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Identification of Urban Centre and Rural Growth Centres Around Guwahati and Its Surrounding Rural Region Using Hierarchical Settlements, Nested Hexagons, Remote Sensing and GIS

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Abstract: Guwahati city is the highest order urban center of Assam and is an important gateway to the north eastern region of India. In this study, a 50km buffer from the master plan boundary of Guwahati Metropolitan Development Authority (GMDA) is selected for identifying potential urban centers and rural growth centers (URGC) of different order for decentralized planning and inter and intra-administrative cooperation around the city using multi-parametric criteria. This includes central place theory, nested hexagon method and thematic information on groundwater potential zones, land use/land cover, flood prone and landslide susceptible zones. Out of the 32 identified potential villages, 15 are proposed for new urban centers and 17 are proposed for development as rural growth centers. 9 towns are also proposed for up-gradation to higher order for proper spatio-functional interaction. However, several suggestions and preventive measures were made before initiating developmental expansion which needs to be considered. The findings of this study would be useful for decentralized planning to minimize the economic imbalances, rural migration and sustainable development of the region.

Keywords: GMDA, GIS, Hierarchical settlements, Nested hexagons, Remote sensing, URGC

1. Introduction

Urbanization in India is characterized by demographic changes like natural population growth and rural urban migration which stimulates growth (Taubenbock & Esch 2011). Over the years, unplanned urbanization and expansion of cities have burdened the poor and marginalized, bio-diversity and economy with stresses and strains (NITI Ayog 2021). Urban settlements in India have experienced rapid growth and population has increased from 14 percent at the time of independence to 31.8 per cent as per 2011 census of India (MoHUA 2020). These urban growths with increasing population in cities, towns and their suburbs have two dimensions. When it grows upwards, we mean increase in density and when it grows outwards it means area expansion. As the city expands outwards, a portion of the rural population is automatically transformed into urban one, but when the city grows upwards its demographic changes are profound (Richardson 1971; Ganguly 1995). Rural areas lack access to economic activities and basic amenities as compared to urban areas which has higher pull factors. Thus, migration from rural to urban areas are stimulated by the forceful 'push-pull factors' in rural settlements arising out of improper distribution of government schemes, inefficient monitoring of development activities, lack of infrastructures on agriculture, health, training & education facilities which restricts their capabilities and hence their services and products are marginally paid. Therefore, to minimize the rift between rural and urban sector, rural areas need to be integrated with urban centers. This integration between rural and urban sectors will lead to regional as well as sustainable development (Mishra & Deodhar 2009). The urbanization process has contributed to the mixture of land uses between rural and urban areas. Such co-existence has helped rural areas to increase their income by generating various opportunity. Similarly, urban sector was also benefitted through local ecosystem and food security. The integration between rural villages and towns will generate employment and markets facility for both farm and non-farm sector. This linkage will help in building the interdependency between urban-rural field in planning and resource management sector (Kim 2015). As per census 2011, urban population in India has an average decadal growth rate of 31.6 percent from 2001-2011. The small and medium towns (class II to VI) have also shown a growth rate of 48.6 percent to 185.7 percent. It is also estimated that by 2051 urban population will increase by 50 percent (MoHUA 2020). North East India is the country's gateway to south east Asian countries and covering 8 percent of India's land and 3.1 percent of India population. Today Guwahati is not only the principal city of Assam but also provide access to six-sister states in Northeast India (KPMG FICCI 2015). Although the urbanization level in North-east India is low but the rate of urbanization is high (Ray et al, 1999). It was therefore expected that small and medium sized towns would emerge. Besides, in the hilly areas, topography warrants that the small and medium sized towns rather than large cities would be the vehicle of urbanization. Growth of urban centers in the entire north eastern region is slow which is mainly due to its rural economy and poor level of industrialization. However, these small towns play a greater role in socio-economic development of the region and securing a better quality of life. The linkage between smaller towns and their rural hinterland provides connections between human, financial and marketing sector. Therefore, before initiating any developmental work for these small and medium towns, proper regional planning framework for the surrounding rural areas along with economic development and infrastructure planning must be incorporated (Sahasranaman 2012). Further, over

the years due to increasing needs and demands for water has caused water stress condition and exploitation. This situation calls for a proper cost-effective evaluation and planning for groundwater resources. Ground water is an important resource for any developmental initiatives which supports health, economic development and ecological diversity (Waikar & Nilawar 2014). Groundwater resources are an important and dependable source of water supply in both urban and rural areas.

