The Rate and Pattern of the Spatio-Temporal Expansion of Rangpur City Corporation, Rangpur, Bangladesh

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Analyzing the spatio-temporal growth of the built-up areas of any urban place is incredibly much vital for the proper planning and development of the urban areas. The present study emphasizes determining the rate and pattern of spatio-temporal growth of Rangpur City Corporation (RpCC) for the year of 1989, 2000, 2010, and 2017 through Shannon's Entropy with the help of GIS and remote sensing techniques. Shannon's Entropy technique was adopted in order to determine the dispersion or compactness in the pattern of the built-up areas in the study area. In the present study, Landsat Operational Land Imager (OLI), Landsat Thematic Mapper (TM) and Landsat Enhanced Thematic Mapper Plus (ETM+) satellite images on the year of 1989, 2000, 2010, and 2017 were analyzed for certain interpretations. The changes of the built-up areas in RpCC were identified and determined through supervised classification using ArcMap10.5 software. The study indicated that spatio-temporal growth of the built-up areas in RpCC existed during 1989-2017. The built-up areas increased by 5.89 sq.km. during 1989-2000, 32.23 sq.km. during 2000- 2010 and 18.85 sq.km. during 2010-2017 and the expansion rates of the built-up areas were 8.02%, 25.64% and 6.01% during 1989-2000, 2000-2010 and 2010-2017, respectively. The relative entropy value of 1989, 2000, 2010 and 2017 was found 0.17, 0.24, 0.47 and 0.53, respectively, which interprets

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that the expansion of the built-up areas existed in RpCC and the pattern of expansion was dispersed. However, the outcomes of this study will be very helpful to formulate perfect planning and management system regarding the expansion of the built-up areas of RpCC.

1. INTRODUCTION

As the global population has been growing dramatically since the last century, the unprecedented concentration of human in urban areas has also been increasing around the world. Urban growth could also be defined as spatial dynamic affairs like population growth, economic expansion, city importance level, and so on [1]. Rapid growth of urban area or urbanization is a common affair now because of economic development across the globe. Noticeable changes in urban places have been occurred due to the rapid economic development of various developing countries throughout the world [2].

Spatio-temporal growth of a city refers to the expansion or increase of city boundary in conjunction with time and space. Urban growth or the expansion of built-up area is defined as the alteration of the environment either natural or agricultural land turned into urban land uses like as building, transportation, parking lots [3] etc. Sprawl could also be defined as a pattern that helps us to understand the spatial distribution [4,5] of any built-up areas. Urban or built-up area sprawl refers to both as a pattern of urban land use and as a process, namely as the change within the spatial structure of cities over different periods [6].

Urbanization or built-up area expansion is the dynamic process and it is one among the more important indicators of development. Therefore, spatial and temporal analysis is vital to know about the expansion pattern of built-up area, and for this both RS (Remote Sensing) and GIS (Geographic Information System) techniques provide incomparable opportunity to analyze the expansion of the built-up areas [7]. In recent years, RS data and GIS techniques are extensively being used for mapping (to understand the built-up area pattern in urban place), monitoring (to understand the urban process), measuring (to analyze), and modeling (to stimulate) the built-up area growth, land-use/land-cover change, and sprawl in urban place. However, it was observed that the physical expressions and patterns of built-up area growth or sprawl in urban place are often detected, mapped, and analyzed by using remote sensing data and GIS techniques [8,9].

Shannon's entropy model is employed to investigate and assess the trends of expansion of the built-up area as a process and pattern within the urban places that may easily verify and identify the disparity of conurbation [1] that can verify and identify the disparity of urban sprawl and urban areas. In this study, pattern of expansion of the built-up areas in RpCC has been detected using Shannon's entropy technique.

