 5000             | 89    |
| X4                | 5000             | 89    |
| X5                | 6000             | 118   |
| X6                | 4000             | 118   |
| X7                | 6000             | 118   |

Different production years denoted by X1 to X7 are the objects of the information system. Fertilizer used and Rice production are two attributes of the information system. Each object has some value for each attribute. From the above example it can observed that, (X3 and X4) and (X5 and X7) have same values for the two given attributes.

3.2.2. Indiscernibility. In information system \( I \), for a set of conditional attributes \( B \) (where, \( B \subseteq A \)) an equivalence relation \( IND(B) \) can be formulated. An equivalence relation \( R \) is reflexive, symmetric and transitive.\(^1\)

\(^1\)\( R\subseteq X \times X \) is reflexive, i.e. an object is in relation with itself
\( \text{IND}(B) = \{(x, x') \in U^2 \mid \forall a \in B \ a(x) = a(x')\} \)

\( \text{IND}(B) \) is B-indiscernibility relation. If \((x, x') \in \text{IND}(B)\), then objects \(x\) and \(x'\) are indiscernible from each other by attributes from \(B\) and will fall into the same equivalence class. The equivalence classes of the B indiscernibility relation are denoted as \([x]_B\).

The subsets of conditional attributes are \{Fertilizer use\}, \{Rice production\} and \{Fertilizer use, Rice production\}. Set of objects can be partitioned into equivalence classes based on conditional attributes. Partition of set of objects is shown below based on conditional attributes provided.

\[
\begin{align*}
\text{IND}\left(\{\text{Fertilizer use}\}\right) &= \\{\{X1, X2, X6\}, \{X3, X4, X5, X7\}\} \\
\text{IND}\left(\{\text{Rice production}\}\right) &= \\{\{X1\}, \{X2\}, \{X3, X4\}, \{X5, X6, X7\}\} \\
\text{IND}\left(\{\text{Fertilizer use, Rice production}\}\right) &= \\{\{X1\}, \{X2\}, \{X3, X4\}, \{X5, X7\}, \{X6\}\}
\end{align*}
\]

The elements of \(A\) are called conditional attributes or simply conditions. There can be another kind of attribute, called decision attributes. Information system, which has decision attributes are called decision systems.

\(I= (U, A \cup \{d\})\), where \(d\) is a decision attribute.

### Table 2. Satisfaction: An example decision table

|                | Fertilizer used ('000 tones) | Rice production (MT) | Satisfaction |
|----------------|-----------------------------|----------------------|--------------|
| X1             | 4000                        | 139                  | Yes          |
| X2             | 4000                        | 110                  | No           |
| X3             | 5000                        | 89                   | No           |
| X4             | 5000                        | 89                   | Yes          |
| X5             | 6000                        | 118                  | No           |
| X6             | 4000                        | 118                  | Yes          |
| X7             | 6000                        | 118                  | No           |

The decision attribute “Satisfaction” is added to the table 1 provided for information system earlier. Satisfaction from production may have “yes” or “no” value (table 2).

As mentioned before (X3 and X4) and (X5 and X7) have the same conditional attribute values. Although the values of conditional attributes for object X3 and X4 are same, the “Satisfaction” level is different. In this case, decision on “Satisfaction” cannot be crisply identified by the values of conditional attributes (Fertilizer used and Rice production).

#### 3.2.3. Rough set computation.

From the Indiscernibility relation, on conditional attributes, set of objects can be partitioned as stated previously. In each partition or equivalence class, all the conditional attributes will have the same values. It may happen that in an equivalence class, decision attribute value differs. It is the situation when the decision attribute value cannot be mapped with conditional attribute value crisply.

Though the value of conditional attributes cannot be mapped to the value of decision attribute crisply, but it is feasible to identify the values of conditional attributes which will certainly give positive decision and the values of conditional attributes which will certainly give negative decision. Finally, value of conditional attributes, for which positive and negative both decisions can occur. These are known as boundary values. If the boundary is not empty, then the set is rough. If boundary is empty then the set is crisp.