The Guwahati city might see an increase in population to about 2.1 million by 2051. Hence to accommodate such growing population, Guwahati Metropolitan Development Authority (GMDA) is reviewing their existing master plan 2025 for possible expansion of present boundary (Hemani & Das 2015). As the city expands due to challenges in civic infrastructures and service delivery capabilities, small and medium towns/urban centers all around start to grow and develop because they act as an interface between agriculture and urban market and their position in rural urban linkages and economic development. Small and medium towns have predominantly rural economic base and most of the workforce are engaged in agriculture. Agriculture is space consuming and labor intensive and requires storage facilities, distribution depot, fertilizers, processing plants, and marketing needs. It is to be noted that small towns appear in a hierarchy because there are different grades of demands from the villages and each having a different threshold of population and ranges of goods. Such a hierarchy should be properly developed without gaps so that every area and everyone gets equal opportunities. Therefore, stress should be given to the small towns/urban centers because they are closer to rural people and will have a greater impact on the lower strata of the society (Ray et al, 1999). Further to achieve national growth along with human development, there is an urgent need to transform the rural landscape of India, bringing them at par with their urban counterparts in terms of amenities and opportunities, while preserving the soul of the village. Further, unplanned urban expansion, economic development and population growth contribute to natural hazards, especially floods, landslides etc. In the state of Assam, one of the most frequent and devastating disaster is flood which causes economic damages, social damages and loss of life and properties. Guwahati city suffers mostly from urban flooding which has become very costly and difficult to manage especially because of high concentration of people and property. Flood has long-term direct and indirect consequences such as loss of educational opportunities, diseases, and reduced nutrition apart from mobility and transportation hazards which impedes the achievement of developmental goals. Similarly, during monsoons, landslides also contribute to various challenges to the people and infrastructure. The present study assumes significance to identify urban centers and rural growth centers as cluster of venues which are geographically close to each other and serve multiple functions to full fill the diverse demand of residents both rural and urban. This study aims to use GIS and remote sensing together with nested hexagon structure and central place theory to identify urban and rural growth center using hierarchical settlement to achieve proper balance between urban and rural areas. Central place theory was developed by Christaller, (1933) and Losch, (1944) to describe the spatial pattern of urbanization and hierarchy of urban center. Their focus was mainly on organizing a city and its surrounding rural areas through geometric and hexagonal model called as nested hexagon. They also stated that the areas falling at the center of nested hexagon will be the main hinterland for its surrounding areas. Combining them with Guttman scalogram scale will help in grouping the settlements into different level of hierarchy of development. The Guttman scalogram can be used to rank the settlement on the basis of function located within them (Rondinelli 1980).

1.1 Study Area

Guwahati city is located in the northeastern part of India surrounded by the hills on the east, west and south and the river Brahmaputra on the north and supports a population of 9, 68, 549 in 2011 (TERI 2013) with a decadal growth of 18.29 percent. The study area was selected by taking a 50km buffer from GMDA master plan boundary comprising a total area of 13013.6km^2 that includes 328km^2 (without Brahmaputra River) GMDA area for identification of urban center and rural growth centers for potential inter- and intra- administrative cooperation in the region. The study area consists of ten districts of Assam namely Kamrup Rural (partial), Kamrup Metro (full), Nalbari (full), Morigaon (partial), Darrang (partial), Barpeta (partial), Goalpara (partial), Baksa (partial), Udalguri (partial) and West Karbi Anglong (partial) besides two districts of Meghalaya state namely Ri Bhoi (partial) and West Khasi Hills (partial) districts for decentralized planning. Figure 1 shows the demarcated study area over Landsat 8 OLI imagery and figure 2 and figure 3 shows population variation and decadal growth of the districts within the study area.

2. Database and Software

In this study GMDA boundary was obtained from the office of GMDA. For identification of the hierarchical order of settlements, urban centers and rural growth centers, villages having population of 5000 & above were selected in the state of Assam, and villages having population of 1000 & above were selected in the state of Meghalaya since in the hilly regions, it is difficult to get villages having population of 5000 and above. Further census villages and municipal town data were also collected from census of India (https://censusindia.gov.in.). Apart from the above, villages with less population but representing Block development office and primary health centers in the state of Assam were also considered so as to cover entire study area and proposed for decentralized planning. ArcGIS 10.3 and QGIS 3.24 software were used for the creation of base map, digitization of vector layers and creation of thematic maps. Population data of villages and towns and their amenities were obtained from census of India village and town directory. From the total sample of 10760 villages in the study area, 154 villages were identified and selected apart from 55 towns from census data which were falling within the 50km buffer region.