RpCC is a newly established city corporation of Bangladesh. In 2001, the city area was 50.66 Sq. km but in 2017 that has been increased by 205.73 Sq. km. Before 15 wards covered the RpCC but now the number of wards is 33 [10]. It has been observed that the rapid prolongation of various economic activities supported urbanization and industrialization in RpCC that was attracting the people to alter their residence from rural to urban place with a view to raising the standard of livelihood. Thus, the land use patterns and population growth has been changed very rapidly outwards the city. Comparison between previous and present data indicated that the boundary of the city or built-up area of RpCC has been changed and being expanded dispersedly outwards too. Hence, it has become very essential to review about the rate and pattern of expansion of the built areas of RpCC so as to form this city model one and avoid possible future problems like water logging, pollutions etc.

1.1 Study Area

RpCC is a newly established city corporation as well as divisional city of Bangladesh which lies between 25°38' and 25°52' north latitudes and 89°05' and 89°20' east longitudes (Fig. 1). Rangpur Pourasava was turned into a city corporation on 01 July 2012. It has an area of around 205.73 Sq.km. lies on the bank of the Ghaghat River. The entire population of the RpCC as of 2017 is 7, 96,556 [10].
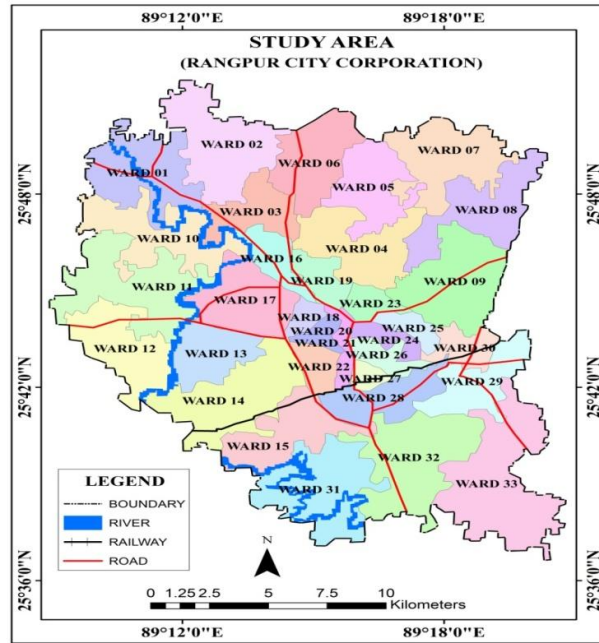
Fig. 1. Study Area (RpCC) (Source: Authors' GIS analysis)

2. MATERIALS AND METHODS

The study incorporated the following materials and methods.

2.1 Materials

The data collection employed to the gathering of satellite images from SPARRSO (Space Research and Remote Sensing Organization, Bangladesh). Four satellite images were accustomed to propulsion this study.

Here is mentionable that the satellite images of various bands, sensors and time were used to conduct this study due to unavailability of the satellite images of same sensor, same band and same time interval during data collection (Table 1).

2.2 Methods

In order to conduct this research work, expansion rate and pattern of the built-up areas of RpCC has been analyzed with the integration of GIS and remote sensing techniques in conjunction with Shannon's entropy. Those processes and techniques fruitfully helped to carry out the study entitled the rate and pattern of the spatio-temporal expansion of Rangpur city corporation, Rangpur, Bangladesh.

2.2.1 GIS and remote sensing

Analysis of built-up areas using remote sensing data is incredibly much helpful to know the changing scenery through the time including (a) the rate of expansion of the built-up area and (b) the spatial configuration of the expansion.

Table 1. Properties of satellite images utilized in the study

Satellite images	Date of images	Sensors	Spatial Resolution	Radiometric Resolution	Rows/ Path
Landsat OLI	24 January,2017	OLI	30	16 bit	711,618
Landsat TM	06 February,2010	TM	30	8 bit	702,627
Landsat TM	19 January,1989	TM	30	8 bit	702,627
Landsat ETM (+)	26 January,2000	ETM+	30	8 bit	701,618

(Source: SPARRSO)

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Using remote sensing and other geospatial datasets GIS can evaluate and predict the probabilities within the different periods where current and historical data are compared [8,9]. The changes pattern of the built-up areas of RpCC have been identified and determined through supervised classification using ArcMap 10.5 software where the built-up areas of RpCC were measured based on the conversion of raster maps or supervised maps into vector maps.

