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# URBAN SPRAWL IN MIDNAPORE TOWN: A GEOSPATIAL ANALYSIS

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***Abstract:*** Urban sprawl refers an accelerated outgrowth of urban areas caused by unplanned, uncontrolled and uncoordinated growth. Therefore, the measurement and direction of urban expansion are important for urban planning beyond the traditional boundaries. The present study is aimed to analyze the special and temporal pattern of urban growth in terms of direction, magnitude. This study highlights the existing trend and pattern of the urban sprawl of Midnapore town from 1991 to 2019, using the Shannon's entropy model and Normalized Difference Built-up Index. The findings of the study revealed that the urban settlement has expanded radically from the time period of 1991 to 2019. The city has extended massively particularly towards the west to north and up to the river on the southern portion. The results showed that the build-up area increased about 40.17% (2019) in respect to 1991. Thus, if the Midnapore city continues growing at the present rate, there might be a frequency of congestion and effective socio-economic problem along with pollution. Therefore, the concerned authorities and the citizens ought to consider every effective and utilize imaginative plans on emergency basis to make a bearable city for all.

***Index Terms*** **- Urban sprawl, urban expansion, Shannon's entropy model, Normalized Difference Build-up Index.**

## I. INTRODUCTION

Urban expansion is a significant influence of dynamics of landscapes (Yangzom et al., 2017). Urban sprawl refers to the uncontrolled, uncoordinated and unplanned outgrowth of urban areas (Peiser, 2001). The city expanded outward day by day at the expense of crop and forest land (Lo & Yang, 2002). This has given rise to urban sprawl along highways radiating from the city centre as radial sprawl (Magidi & Ahmed, 2019; Sperandelli et al., 2013; Sudhira et al., 2009). Migration of rural-urban also contributes to urban growth positively (Metropolis et al., 2019). Land use and land cover (LULC) dynamics have been regarded one of the most important process associated to earth ecological environment deterioration (Chishugi et al., 2021; Hua, 2017; P. Liu et al., 2020; Mallupattu & Sreenivasula Reddy, 2013; Salghuna et al., 2018; F. Yuan, 2008), related to global and regional changes (Belal & Moghanm, 2011; Butt et al., 2015; P. Liu et al., 2020; F. Yuan, 2008), has largely influenced earth biological cycle (X. Li et al., 2018; Z. Li et al., 2013; Powers, 2004), sustainable use of resource (Fu et al., 2012; Zhang et al., 2020), and urban planning and policy making. Land use and land cover changes mainly driven by natural phenomena and anthropogenic activities, which in turn drive changes that would impact natural ecosystem (Teixeira et al., 2014), and have been thus consider an important research topic with regard to global environmental change and sustainable development (Lambin et al., 2003; J. Liu et al., 2005; Pricope et al., 2019; Van Asselen & Verburg, 2013; Zomer et al., 2016). Urban Sprawl has been criticized for eliminating agricultural lands, spoiling water quality and causing air pollution (Basawaraja et al., 2011). Satellite data are now widely applicable and useful for detecting land use/ land cover transition and nature of urban sprawl studies (Gastellu-Etchegorry, 1990; Hadeel et al., 2009, 2009; Fei Yuan et al., 2005). Assessment, prediction, and monitoring of urban sprawl represent the necessary information for urban development plans which is very essential for further development (Alsharif et al., 2015). Urban planners require usable tools to achieve active, smart and balanced growth (Alpopi et al., 2011), examine and understand current land-use status on sprawling region, and measure future requirements (Baptista e Silva et al., 2012; Huang et al., 2009; Lo & Yang, 2002; Mohsen Dadras, Helmi Zulhaidi Mohd Shafri, Noordin Ahmad, Biswajeet Pradhan, 2014; Sperandelli et al., 2013). At the beginning of the 20th century, India's urban population was 25.85 million. It accounted for 10.84% of the urban population in 1901 until reaching 31.2% by 2011. The nation as a whole's urbanization rate rose from 27.7% in 2001 to 31.1% in 2011 - a rise of 3.3% during 2001-11 compared to the increase of 2.1% in 1991-2001 (Bhagat, 2015; Sarkar, 2019). In India, the urban planners are giving more emphasize specially on metropolitan and large size cities for urban planning, therefore, the small cities become ensnare which are also gradually grow up (Bhatta, 2009; Dinda et al., 2019). Midnapore town is a very old municipality with 150-year past. On present day context enormous unplanned growth create challenges for the planner which also effected the physical environment drastically. The purpose of this research is to design a remote sensing-based framework that investigates and analyzes the trend and nature of urban sprawl.

## II. THE STUDY AREA:

Midnapore Municipality is an administrative head quarter of West Midnapore district in West Bengal. Geographically Midnapore municipality is located in the central part of Midnapore district. It extends from 87° 17' 18.57" to 87° 20' 30.12" East Longitude and 22° 23 '44.56" to 22° 26' 34.91" North Latitude. It is situated by the banks of the Kangsabati River (differently known as Kasai and Cossye).