Lower approximation is defined by the objects (belong the equivalence classes, for which decision values are always YES) certainly belong to the positive set and upper approximation is defined by the objects (belong to an equivalence classes, for which one of the decision values is YES) which may possibly belong to the set. A boundary set can be defined from the difference between upper and lower approximation.

\[
\text{If } xRy\text{ is yRx means it symmetric} \\
\text{If } xRy\text{ and } yRz\text{ then } xRz \text{ means transitive}
\]
If a set of attributes \( B \subseteq A \) and a set of objects \( X \subseteq U \) is considered where, \( X \) are those objects for which the value of decision attribute is YES, then it is possible to approximate \( X \) by using the values from attributes contained in \( B \). B-lower and B-upper approximation of \( X \), are denoted by \( B_X \) and \( \bar{B}_X \) respectively.

\[
B_X = \{ x | [x]_B \subseteq X \} \quad \text{and} \quad \bar{B}_X = \{ x | [x]_B \cap X \neq \emptyset \}.
\]

In the above example, equivalence classes \( \{X_1\}, \{X_6\} \) form to \( B_X \) and \( \{X_1\}, \{X_6\}, \{X_3,X_4\} \) from \( \bar{B}_X \). The equivalence class containing objects \( \{X_3, X_4\} \) forms the boundary. This non-empty boundary forms rough set.

4. Materials and methods

4.1. Data sets

The satellite image (tile Path 138 and Row 44) covering the study area has been downloaded free from the United States Geological Survey (USGS) website for all of the study periods. The acquired images were corrected radiometrically and geometrically. Atmospheric correction was not performed since the images were cloud free [22-23]. Based on the topographical map (scale-1:50000), the administrative map of Barasat was registered in the Universal Transverse Mercator (UTM) (Zone 45) and World Geodetic System (WGS84). The rectified map of Barasat was used to subset the processed images. Then, the clipped images were used as inputs to generate the land use land cover (LULC) data and to calculate land use diversity of 1989 and 2017 (April) for this study. It is noteworthy that the image processing was performed by TNT MIPS Pro 2015, ArcGIS Desktop 10.1 platform. The details of the sensors used in this study have been documented in table 3.

| Table 3. Details of sensors data used |
|--------------------------------------|
| Year | 1989 | 2017 |
| Satellites | Landsat 5 | Landsat 8 |
| Sensors | TM | OLI/TIRS |
| Date | 1989-04-25 | 2017-04-14 |
| Path/Row | 138/044 | 138/044 |
| Spatial Resolution | Optical 30m, Thermal 120m | Optical 30m, Thermal 100m |
| Spectral Bands | 7 | 11 |
| Radiometric Resolution | 8 | 8 |

4.2. Land use land cover (LULC) classification and accuracy assessment

For this analysis, the 1989 and 2017 clipped images are categorized into six different LULC categories following the USGS level I classification scheme. The built-up category includes together settlements, infrastructures, industrial areas, road network, pavements, and man-made structures, water body includes ponds, lakes, vegetation means natural vegetation, bare soil consists of bare surfaces, and open space, homestead with plantation comprises of semi-built-up areas and, slums, orchards and agricultural land takes account crop fields. After verifying with the Google earth image, a total of 100 training areas were selected on the image to train signature of six LULC classes. These signatures are used for maximum likelihood based supervised classification that runs with a feature-space non-parametric decision rule [24-26]. Afterwards, all classes are merged into suitable six classes using recode function. After classification, 50 samples are randomly selected from each category to check the accuracy of the classified maps of 2017. The classified images are compared with the Google earth maps of 2017. The total number of sample points was 135 for 1989, due to the unavailability of high
resolution Google Earth image. The kappa coefficient has been calculated from the confusion matrix to test the classification reliability.

4.3. Global diversity value based fringe delineation
Fishnet consisting of 500 m side length square was generated using ArcGIS to cover whole land use land cover map of the study area. The Land use Diversity is computed using the Shannon Diversity Index as given in equation (1). Where \( P_i \) is the proportion of land uses belong to the \( i^{th} \) land use category. Transect based fringe delineation [21] using Land use diversity index (LUDI), may not give the desired result within a growing city like Barasat. The land use map confirms the rural activity within the administrative boundary but the absence of prominent rural core will foil to get four points of inflection. Thus, instead of taking into account certain transect based local values, in this paper, the author has tried to demarcate fringe based on global diversity value. For a better result, in this work, an expert-defined threshold value has been taken, to delineate fringe followed by repetitive field visits and survey using Google earth image. This threshold value will be area, time-independent with similar land use classes which will enable us to compare the transformation of specific area over time and space.