2.2.2 Shannon's entropy method

The relative Shannon's entropy is an important technique to review the expansion pattern of the built-up areas of any urban area. In this study, the Shannon's entropy technique was adopted to see the dispersion or compactness [11,12,13,14] of the expansion of the built-up areas of RpCC.

The level of expansion of the built-up areas is acknowledged by the entropy value. The relative entropy value starts from zero (0) to one (1). A zero (0) value denotes the compact distribution of the built-up areas, whereas values near one (1) indicates the dispersed distribution of the built-up areas [15]. Thus, higher entropy values indicate higher expansion rate of the built-up areas. In this research, the relative Shannon's entropy values were calculated using the following equation (i):

$$\text{En} = \sum_i^n Pi \log\left(\frac{1}{Pi}\right)/\log n \qquad (i)$$

Where,

En= Shannon's entropy
Pi= Development density i-th zone.
Where Pi= $Xi/\sum Xi$(Where Xi is observed value in the i-th zone in a total of n zones that is development density).
n= Total number of zones

The measurement of the difference of entropy between two different time periods was also accustomed to ascertain the changes in the degree of dispersion of the built-up areas expansion with the help of equation (ii).

$$\Delta \text{En} = (t + 1) - (t) \qquad (ii)$$

Where, ΔEn = Difference of relative entropy values between two time periods.
$En(t + 1)$ = The Relative entropy value at time period t+1.

$En(t)$=The relative entropy value at time period t.

2.2.3 Measurement of the rate of growth of the built-up area

Determining the share of the changes of built-up area is incredibly much significant way to compare among the different years [16]. Integrating equation (iii) and equation (iv), the growth rate of the built-up areas of RpCC on different years were estimated.

Percent Change = 100× (Present value – Past value)/ Past value (iii)

The percent rate of growth has been calculated using the following equation iv:

Percent Growth Rate= Percent Change/Number of Years (iv)

3. RESULTS AND DISCUSSION

3.1 Spatio-Temporal Growth of Built-Up Areas in RpCC (from 1989-2017)

This study has been conducted focusing on the identification of the spatial and temporal expansion of the built-up areas of RpCC over the various years. The results for supervised classification have been acquired by using four remotely sensed images (Landsat OLI, Landsat TM, Landsat ETM+) of RpCC over different time periods (1989, 2000, 2010, 2017) through GIS analysis. The classified images indicated the presence of expansion of the built-up areas and also the changing boundaries of built-up areas (buildings, roads, railway etc) and non built-up areas (agricultural land, barren land, river etc.) as well of RpCC (Fig. 2). It was found that red color has been increased during over 28 years meaning the built-up area has been elongated and lite olivenite color has been shortened which means the non-built-up area has been waned on that period (Fig. 2).