The urban development of Midnapore has undergone extensive metamorphosis of its socio-economic and demographic structure under the changing influences of historical, social, economic, political and administrative and many other determinants at local and regional scales. Such dynamism has been reflected on the morphological, occupational, livelihood, cultural and other behavior of the urban system. Midnapore Municipality consists of 25 wards with an area of 18.36 sq. km.

Midnapore Municipality has consistently high rate of population growth throughout its 152 years of existence. The growth of population growth is shown in the table. 50.47 % of total population of Midnapore Municipality is male, other 49.53% is female. Here the density of population is 9212 persons/ sq. km.

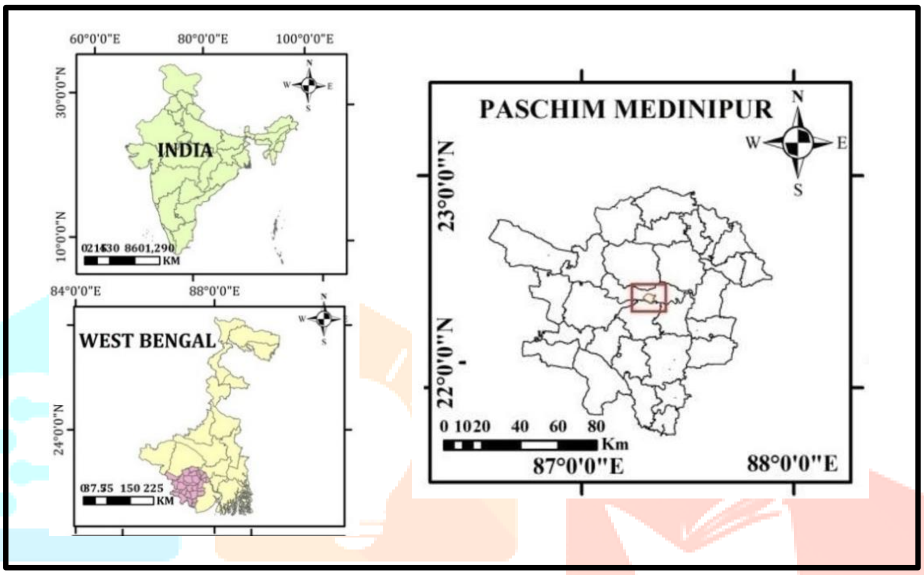


**Figure 2.1: Study Area**

## III. MATERIALS AND METHODS:

Multi-temporal satellite data are used for this study. Landsat Thematic Mapper (TM) images of 1991 and 2001 and Operational Land Imager-8 (OLI-8) image for 2019 are used for measurement of temporal urban growth pattern. The Landsat multi-temporal data are collected from the United States Geology Survey (https://earthexplorer.usgs.gov/).

The boundary map and district shapefile of Midnapore town were obtained through geo- referencing techniques. The collected images were pre- georeferenced to the UTM-Zone 45 North Projection with WGS-84 datum (Path/Row: 139/44).

**Table 3.1: Sources of Satellite Data**

| Satellite | Sensor | Date of Acquisition | Path | Row | No of Band | Spatial Resolution (m) | Spectral Resolution (μm) | Radiometric Resolution |
|---|---|---|---|---|---|---|---|---|
| Landsat-5 | TM | 29.01.1991 | 139 | 44 | 7 | 30m | 0.45-2.35 | 8 Bit |
| Landsat-7 | ETM+ | 19.01.2001 | 139 | 44 | 8 | 30m | 0.45-2.35 | 8 Bit |
| Landsat-8 | OLI, TIRS | 02.02.2019 | 139 | 44 | 11 | 30m | 0.45-12.50 | 16 Bit |

**TM**= Thematic Mapper, **ETM+**= Enhanced Thematic Mapper+, **OLI**=Operational Land Imager, **TRIS**= Thermal Infrared Sensor

The built-up area is identified from the Normalized Difference Built-up Index (NDBI). The NDBI is a very accurate and common useful technique for the identification of built- up area, i.e. impervious surface (Zha et al., 2012.; Zhang et al., 2009). The generalized equation of NDBI is represented as:

$$NDBI = \frac{SWIR - NIR}{SWIR+NIR}$$

Where, SWIR is the Short infrared band (band 5 for TM and band 6 for OLI-8) and Near infrared (NIR) is the band (band 4 for TM and band 5 for OLI-8). After NDBI extraction with construction of signature files, there classify built-up and non- built-up area through supervised classification for the year of 1991,2001 and 2019. NDBI is a very specific and sensitive index to the extraction of built-up area, this one should apply the optimal threshold value of each and every Landsat satellite image. Difference threshold values of the respective year are used for this study.