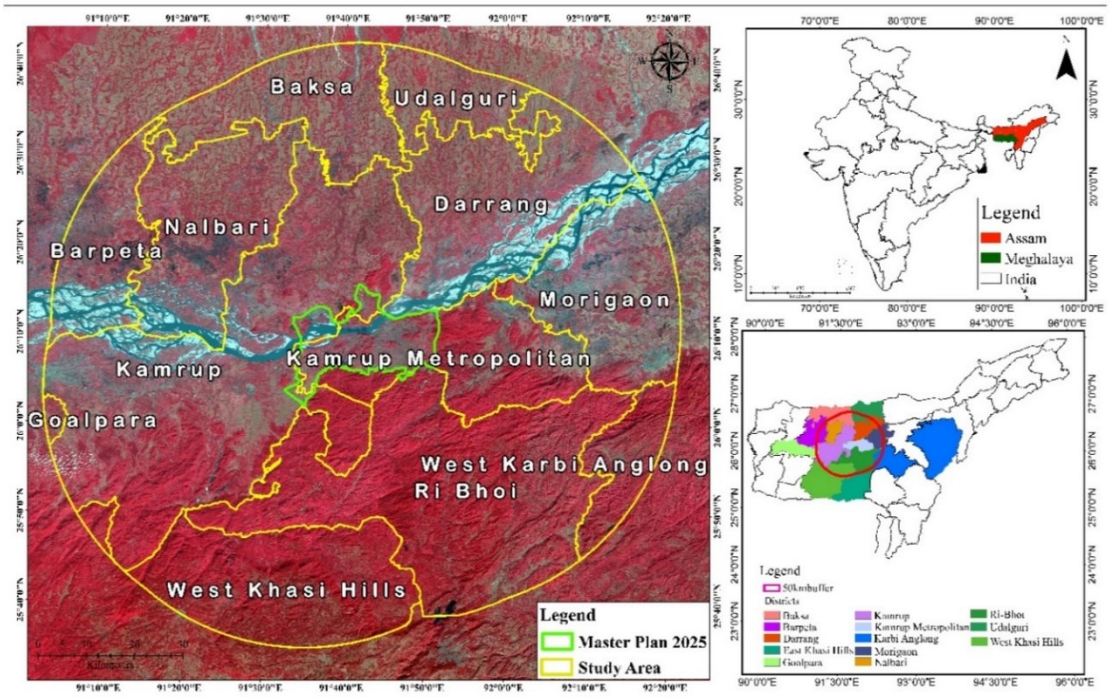

Figure 1. Study Area over Landsat 8 imagery

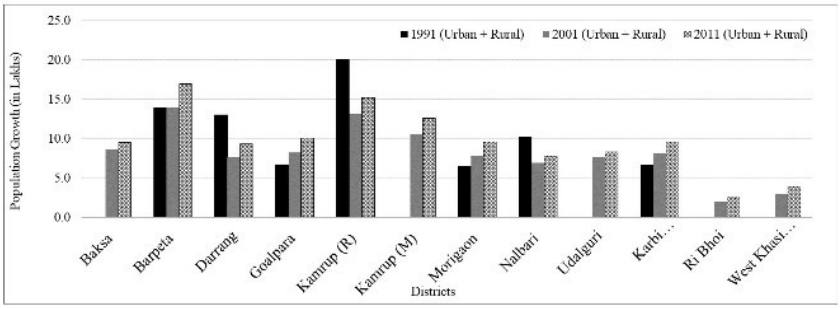

Figure 2. Populations Variation of districts year wise

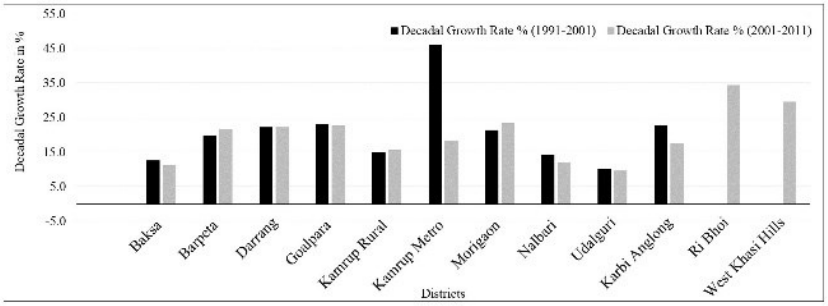

Figure 3. Decadal growth rates of districts

The geographical location of the villages and towns and administrative centers were obtained from Gram manchitra (https://panchayatonline.gov.in), Bhuvan panchayat (https://bhuvan-panchayat3.nrsc.gov.in) and ASDMA GIS portal (http://sdmassam.nic.in). Landsat 5 TM satellite imageries from U.S. Geological Survey (USGS) Earth explorer (https://earthexplorer.usgs.gov) were extracted for mapping land use land cover. The information on ground water potential zones, thematic layer was collected from North Eastern District Resource Plan (NEDRP) of North Eastern Space Application Centre (NESAC), Umiam, Meghalaya and information on flood prone areas was obtained from Bhuvan web portal. Further, the landslide susceptibility map of the study area was also obtained from global landslide susceptibility map from NASA for this study and analysis.

3. Methodology

The methodology to identify the potential centers in the study area involves following steps:

3.1 Creation of Base Map

The base map is generated in 1:50k scale in GIS software. Road network, railway line and water bodies like river and streams were digitized from Landsat 8 OLI satellite

imagery and google earth and later were verified and updated from north eastern district resource plan (NEDRP) portal.