However, quantification of expansion of the built-up area, as a pattern or process, is a really challenging issue [17]. Extension and variation of the built-up areas in RpCC during 1989- 2017 were represented in Fig. 3 (modified from Fig. 2) where raster maps or supervised classified maps have been converted into polygons (Fig. 3) through GIS analysis using Arc Map 10.5.
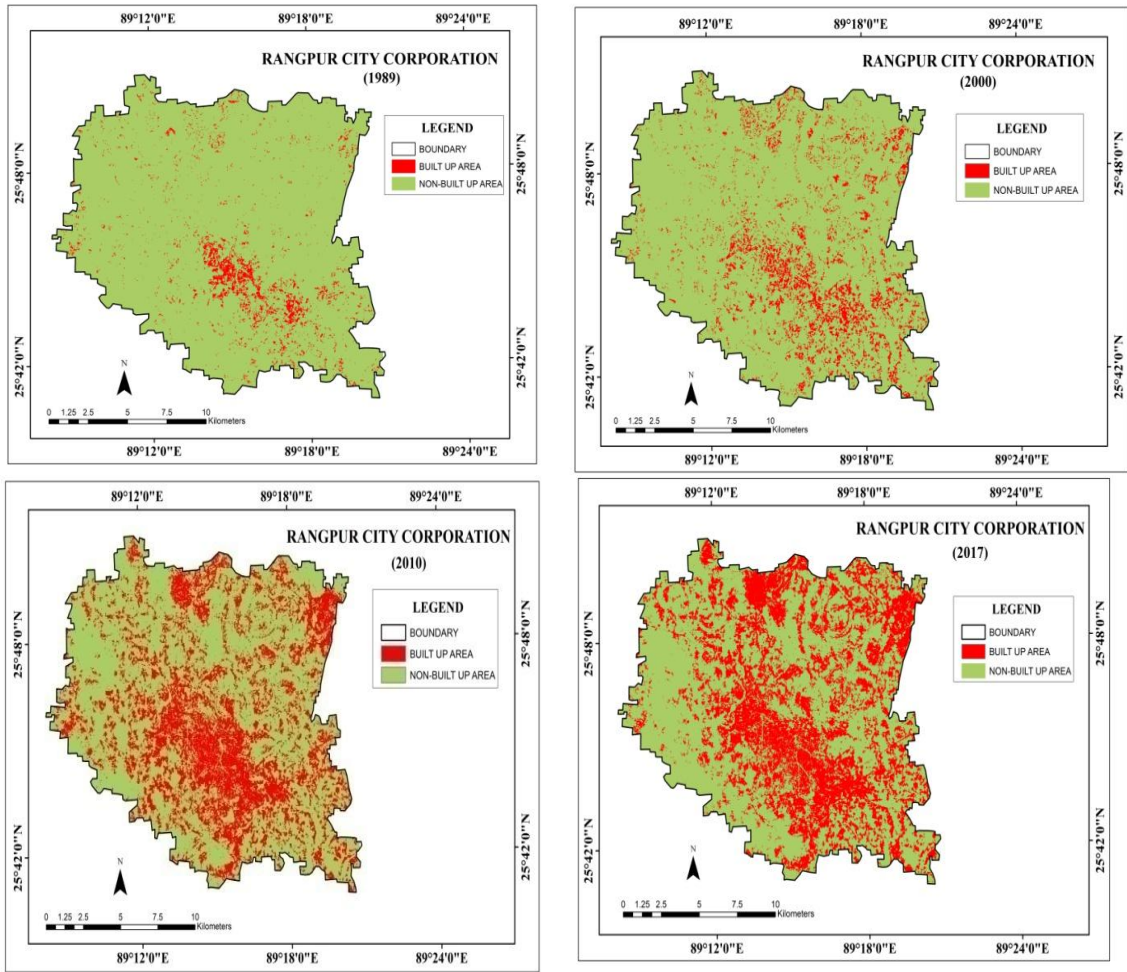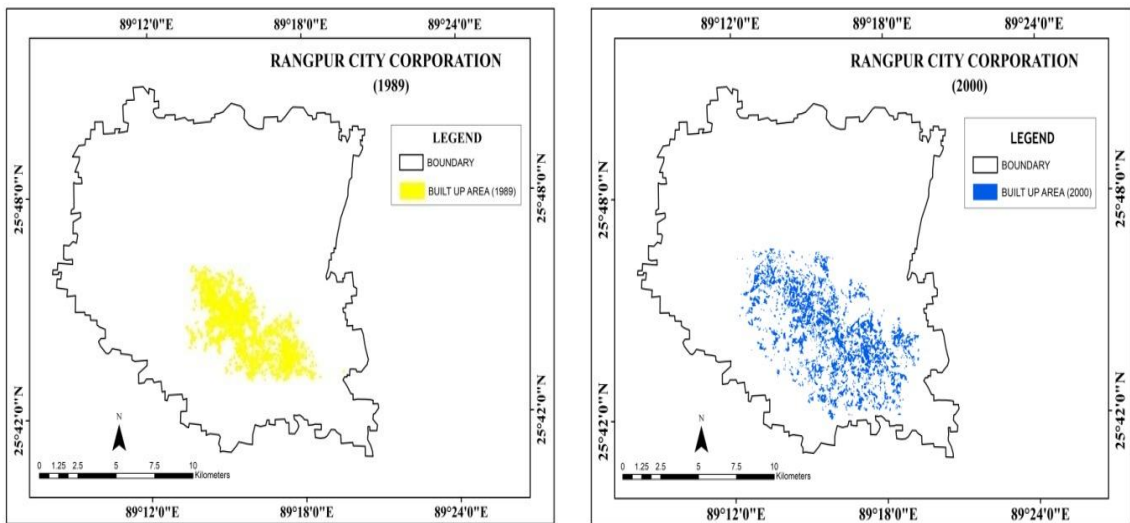
Fig. 2. Detected built-up and non- built-up areas of RpCC during 1989- 2017 through supervised classification (Source: Authors' GIS analysis, 2018)
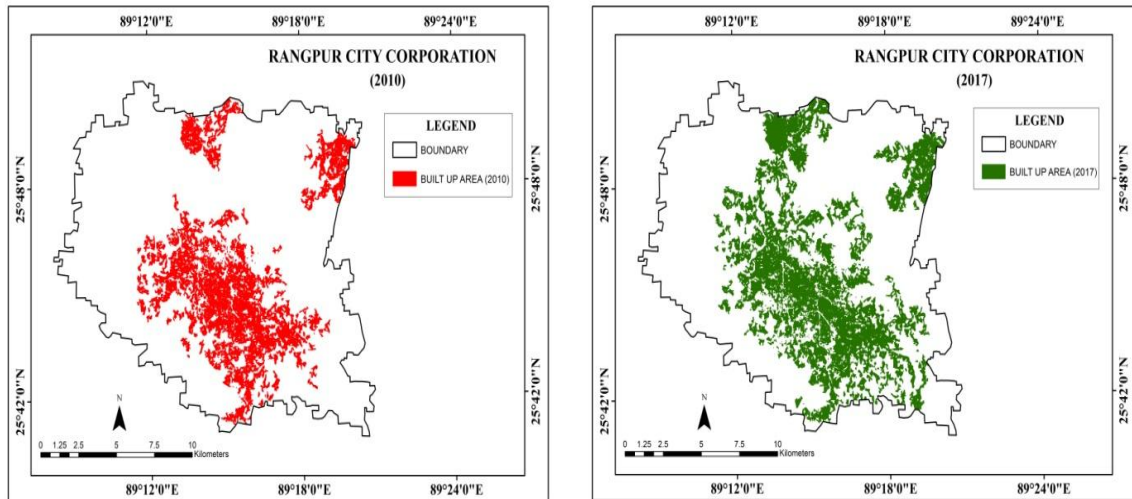
Fig. 3. Extension and changes of built-up areas in RpCC during 1989- 2017, modified from figure 2 (Source: Authors' GIS analysis, 2018)