Shannon's entropy is one of the important effective technique for measuring and monitoring of urban sprawl. Shannon's entropy model used to measure the degree of compactness and dispersion of a geophysical variable among 'n' spatial units (Mohammady & Delavar, 2016; Rahman et al., 2011; Sudhira et al., 2003). Shannon's entropy calculated by (Yangzom et al., 2017)

$$Hn(Ei) \cong \sum_{i}^{n} Pi \log\left(\frac{1}{Pi}\right)$$

Where, $P_1$ is the probability or proportion of the variable occurring in the districts, ***n*** is the total numbers of districts or zones.

The Shannon's entropy values are differed between 0 and log(n). The value closer to '0' means compact urban growth consist with higher density, while value closer to log n (1) indicates dispersed distribution of city which indicate urban sprawl-built environment.

## IV. RESULTS AND DISCUSSION

### 4.1 IMAGE PROCESSING AND EXTRACTION OF THE BUILT-UP AREA:

Proper planning of an Urban area is a complicated complex way of development. Urban growth is a continuous process which is influence other factors phenomenally. Assessment of urban growth plays a significant role in sustainable urban development and planning. Growth of every city are going through high spatial and temporal process. Built-up area of a town is defined as the areas of human habitation and their associated infrastructural development whereas non-agricultural activity associated with water bodies, vegetation and vacant land. The NDBI based built-up area was extracted for the three selected years of 1991, 2001 and 2019. The built-up areas of a town are gradually increasing in different directions enormously. The built-up area of 1991 was 15.73sq. km and it increased its area in 2001 calculated as 20.86 sq. km with a growth rate of 32.61%. The growth rate of the built-up area was rapidly increasing in the period between 2001 and 2019. In 2019 it measures as 29.24 sq. km. The growth rate of the built-up area in between the time period 2001 to 2019 about 40.17% (Fig 4.1). The trend of growing of buildup area indicate the tendency of urban sprawling as well as significant indication of infrastructural development. Though Midnapur town is a very old town of West Bengal.