3.2 Identification of Hierarchical Settlements

3.2.1 Determination of Centrality score and weightage of villages

Centrality score measures the importance of a settlement based on its socio-economic facilities and services irrespective of its hierarchy and location (Mishra & Deodhar 2009). In order to calculate the centrality scores, weightage of all the facilities at the villages were calculated first. Thereafter, it was multiplied with the number of times the facility available in the villages. Then the values were added up to calculate the centrality score of that particular village. The weightage calculated using Equation 1 (Rondinelli 1980; Mishra & Deodhar 2009; Rahman & Noor 2005).

$$W_f = \frac{N}{F_f} \quad (1)$$

Here N is the total number of villages, F_f is the total number of villages having that facility and W_f is the weightage of the particular facility. The Centrality Score can be obtained using Equation 2, (Rondinelli 1980; Mishra & Deodhar 2009; Rahman & Noor 2005)

$$\mathrm{CS} = \sum N_f \times W_f \quad (2)$$

Here CS is the centrality Score of the village, N_f is the number of a particular facility in the village.

The facilities and functions considered for calculation of centrality score for settlements are pre-primary school, primary school, middle school, secondary and senior-secondary school, degree college, government vocational /ITI centers, community health centers, primary health center, primary health sub-center, hospital, dispensary, family welfare center, anganwadi centers, ASHA, veterinary hospital, public bus service, railway station, post office, post & telegraph office, telephone (landlines), banking service ,self-help group, domestic, agriculture, commercial, all users for power supply.

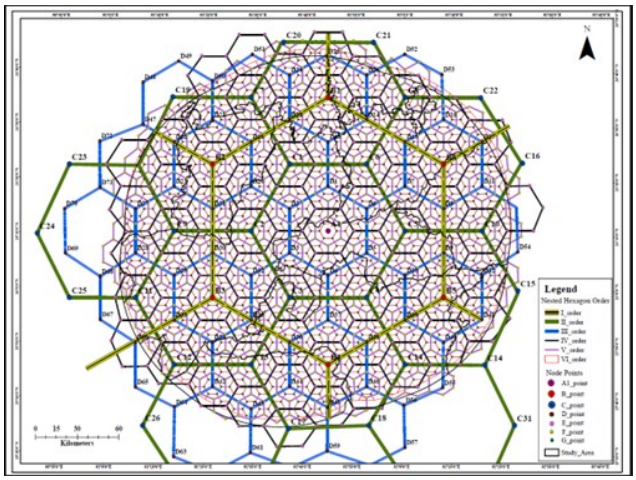

Figure 4. Nested Hexagon model with Guwahati as centre (A1)

3.2.2 Nested Hexagon

Figure 4 shows the nested hexagon covering the entire study and keeping Guwahati at its centre.

3.2.3 Identification of Potential Urban centres and Rural growth Centres:

The potential centers will be selected based on following criteria:

i) Population of the proposed urban center settlements must be 5000 and above.
ii) Rural growth centers to be proposed based on nested hexagon model even if it has population less than 5000.
iii) If two or more villages are at a close distance with each other, then on the basis of its centrality score suitable settlements will be selected.
iv) If settlements are already near to any existing urban center at a distance of 5km, then that settlement will not be proposed for urban centers.
v) Proximity of the settlements to road network.
vi) Potential ground water zones of the area.
vii) Flood prone and landslide susceptible zones within the study area.

4. Results and Discussion

4.1 Creation of Base Map

The primary approach for any analysis requires generation of base map. The base map of the entire study area was generated at a scale of 1:50k and contains information on geographical location of towns and villages and administrative units falling within the study area (Figure 5).

4.2 Hierarchy of the Village and Town Settlements over Nested Hexagon

The identified village settlements were overlaid on nested hexagonal structure to propose decentralized hierarchical settlement of different orders. But for town settlements, hierarchical order is given as per census class. The Figure 6 shows the existing settlements in the study area overlaid on nested hexagon. Altogether 209 settlements were identified including village settlements and existing towns for the proposal of hierarchical settlement. Out of these 209 settlements, 55 villages are having population more than 5000 and 99 villages having population less than 5000 and remaining 55 are already existing towns. The settlements falling outside the study area were not considered for this proposal.

The existing 55 towns are ordered as per their existing census order and shown in Figure 6. As per the census class, Guwahati is the only settlement that falls in the first order or class I category. No second order town settlement falls within the study area as per census 2011. Table 1 represents the number of town settlements and their respective census class. As per the nested hexagon pattern, out of 154 identified villages, none of the villages are falling in the first order of hierarchical order. Table 2 represents the existing order of the village settlements as per nested hexagon