3.1.1 Amount of spatio-temporal rate of expansion of the built-up areas in RpCC

Built-up and non-built-up areas per time span signify the conditions of expansion of the built-up area. Measuring the changes of the built-up area between two dates is very meaningful to indicate the expansion approach of the built-up area [18,19]. Built-up and non-built-up areas of RpCC have been calculated over the year of 1989, 2000, 2010 and 2017 using the area value of each polygon perceived from classified maps represented in Fig. 3. The estimated built-up area of RpCC in 1989, 2000, 2010 and 2017 was found 6.67 Sq. km., 12.57 Sq. km., 44.80 Sq. km. and 63.65 Sq. km. respectively out of the total 205.73 Sq. km. (Table 2).

Fig. 4 reveals that the built-up areas in RpCC in 1989, 2000, 2010 and 2017 covered 3.24%, 6.11%, 21.78% and 30.94% respectively of the total area (205.73 Sq. km.).

The spatio-temporal expansion rate of the built-up areas of RpCC was analyzed and computed using equation (iii) and equation (iv). The expansion of the built-up areas was increased by 5.89 Sq. km. during 1989-2000, 32.23 Sq. km. during 2000-2010 and 18.85 Sq. km. during 2010-2017 and the rate of average expansion of the built-up areas were 0.08, 0.25 and 0.06 Sq. km. per year respectively (Table 3).