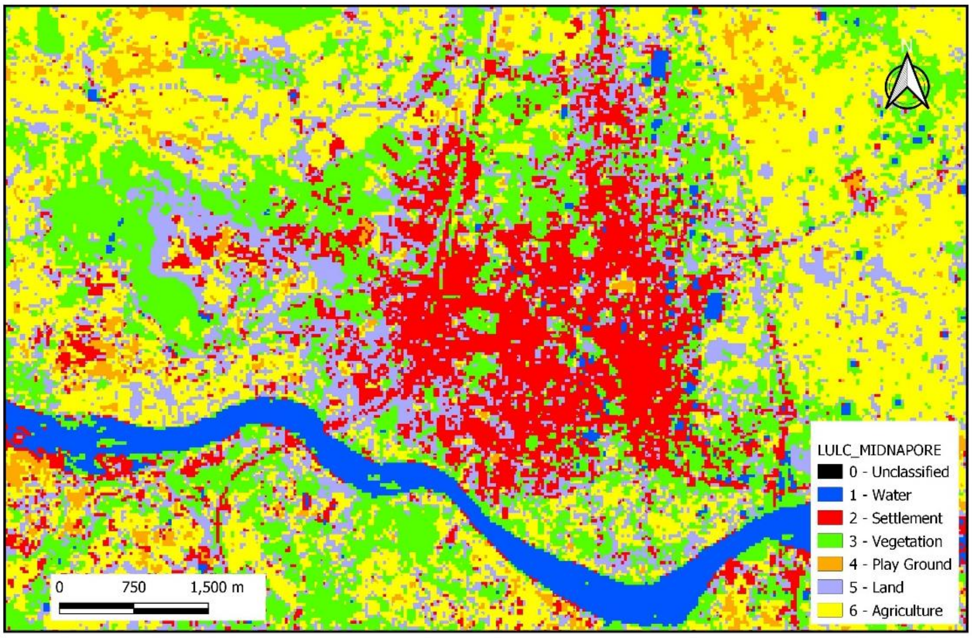


**Figure 4.1: Land Use Land Cover Map of Midnapore Town**

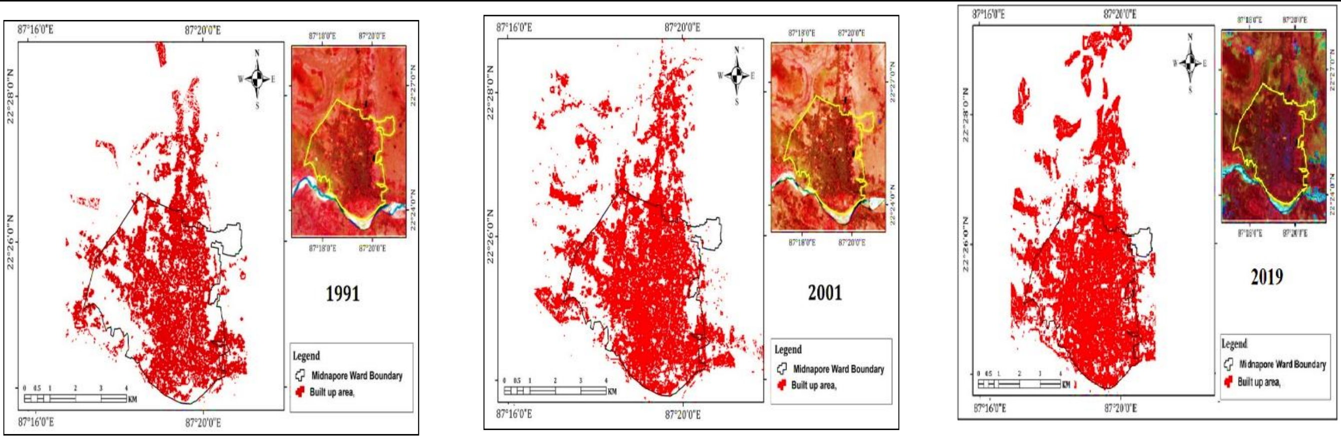


**Fig4.2: Maps of built-up area of Midnapore town of the year 1991, 2001 and 2019**

**Table 4.1: Build-up area (in sq. km) and growth rate of the Midnapore town for the years of 1991, 2001 and 2019**

| Year | Area (km$^2$) | Built-up area growth rate (in %) |
|---|---|---|
| 1991 | 15.73 | – |
| 2001 | 20.86 | 32.61 |
| 2019 | 29.24 | 40.17 |

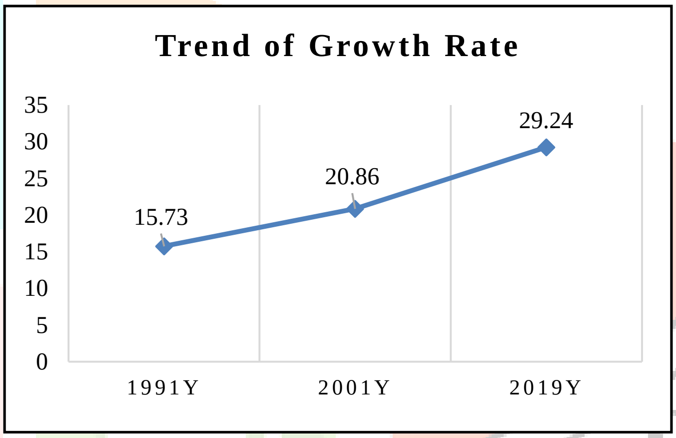


**Fig 4.3: Trend of growth rate of build-up area for the year of 1991,2001 and 2019**

## 4.2 MEASUREMENT OF THE PATTERN OF URBAN SPRAWL USING SHANNON'S ENTROPY:

Entropy indicates disorders, so maximum entropy means maximum dispersion. Shannon (1948) established the concept of entropy to measure the uncertainty of a variable. This uncertainty is represented as the average expected value of information contained in a message. Information can be defined as the negative log of the probability distribution of outcomes. The probability distribution used for the set of all discrete probabilities. The logarithmic($\log_n$) function is used because many variables of information science have been observed to vary linearly with the logarithm of the number of possibilities (Shannon 1948).

$$\text{Hn(Ei)} \cong \sum_{i}^{n} \text{Pi} \log\left(\frac{1}{Pi}\right)$$

Where, ***Pi*** is the probability or proportion of the variable occurring in the districts, ***n*** is the total numbers of districts or zones. The relative entropy scale value varies from 0 to 1. This scale indicates amount and direction of sprawl if the value measure 0, which indicate compactness of town if the value crossing the half (0.50) then dispersion started i.e., urban sprawl started.