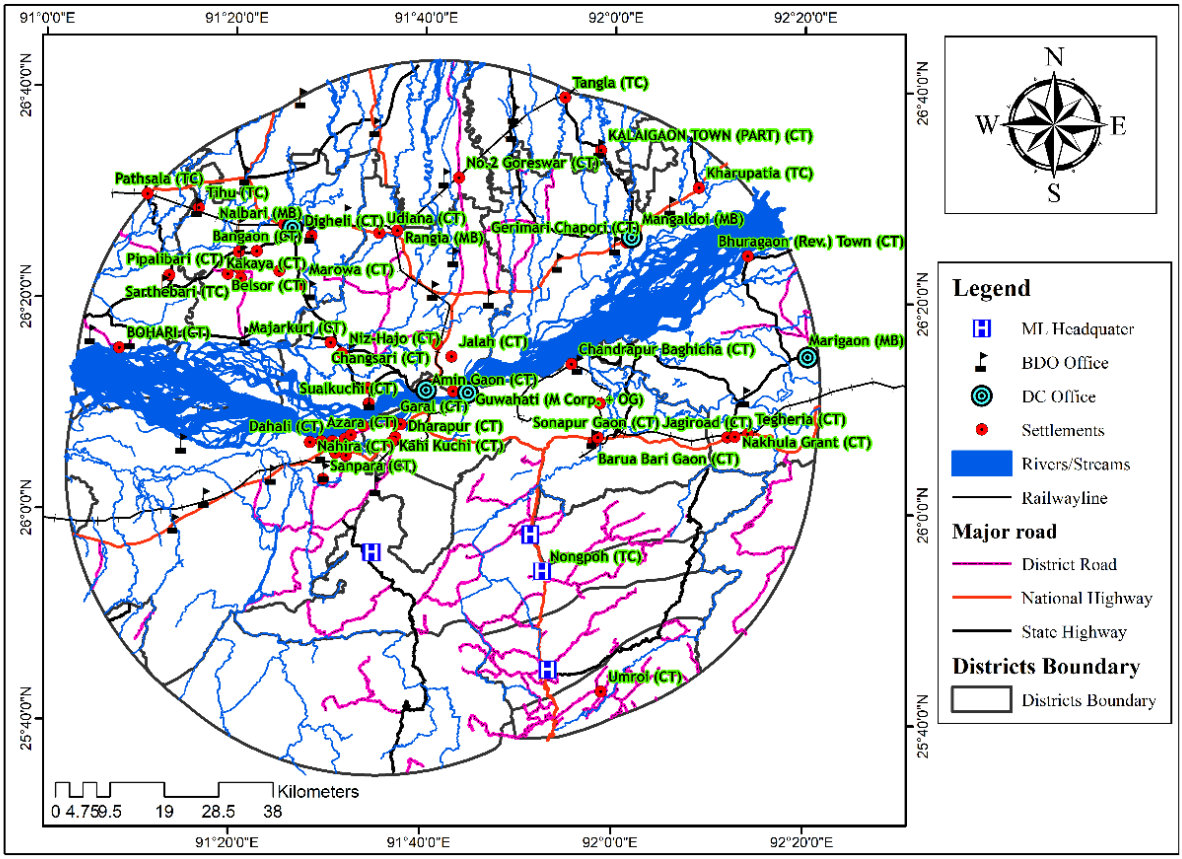

Figure 5. Base map of Study area

.Table 1. Existing Hierarchical order of Town settlement

No of Settlements	Census Order/Class
1	I Class
4	III Class
10	IV Class
28	V Class
12	VI Class

Table 2. Existing Hierarchical order of village settlement

No. of settlements	**Hierarchical order**
2	II order
7	III order
28	IV order
45	V order
72	VI order

Table 3 Population Size of settlement

Sl. No	Population size	Number of Settlements
1.	Less than 1300	45
2.	1300-2300	37
3.	2300-4000	16
4.	4000-11000	53
5.	More than 11000	3

Table 4 Centrality score of Village settlements

Centrality score	**No of Village settlements**
4-13	31
14-21	48
22-31	29
32-47	23
48-78	18
79-151	5