The expansion rate of the built-up areas was 8.02%, 25.64% and 6.01% during 1989-2000, 2000-2010 and 2010-2017 respectively. It is mentionable that the expansion of the built-up areas has been occurred mostly during 2000-2010 (Fig. 5). That mostly expansion rate of the built-up areas during 2000-2010 might have been occurred due to many reasons like as increasing facilities and services of the city that attracted the people to make settlement in the city area.

Table 2. Built-up and non-built-up areas of RpCC during 1989- 2017

Total Area (Sq. km.)	205.73	
Classification	**Built-up Area (Sq. km.)**	**Non-Built-up Area (Sq. km.)**
Years		
1989	6.67	199.06
2000	12.57	193.16
2010	44.80	160.93
2017	63.65	142.08

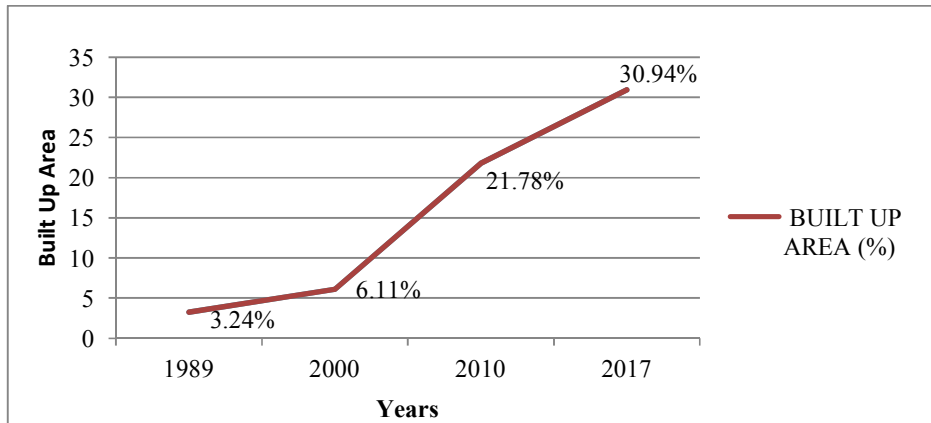*(Source: Authors' GIS analysis, 2018)*

Fig. 4. Built-up covered areas in RpCC during 1989- 2017. (Source: Authors' analysis, 2018)

Table 3. Extent and rate of spatial expansion of the built-up areas of RpCC during 1989- 2017

Years	Built-up Area (Sq. km.)	Growth Increase (Sq. km.)	Growth Rate (Sq. km.)/Year
1989	6.67	-	-
2000	12.57	5.89	0.08
2010	44.80	32.23	0.25
2017	63.65	18.85	0.06

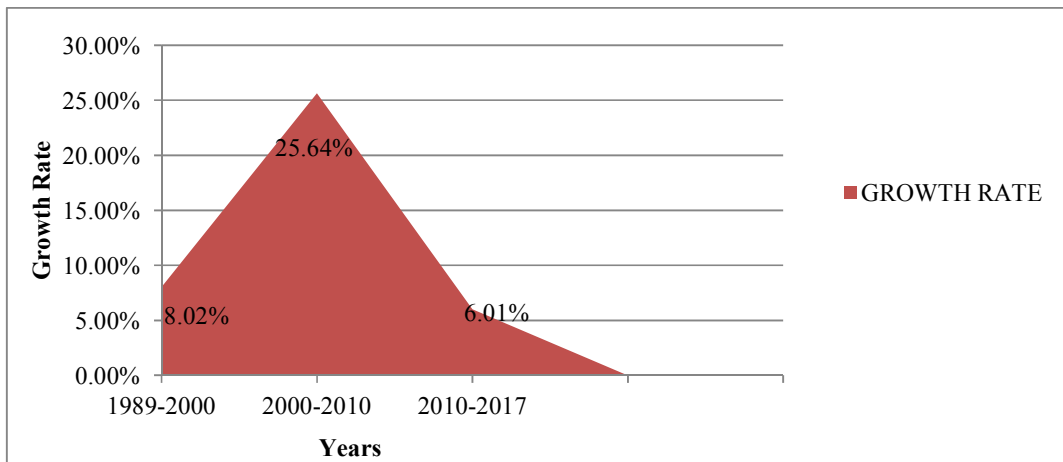*(Source: Author's analysis, 2018)*

Fig. 5. The rate of expansion of the built-up areas in RpCC during 1989-2017 (Source: Authors' analysis, 2018)