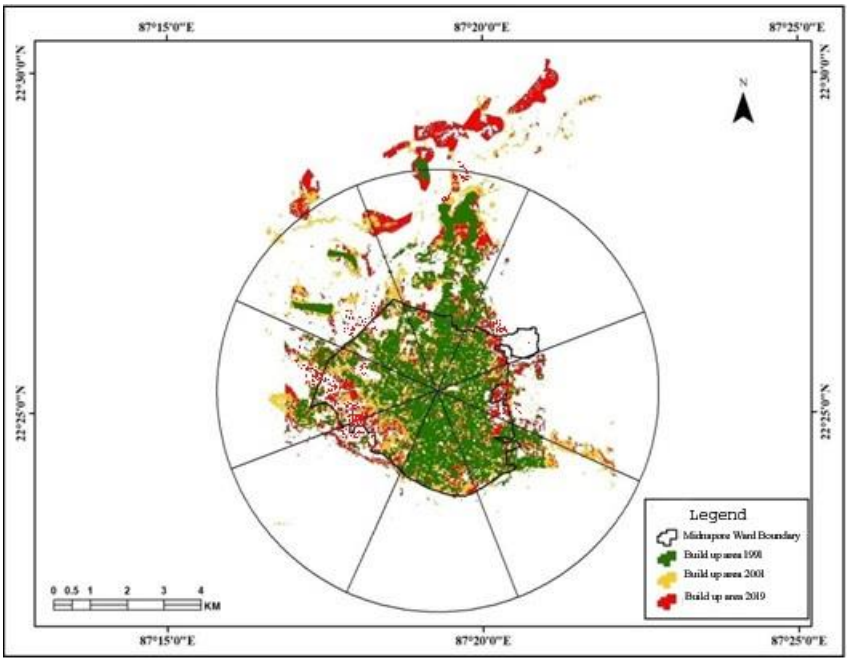


**Figure 4.4: Spatial direction of Midnapore town according to Shannon Entropy**

**Table4.2: Entropy calculation for the period of 1991 of different direction**

| Zone Id | Toatl Area (Sq. Km.) | Build up Area (Sq. Km) | Built up Area Density (i) | Proportion of Density (P) | 1/Pi | log(1/Pi) | P. log (1/Pi) |
|---|---|---|---|---|---|---|---|
| North | 14.7 | 4.18 | 0.284 | 0.266 | 3.76 | 0.58 | 0.153 |
| North East | 14.7 | 1.421 | 0.097 | 0.090 | 11.07 | 1.04 | 0.094 |
| East | 14.7 | 0.976 | 0.066 | 0.062 | 16.12 | 1.21 | 0.075 |
| South East | 14.7 | 2.71 | 0.184 | 0.172 | 5.80 | 0.76 | 0.132 |
| South | 14.7 | 2.034 | 0.138 | 0.129 | 7.73 | 0.89 | 0.115 |
| South West | 14.7 | 0.923 | 0.063 | 0.059 | 17.04 | 1.23 | 0.072 |
| West | 14.7 | 1.943 | 0.132 | 0.124 | 8.10 | 0.91 | 0.112 |
| North West | 14.7 | 1.543 | 0.105 | 0.098 | 10.19 | 1.01 | 0.099 |
| Σ | 117.6 | 15.73 | 1.070 | 1.00 | | | 0.852 |

Calculation of Entropy (Ei):

Log (n)= Log (8)
Log (8) = 0.90309
Entropy Index (Ei) = (0.852/0.90309)
Ei = **0.9434**

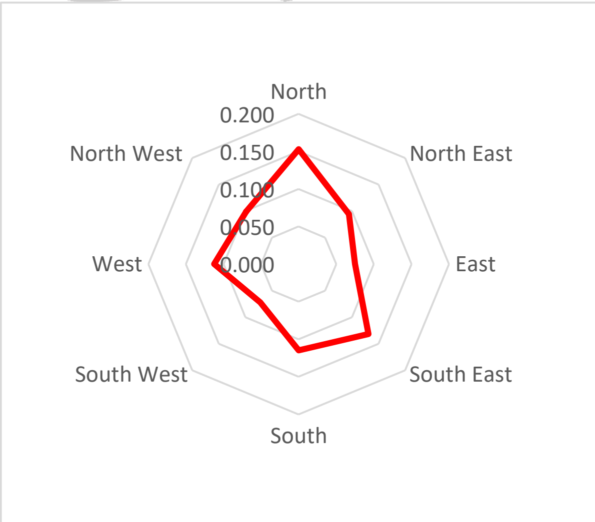


**Figure 4.5: Direction & Growth of settlement, 1991**

**Table 4.3: Entropy calculation for the period of 2001 of different direction**

| Zone Id | Total Area (Sq. Km.) | Build-up Area (Sq. Km) | Built up Area Density (i) | Proportion of Density (P) | 1/Pi | log(1/Pi) | P. log (1/Pi) |
|---|---|---|---|---|---|---|---|
| North | 14.7 | 4.68 | 0.318 | 0.224 | 4.46 | 0.65 | 0.146 |
| North East | 14.7 | 1.542 | 0.105 | 0.074 | 13.53 | 1.13 | 0.084 |
| East | 14.7 | 1.476 | 0.100 | 0.071 | 14.13 | 1.15 | 0.081 |
| South East | 14.7 | 2.965 | 0.202 | 0.142 | 7.04 | 0.85 | 0.120 |
| South | 14.7 | 2.38 | 0.162 | 0.114 | 8.76 | 0.94 | 0.108 |
| South West | 14.7 | 1.657 | 0.113 | 0.079 | 12.59 | 1.10 | 0.087 |
| West | 14.7 | 3.23 | 0.220 | 0.155 | 6.46 | 0.81 | 0.125 |
| North West | 14.7 | 2.93 | 0.199 | 0.140 | 7.12 | 0.85 | 0.120 |
| Σ | 117.6 | 20.86 | 1.419 | 1.000 | | | 0.871 |

Calculation of Entropy (Ei):

Log (n)= Log (8)
Log (8) = 0.90309
Entropy Index (Ei) = (0.871/0.90309)
Ei = **0.9645**