Let, LUDI is the value of Land use Diversity Index computed for all the cells (500X500m).

\[ \text{LUDI}_k \] is the value of Land use Diversity Index for cell \( k \).

In this work, LUDI_F is the expert-defined threshold value for delineating fringe.

For cell \( k \), if \( \text{LUDI}_k > \text{LUDI}_F \) then cell \( k \) is defined as fringe, otherwise core.

Therefore, cells of the study area can be classified into fringe or core based on LUDI_F

4.4. Advanced Method of Fringe Delineation
Composite Social Diversity Index (CSDI) of 17 sample cells has been used for estimating accuracy of the crisp classification of core and fringe.

4.4.1. CSDI. In this study, educational, health and occupational diversity indexes were computed using the formula for Shannon’s Diversity Index as in equation (1). Educational diversity is measured by counting the residents belong to various educational levels among the five randomly selected individuals from each sample cell. Using Shannon’s Index of Diversity the proportion of individuals \( (P_i) \) belonging to the \( i^{th} \) type of educational category has been calculated.

Diversity in health habits is also calculated by Shannon Diversity Index (SDI) by counting the individuals belong to the health variables. Similarly, the output of occupational diversity is expressed as the proportion of individuals belongs to the occupational sectors. All of the data have been obtained from the questionnaire survey.

A Composite Social Diversity Index (CSDI) was calculated for each sample cell using proportions from education, health and occupation using the equation (2):

\[
\sum SDI_{Education} + SDI_{Health habit} + SDI_{Occupation}
\]

Five variables have been chosen for calculating each diversity index suitable for the study area, presented in table 4.

| Table 4. Social and economic variables included in diversity index |
|---|
| 1. Educational Variable |
| a) Illiterate |
| b) Less than 5 years of education |
| c) More than 5 years of education but did not finish high school |
| d) High school education |
4.4.2. Normalization of CSDI values: To transform the values of CSDI in the range [0, 1] normalization technique has been used by using the equation (3)

$$CSDI_k = \frac{CSDI_k - CSDI_1}{CSDI_{max} - CSDI_1}$$  \hspace{1cm} (3)

Based on this normalised CSDI value the information system and decision tables have been generated later for the 17 sample cells. Social diversity index of the sample cells has been used for estimating accuracy of the crisp classification of core and fringe. The overall methodology adapted for the study is presented in the diagram below (figure 2)

![Methodology of the study](image)

**Figure 2.** Methodology of the study

5. Result and discussion

5.1. Land use accuracy and dynamics
The achieved overall classification accuracies are 85.19%, and 85.7 % and overall kappa statistics are 0.817, and 0.828 respectively for the classification of 1989, and 2017 images.

The land use land cover has changed significantly over the study period which can be perceived even by visual inspection (figure 3). At the early stage of urbanization, in 1989, the built-up area of the municipality was restricted within a specific limit. Within a span of 28 years the urban built-up area has substantially increased and nearly the entire town has experienced urbanization. There has been a continuous loss of vegetation, agricultural land, water body and open spaces and extension of built-up land. The change statistics for the land use class has been given in table 5. This mixture of land uses and their transformations gives a satisfactory indication of the existence and the dynamic changes of fringe.

![Land use land cover map](image)

**Figure 3.** Land use land cover map

| LULC classes       | 1989  | 2017  |
|--------------------|-------|-------|
|                    | (Km²) | (%)   | (Km²) | (%)   |
| Vegetation         | 9.97  | 31.06 | 2.35  | 7.32  |
| Homestead with Plantation | 2.94  | 9.15  | 6.20  | 19.30 |
| Built-up Area      | 3.85  | 11.98 | 20.71 | 64.52 |
| Bare Soil          | 1.15  | 3.58  | 0.13  | 0.41  |
| Water Body         | 0.77  | 2.39  | 0.56  | 1.76  |
| Agricultural Land  | 13.44 | 41.84 | 2.15  | 6.69  |
| **TOTAL**          | 32.11 | 100.00| 32.11 | 100.00|