3.1.2 Rate and pattern of expansion of the built-up areas in RpCC based on shannon's entropy

Entropy method is a robust spatial statistics to measure the extent of built-up area sprawl with the integration of GIS and remote sensing [2,11,12]. In this study, the pattern of the expansion of the built-up areas has been

observed on the basis on Shannon's entropy value. Relative entropy value of the built-up area was calculated using equation (i) and equation (ii).

The density developments of the built-up area in RpCC were 0.03, 0.06, 0.21, and 0.31 in 1989, 2000, 2010 and 2017 respectively. The relative entropy value in the year of 1989, 2000, 2010

and 2017 was estimated 0.17, 0.24, 0.47 and 0.53 which interpreted that the expansion of the built-up area was existed in RpCC. The difference in entropy during 1989-2000 is 0.07 represented the slight expansion of the built-up areas; the difference entropy during 2000-2010 was found 0.23 meaning expansion of the built-up areas has been increased and through 2010-2017 the difference in entropy showed 0.06 that depicted that the expansion rate of the built-up areas has been decreased than the previous years (Table 4); it might be for the lower constructing or building works on that period.

Fig. 6 indicated that the built-up areas in RpCC during 1989-2017 have been expanded and the pattern of the expansion was dispersed and that dispersion was found gradually increasing as the relative entropy value has been increased gradually over the different periods. The estimated relative entropy value has been found 0.17 in 1989, 0.24 in 2000, 0.47 in 2010 and 0.53 in 2017 which were greater than zero and near to one meaning continued and scattered pattern of expansion of the built-up areas.

Fig. 7 shows the continued and dispersed pattern of expansion of the built-up areas in RpCC during 1989-2017.

3.2 Discussion

Spatio-temporal rate and pattern of expansion of the built-up areas of RpCC was identified using Shannon's entropy method on the basis of satellite imageries on the year of 1989, 2000, 2010, and 2017. Shannon's entropy method provided very fruitful result in finding out the pattern of urban area expansion [1] on different times. From the study results, it has been clearly understood that the built-up areas of RpCC have been expanded during 1989-2017. The built-up areas have been expanded by 5.89 Sq. km. during 1989-2000, 32.23 Sq. km. during 2000-2010 and 18.85 Sq. km. during 2010-2017 (Table 3). The expansion rates of the built-up areas were observed 8.02%, 25.64% and 6.01% during 1989-2000, 2000-2010 and 2010-2017 respectively (Fig. 5). The entropy values were estimated 0.17 in 1989, 0.24 in 2000, 0.47 in 2010 and 0.53 in 2017 (Fig. 6) that ratify that the continuous expansion of the built-up areas was existed in the study area and the pattern of the expansion was dispersed [1]. Here is mentionable that except center part there were found two more pockets of expansion of the built-up areas towards northern and north-eastern part of the study area which were being developed from the year of 2010 (Fig. 7) that also bears the