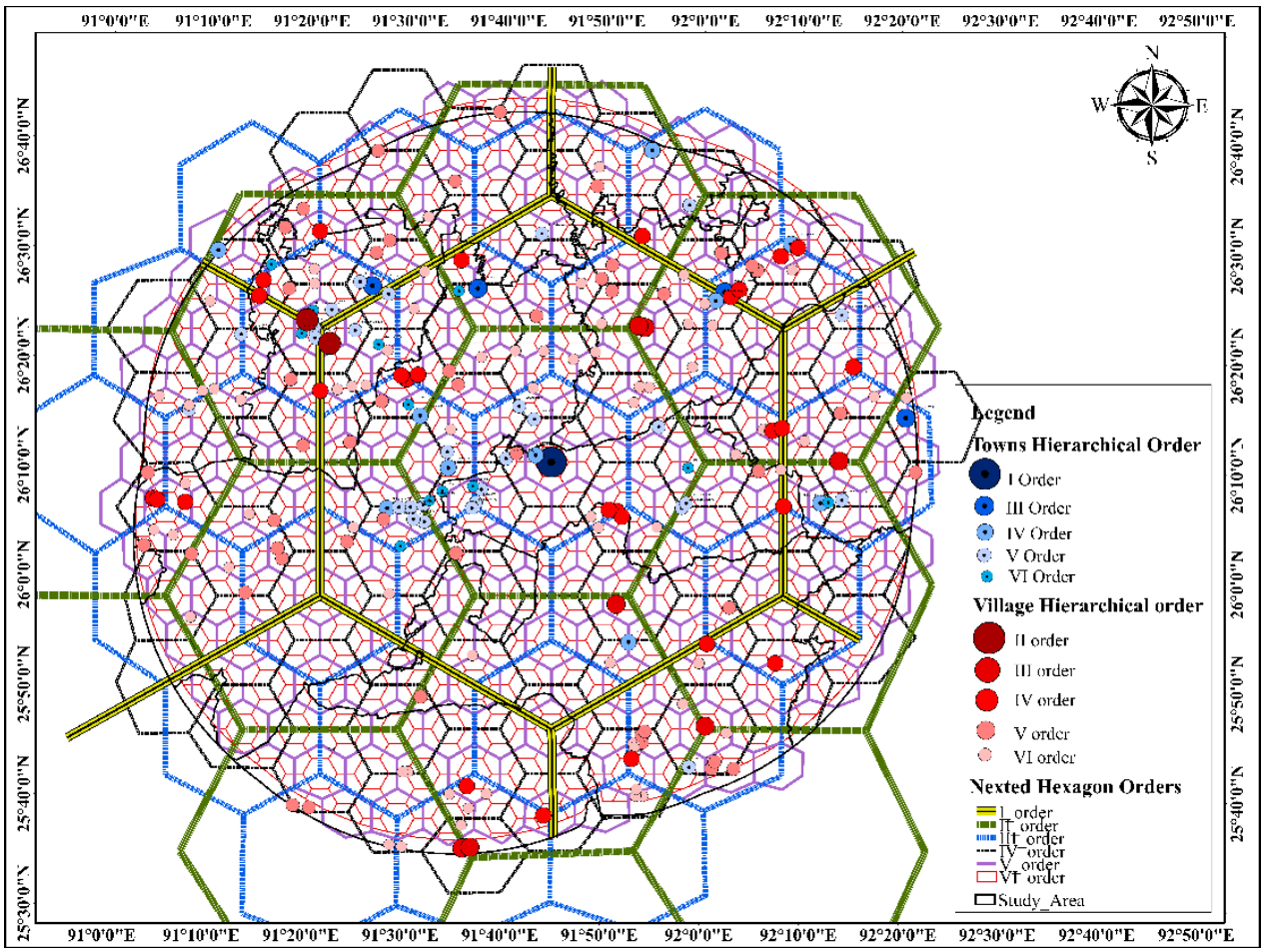

Figure 6. Existing Village and towns over nested hexagon

4.3 Identification of Potential Centres

To identify potential centers, some criterion has been selected which are illustrated below

4.3.1 Population

As per Urban and regional development plan formulation and implementation (URDPFI) guidelines 2015, Government of India, places having population **Table 3** *Population Size of settlement* of 5000 to 20000 are classified as small towns under the sub category of small town I and population ranging from 20000-50000 are classified under sub category small town II. However, any urban centers even if has less than 5,000 population may be given a statutory status and be called as a statutory town. Accordingly, 97 settlements were identified in the study area of which 55 are having population of more than 5000 in the ten districts of Assam and 42 settlements with population more than 1000 but less than 5000 in the two districts of Meghalaya state. For decentralized planning, another 57 settlements were identified which are having block development office and primary health centres having population less than 5000 (Figure 7). The settlements falling outside the buffer region are not included in this study.

4.3.2 Centrality Score

The result (Table 4) shows the centrality score of the settlements ranging from lowest to the highest and the calculation is based on amenities and functions. This reflects settlements with high centrality score have more functional capacity to serve the needs and demands of the surrounding regions. The centrality score of the 55 towns have also been calculated purely based on amenities and functions. The result indicates that out of all the 55 towns, only 1 town i.e., Guwahati (M Corp. + OG) with highest centrality score. After Guwahati, 7 towns are having second highest centrality score ranging from 37-51. Thereafter, 11 towns having centrality score ranging from 26-36. Similarly, centrality score of 12 towns is ranging from 18-25, 16 towns are having centrality score between 13-17 and 8 towns are having score ranging from 7-12.

4.3.3 Distance of selected villages from existing urban centres/towns

Under this criterion, a buffer ring of 5km was generated from existing towns in GIS software for analysis. The villages which are not close to existing towns or any urban centres are selected for further analysis.

4.3.4 Road connectivity

Road connectivity is another very important criterion for the selection of potential urban centres and rural growth centres which is carried out and shown below. Road connectivity helped us to identify the centres having proper communication network with neighbouring rural as well as urban areas.