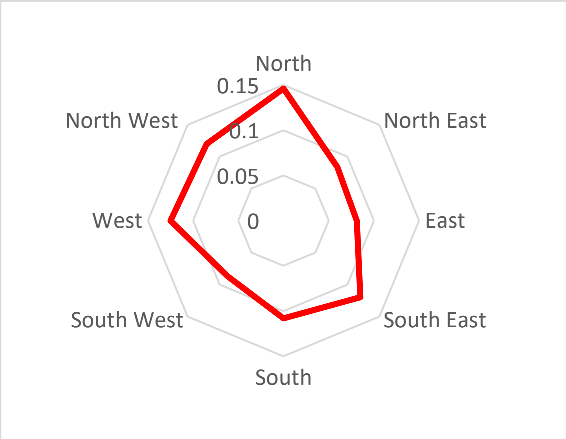


**Figure 4.6: Direction & Growth of settlement, 2001**

**Table 4.4: Entropy calculation for the period of 2019 of different direction**

| Zone Id | Total Area (Sq. Km.) | Build-up Area (Sq. Km) | Built up Area Density (i) | Proportion of Density (P) | 1/Pi | log(1/Pi) | P. log (1/Pi) |
|---|---|---|---|---|---|---|---|
| North | 14.7 | 6.891 | 0.469 | 0.236 | 4.24 | 0.63 | 0.148 |
| North East | 14.7 | 2.068 | 0.141 | 0.071 | 14.14 | 1.15 | 0.081 |
| East | 14.7 | 2.147 | 0.146 | 0.073 | 13.62 | 1.13 | 0.083 |
| South East | 14.7 | 3.93 | 0.267 | 0.134 | 7.44 | 0.87 | 0.117 |
| South | 14.7 | 2.69 | 0.183 | 0.092 | 10.87 | 1.04 | 0.095 |
| South West | 14.7 | 3.65 | 0.248 | 0.125 | 8.01 | 0.90 | 0.113 |
| West | 14.7 | 4.014 | 0.273 | 0.137 | 7.28 | 0.86 | 0.118 |
| North West | 14.7 | 3.85 | 0.262 | 0.132 | 7.59 | 0.88 | 0.116 |
| Σ | 117.6 | 29.24 | 1.989 | 1.000 | | | 0.872 |

Calculation of Entropy (Ei):

Log (n)= Log (8)
Log (8) = 0.90309
Entropy Index (Ei) = (0.872/0.90309)
Ei = **0.9656**

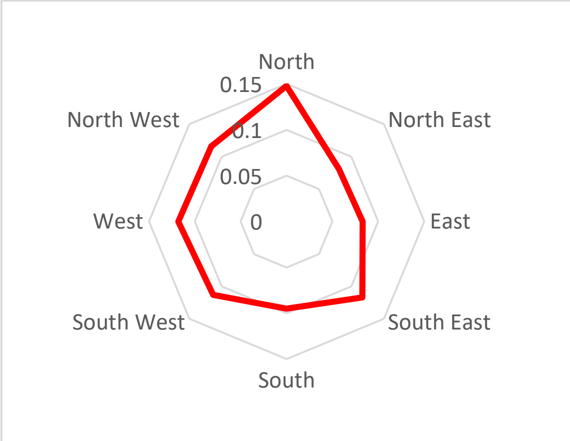


**Figure 4.7: Direction & Growth of settlement, 2019**

**Table 4.5: Entropy calculation for the period of 1991 to 2001 of different direction**

| Zone Id | Total Area (Sq. Km.) | Build-up Area (Sq. Km) | Built up Area Density (i) | Proportion of Density (P) | 1/Pi | log(1/Pi) | P. log (1/Pi) |
|---|---|---|---|---|---|---|---|
| North | 14.7 | 0.5 | 0.034 | 0.097 | 10.26 | 1.01 | 0.099 |
| North East | 14.7 | 0.121 | 0.008 | 0.024 | 42.40 | 1.63 | 0.038 |
| East | 14.7 | 0.5 | 0.034 | 0.097 | 10.26 | 1.01 | 0.099 |
| South East | 14.7 | 0.255 | 0.017 | 0.050 | 20.12 | 1.30 | 0.065 |
| South | 14.7 | 0.346 | 0.024 | 0.067 | 14.83 | 1.17 | 0.079 |
| South West | 14.7 | 0.734 | 0.050 | 0.143 | 6.99 | 0.84 | 0.121 |
| West | 14.7 | 1.287 | 0.088 | 0.251 | 3.99 | 0.60 | 0.151 |
| North West | 14.7 | 1.387 | 0.094 | 0.270 | 3.70 | 0.57 | 0.154 |
| Σ | 117.6 | 5.13 | 0.349 | 1.000 | | | 0.804 |

Calculation of Entropy (Ei):

Log (n)= Log (8)
Log (8) = 0.90309
Entropy Index (Ei) = (0.804/0.90309)
Ei = **0.890**