Table 4. Relative entropy value of RpCC during 1989-2017

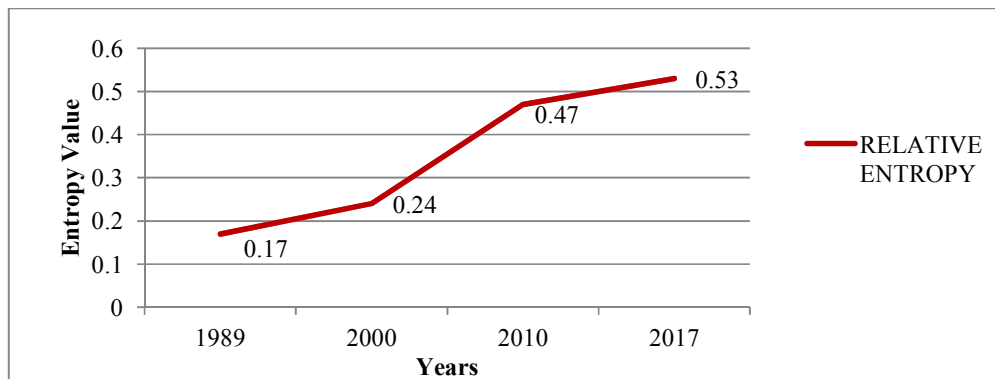| Years	Total Land (Sq. km.)	Built-up Area (Sq. km.)	Density of Development	Relative Entropy	Difference in entropy (ΔEn)
1989		6.67	0.03	0.17	-
2000	205.73	12.57	0.06	0.24	0.07
2010		44.80	0.21	0.47	0.23
2017		63.65	0.31	0.53	0.06

(Source: Authors' analysis, 2018)

Fig. 6. Variation of entropy values in RpCC during 1989-2017 (Source: Authors' analysis, 2018)
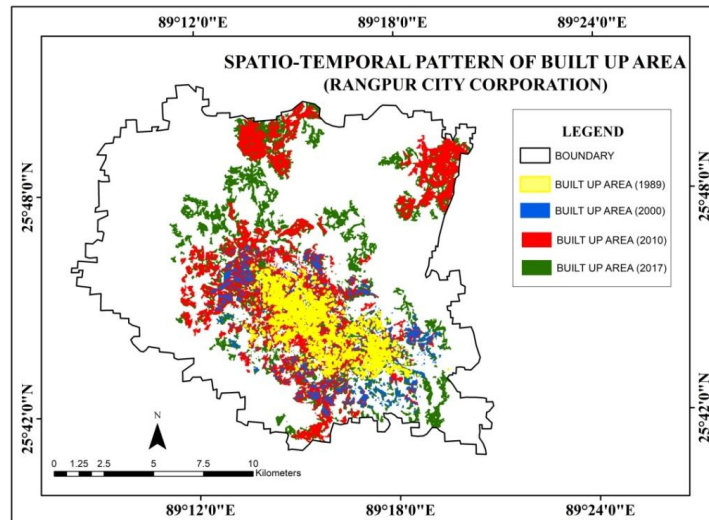
**Fig. 7. Pattern of Expansion of the built-up areas in RpCC during 1989-2017 (Source: Authors'
GIS analysis, 2018)**

significance evidence of the built-up areas expansion in RpCC. Dispersed expansion process of the built-up areas has been continued significantly during 1989-2017 that might be happened due to gradual industrialization, development of transportation, lower land rates, population growth [4,12] after all as the city has increased many services and facilities being city corporation and divisional city as well during that periods. Generally expansion of any city area increased when the city is turned into new development stage [4] like as administrative development; pourasava into city corporation, district into division. As RpCC has been adorned with the services like as health, education etc. due to its various development stage like as it has been turned into division and city corporation as well during 1989-2017 [10] that has attracted the people to make the city area extended dispersedly [4].

4. CONCLUSION

This study represents the rate and pattern of expansion of the built-up areas of RpCC over the years of 1989, 2000, 2010 and 2017. The study results indicated that RpCC is an emerging city and it will be a larger city according to area and population in near future within the country but the dispersed pattern of expansion of the built-up areas focused that the city has not been expanded with proper planning in the previous periods that may create some problems like as pollution, water logging etc. and these sorts of problems are already being faced in the

other cities of the country like as Dhaka, Chittagong etc due to unplanned dispersed expansion of the built-up areas. As an emerging city, RpCC is being expanded rapidly and the pattern of expansion is scattered and within the few years the scattered situation will be very higher with lots of problems as a result the city will not comfortable to its inhabitants. Thus the present paper recommends the concerned authority, urban planners and decision makers to understand the rate and pattern of expansion of the built-up areas of RpCC very deeply in order to formulate proper plans to develop the city as a model one.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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