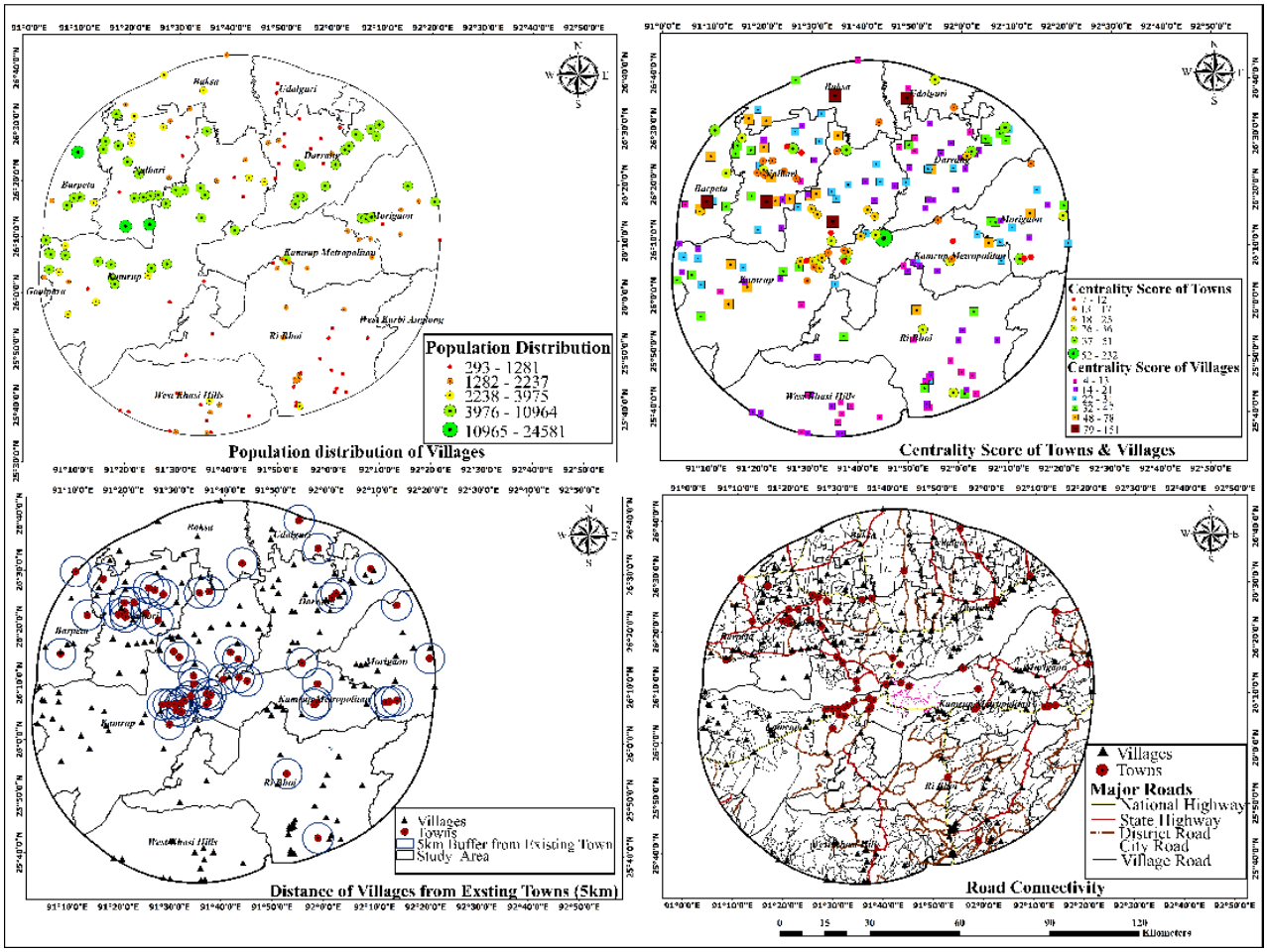

Figure 7. Criteria Map

Figure 7 shows the criteria map such as population distribution of villages, centrality score of towns and villages, distance of villages from existing towns and road connectivity to identify potential centers for decentralized planning and development within the study area.

4.4 Suitability Assessment of Identified Urban Centres, Rural Growth Centres and Towns using Multiple Parameters

After analyzing various multiple parameters, 34 village settlements and 10 existing towns were selected for suitability assessment. These were then overlaid over multiple thematic layers (Figure 8) such as land use land cover, ground water potential zones, flood prone zones and landslide susceptible zones. Land use land cover of 2011 was generated using Landsat 5 imagery and various classes were digitized following NRSC Land use/Land cover mapping guidelines and categorized into agriculture land, built-up, forest, grassland/grazing land, tree clad, shifting cultivation, wasteland, water bodies and wetland.