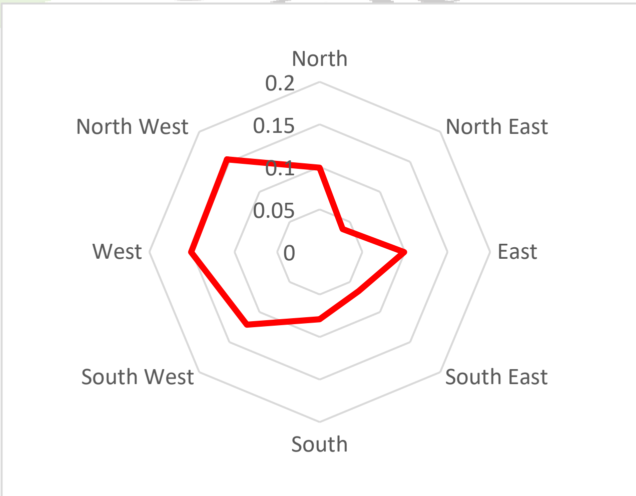


**Figure 4.8: Direction & Growth of settlement, 1991 to2001**

**Table 4.6: Entropy calculation for the period of 2001 to 2019 of different direction**

| Zone Id | Total Area (Sq. Km.) | Build -up Area (Sq. Km) | Built up Area Density (i) | Proportion of Density (P) | 1/Pi | log(1/Pi) | P. log (1/Pi) |
|---|---|---|---|---|---|---|---|
| North | 14.7 | 2.211 | 0.150 | 0.264 | 3.79 | 0.58 | 0.153 |
| North East | 14.7 | 0.526 | 0.036 | 0.063 | 15.93 | 1.20 | 0.075 |
| East | 14.7 | 0.671 | 0.046 | 0.080 | 12.49 | 1.10 | 0.088 |
| South East | 14.7 | 0.965 | 0.066 | 0.115 | 8.68 | 0.94 | 0.108 |
| South | 14.7 | 0.31 | 0.021 | 0.037 | 27.03 | 1.43 | 0.053 |
| South West | 14.7 | 1.993 | 0.136 | 0.238 | 4.20 | 0.62 | 0.148 |
| West | 14.7 | 0.784 | 0.053 | 0.094 | 10.69 | 1.03 | 0.096 |
| North West | 14.7 | 0.92 | 0.063 | 0.110 | 9.11 | 0.96 | 0.105 |
| Σ | 117.6 | 8.38 | 0.570 | 1.000 | | | 0.827 |

Calculation of Entropy (Ei):

Log (n)= Log (8)
Log (8) = 0.90309
Entropy Index (Ei) = (0.827/0.90309)
Ei = **0.915**

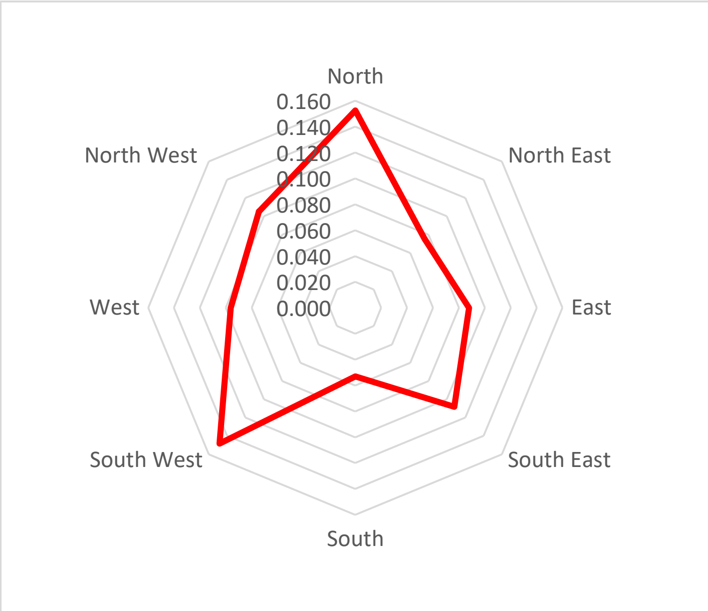


**Figure 4.9: Direction & Growth of settlement, 2001 to 2019**

**Table 4.7: Entropy value of different time period**

| Year | Entropy (H) | P. log (1/Pi) | P. log (1/Pi)/2 |
|---|---|---|---|
| 1991 | 0.9434 | 0.852 | 0.426 |
| 2001 | 0.9645 | 0.871 | 0.4355 |
| 2019 | 0.9656 | 0.872 | 0.436 |
| 1991- 2001 | 0.890 | 0.804 | 0.402 |
| 2001-2019 | 0.915 | 0.827 | 0.4135 |