**Table 5.** Area of LULC Classes in 1989 And 2017
5.2. Fringe delineation and dynamicity

Fringe is an area which starts beyond the urban landscape. The central part of the study area is characterized by the almost complete absence of non-farm dwellings and land use called the urban core. Some peripheral patches are characterized by the absolute absence of the built environment. The uniform urban core and fragmented rural cores are with low diversity value marked in yellowish-red colour (figure 4). The higher LUDI value area contagious to the core built-up is demarked by blue colour where different land use type exists. This diagram gives a preliminary visual assessment of fringe and core. Thus, SDI can be assumed as a feasible indicator of the urban fringe in the study area.

In quick, unplanned developing cities such as Barasat, the patchy native vegetation near the concrete roads bear the brunt of urban expansion and there are many areas where the non-urban plots are near to the concrete high-rise buildings, making the LUDI value large. The natural water bodies coincide with an artificial one. Thus, just beside the urban core, there is an area which is also urban in nature. It has buildings of high rise-high density mainly along the streets but lacks continuity as other land uses begin to emerge. This landscape is of urban nature will have higher diversity values than the uniform urban core but that may or may not be called fringe.

Similarly, rural homogeneity starts to decrease when people who prefer to live in closeness to nature live in segregated urban plots surrounded by agricultural land and vegetation in the periphery of the town. With a few high-rise buildings and extensive rural land use, the area this area gives a higher diversity value than rural core but cannot undoubtedly assume to be classified as fringe according to their associated information. The interface between these two is epitomized by a mixture of urban and rural uses. This territory is characterized by high fragmentation, lack of urban or rural continuity, hybrid (neither rural nor urban) conditions, marked decline of urban lifestyles categorized as fringe.
within the city limit. Experts’ view of defining threshold value for delimiting fringe in the study area has been used followed by field verification. In this study judgment of five experts from the urban study are collected, and averaged. LUDI value 1.0 among the four considered thresholds (figure 5) is considered the most suitable threshold for demarcating fringe. If an area crosses the threshold of 1.0 then only the area can be surely labeled as fringe, otherwise core. In a few directions, the study area has a scattered fringe instead of a continuous one. This area has a mixture of land uses such as some housing, gardens, green spaces and water bodies. The informal natural households coexist with two or three-storey buildings.

![Figure 6. Fringe dynamicity](image)

Being time-independent this threshold value has been applied to delimit the fringe in 1989 as well and the dynamicity of it can be well established (figure 6). In 1989 fringe had been occupying an area of 20.6 sq km which has shrunk to 14.4 sq km in 2017.

5.3. Advanced Method of “Possible” Fringe Delineation

Without a consensus definition of the urban fringe, the accuracy assessment remains a challenge. Aspect of social diversity is incorporated for validation.

5.3.1. Generating the information system (IS). In the case of study, 17 sample cells (figure 7) represent the set of objects $[U]$, and “Categorized CSDI” is the conditional attribute $[A]$ (table 6). Value set of $a$, $Va$ (where, $a \in A$) can have five different values, very low, low, medium, high, and very high. Based on the sample survey an Information System is generated. In this case, set $A$, contains one attribute only and $B=A$. Using indiscernibility relation $IND(B)$ set of sample cells can be partitioned as follows:

$IND(\{\text{CSDI}\}) = \{\{124, 139, 76\}, \{74, 122, 156, 16, 118\}, \{107, 25, 112, 62, 77, 64\}, \{136\}, \{174, 145\}\}$

5.3.2. Rough set approximation. The decision attribute “Fringe” is added in the information system (table 7). This attribute is describing whether the cell is fringe or not. Depending on LUDI value, the value of fringe attribute is set. $X$ is the set of cells for which value of “Fringe” attribute is yes. All the objects of equivalence classes with “Categorized CSDI” value ‘Very High’ and ‘High’ have ‘Yes’ for the value of “Fringe” attribute. Objects of these equivalence classes form $B_X$. At least one of the objects of equivalence classes with “Categorized CSDI” value ‘Very High’, ‘High’ and ‘Medium’ have ‘Yes’ for the value of “Fringe” attribute. Objects of these equivalence classes form $\bar{B}_X$. 
The objects having ‘Medium’ values for ‘Categorized CSDI’ attribute are forming the boundary region of the rough set.