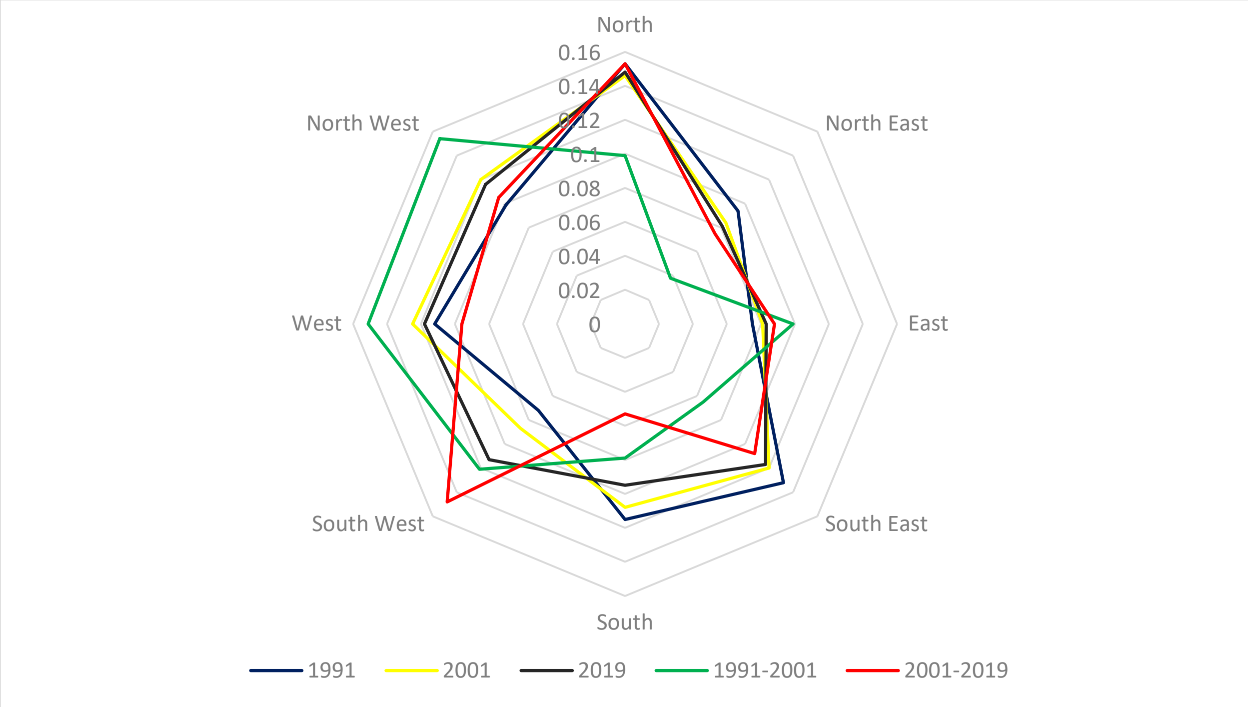


**Figure 4.10: Spatio -temporal direction of urban sprawl of Midnapore Town**

Here draws a radius of 6 km distance from the CBD. The whole radius is divided into 8 equal zones according to direction and these subzones are- North, North-East, East, South- East, South, South-West, West and North West. The total area of the radius is 117.60 Sq. Km so the area of each zone is 14.70 Sq. Km and those are equal to each other. Then calculate the Built-up area of each zone beside that the proportion of built-up area also. Entropy values are calculated to proving the degree of sprawl and it's Spatio-temporal pattern with the selected zones for the year 1991, 2001 and 2019. Moreover, change of built-up area from 1991 to 2001 and 2001 to 2019 is also determined to show the trend of urban expansion and its pattern.

## V. CONCLUSION:

Assessment of urban growth plays an important role in planning and sustainable urban development. The build-up area gradually increases day by day without proper panning tremendously. Which degraded our local environment in an extreme manner. On present day context agricultural land, waterbodies, vegetation coverage are degraded and concretization increase so rapidly specially on the peripheral zone of Midnapore town. The NDBI based built-up area was extracted for the three selected years of 1991, 2001 and 2019. The built-up areas are gradually increasing rapidly in different directions. In 1991 amount of build-up area was 15.73 sq.km and it increased its area in 2001 20.86 sq. km with a growth rate of 32.61%. The amount of build-up on 2019 measured 29.24 sq. km and growth rate of the built-up area about 40.17%. Due to physical river boundary on southern portion of that town it increases towards North, West and North West direction parallel with railway track and national high way. If the sprawling cannot be regulated by strict policy in the future the urban environment might reach in a stage where the situation is critical and irredeemable. Finally, it is recommended that Shannon's entropy should be important for the measurement of the temporal pattern and direction of urban growth and intensive field survey should be used to under- stand the process of urban sprawl in depth, that should be helpful for adopting long- term planning and sustainable urban development. Implementation of 'Smart growth' i.e., the policy oriented urban development strategy shall be very effective to minimize impact of urban sprawl and it advocates implementation of higher residential densities and consideration of preserving agricultural land.

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