**Table 6. Information system**

| Grid No. | Categorized CSDI |
|----------|------------------|
| 124      | Very Low         |
| 139      | Very Low         |
| 76       | Very Low         |
| 74       | Low              |
| 122      | Low              |
| 156      | Low              |
| 16       | Low              |
| 118      | Low              |
| 107      | Medium           |
| 25       | Medium           |
| 112      | Medium           |
| 62       | Medium           |
| 77       | Medium           |
| 64       | Medium           |
| 136      | High             |
| 174      | Very High        |
| 145      | Very High        |

**Table 7. Fringe: A decision table**

| Grid No. | Categorized CSDI | Fringe |
|----------|------------------|--------|
| 124      | Very Low         | No     |
| 139      | Very Low         | No     |
| 76       | Very Low diversity | No |
| 74       | Low diversity    | No     |
| 122      | Low diversity    | No     |
| 156      | Low diversity    | No     |
| 16       | Low diversity    | No     |
| 118      | Low diversity    | No     |
| 107      | Medium diversity | No     |
| 25       | Medium diversity | No     |
| 112      | Medium diversity | Yes    |
| 62       | Medium diversity | Yes    |
| 77       | Medium diversity | Yes    |
| 64       | Medium diversity | Yes    |
| 136      | High diversity   | Yes    |
| 174      | Very High diversity | Yes |
| 145      | Very High diversity | Yes |

Significant differences found in social behaviour like health habits, literacy and livelihood earning, indicate various degree of urbanism in the study area. Educational level, occupational status and health habits of the residents can summarize the social framework of the city. 65% of the sample cells indicate a satisfactory correspondence with the delineation result from land use diversity index but rest 35% differs in social context. In this study the very high and high social diversity value corresponds with the fringe whereas, low and very low social diversity values concur with core (urban or rural). Medium social diversity corresponds with both fringe and core. Therefore, it is possible to delineate the cells that certainly fall into the category of fringe. Medium values for “Categorized CSDI” attribute, is
describing inaccurate classification of fringe and core by LUDI. Therefore, forms the boundary region or “possible fringe”.

Finding precise or crisp boundary between core and fringe is practically impossible as fringe has areas of fuzziness and vagueness. Therefore, the global diversity value based delineation method will give some false negatives (when a cell should come under fringe will be counted as core) and some false positive (when a cell should come under core buy will be counted as fringe). This phenomenon is common in the adjoining regions of core and fringe.

The secondary goal of designing this system is to obtain the expert knowledge for fringe delineation from LUDI and transforming it into the CSDI. In nutshell, CSDI value emulates the fringe delineation ability of LUDI value. In future this system will also be able to demarcate fringe for other cells in this study area and for other similar region from the social data.

6. Conclusion

In simple words, fringe is a direct result of urban development, as a product of population and economic growth, resulting in demand for housing and commercial areas. Therefore, the identification and delineation of fringe is undeniably significant. Because Barasat is a developing town that has evolved from an agrarian history, the existence of the fringe is evident. The determined global diversity value was applied to demarcate the fringe which yielded a satisfactory outcome. It helps to ensure that, in this process of expansion, the contagious built-up area has been transformed and acquired an urban character that was once of a transitional nature. As a result, an urban fringe, which developed well in the early stages within the city borders due to the prevalence of mixed land uses (urban and non-urban), has decreased in extension. The engulfment of the fringe by the expansion of urban land forces the fringe to contract and shift outward of the centre of the city. In order to have a deeper insight, the author evaluates the diversity of social behaviour, along with the land use which shows that the boundary of the core and the fringe starts to become unclear sometimes. Consequently, the delineation by a definite boundary may not always be justified. Because of the fuzziness in nature, the change over from core to fringe is characteristically zonal i.e. it extends for a distinct region where this transition is visible in the form of mixed land use and social behaviour. This gives birth to a boundary area instead of a precise boundary line that could be termed as "possible fringe."

7. References

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