Land use land cover map shows an upsurge in developed areas within the Guwahati metropolitan region which is expanding towards the eastern, western and northern areas. Guwahati metropolitan region is already congested and densely built; hence it is essential and felt necessary to identify more urban centers and rural growth centers to reduce the pressure on Guwahati city. The ground water prospect (GWP) map was downloaded in raster format from open source NEDRP except West Khasi hills district in Meghalaya falling in the study area due to its non-availability. The GWP maps were categorized into excellent, good, moderate, nil, poor, very good, high and low prospect areas. Further, in absence of village boundary, a hexagonal bin of 5km was generated and 34 villages as identified were overlaid on this hexagonal bin and then on land use/land cover, flood hazard zones (BHUVAN, NRSC), landslide susceptible zones (Stanley and Kirschbaum 2017) and Ground water prospect zones (NEDRP) (Figure 10) for suitability assessment. The landslide susceptible map of the study area shows the villages falling within slight, moderate or severe zones. The flood prone zones (Figure 11) were used for analyzing and ascertaining whether the identified centers are falling into the different categories namely (Figure 8) very low, low, moderate, high, very-high, and no data zones in the study area. The table 5 and table 6 below showing suitability of selected 34 settlements of different orders for the proposed new urban centers and rural growth centers based on the selected parameters.

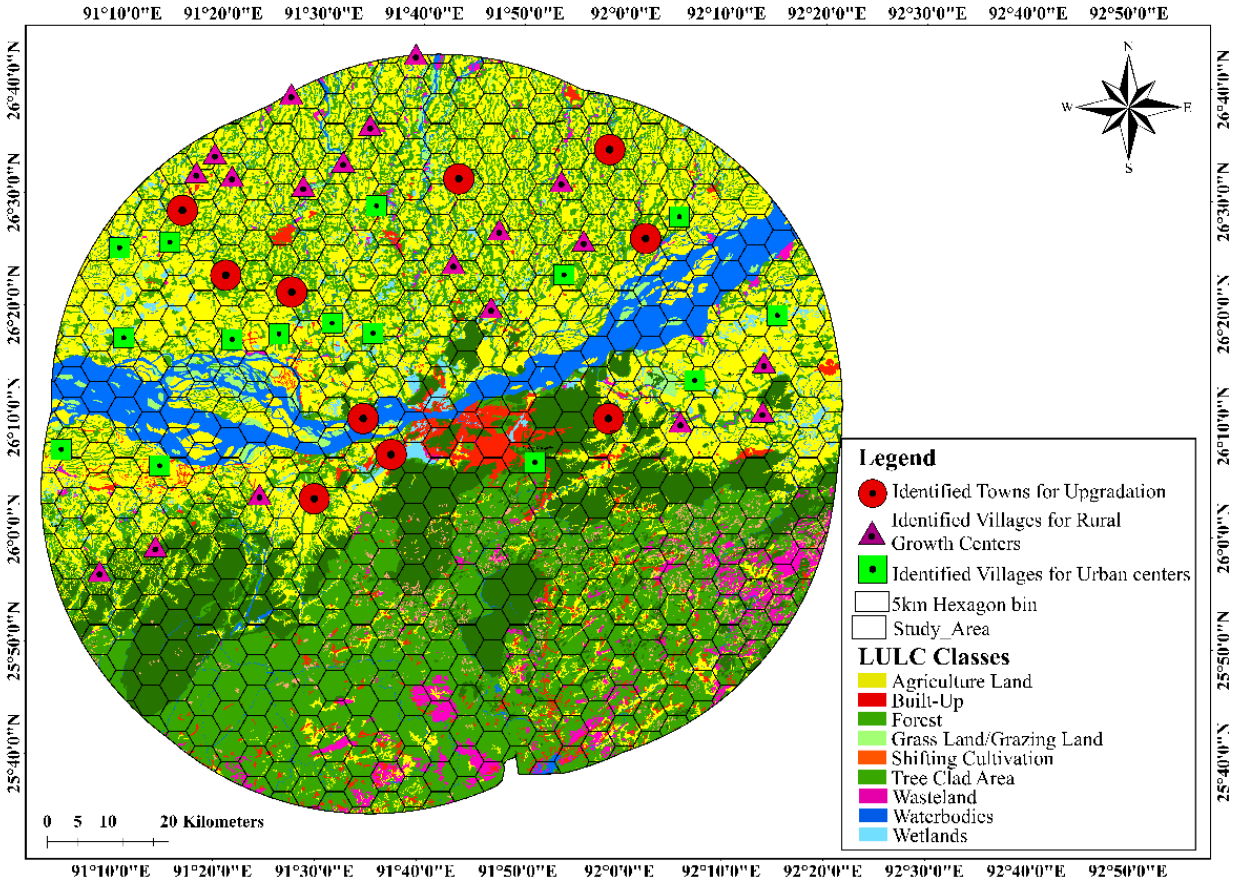

Figure 8. Identified Villages and Towns over LULC

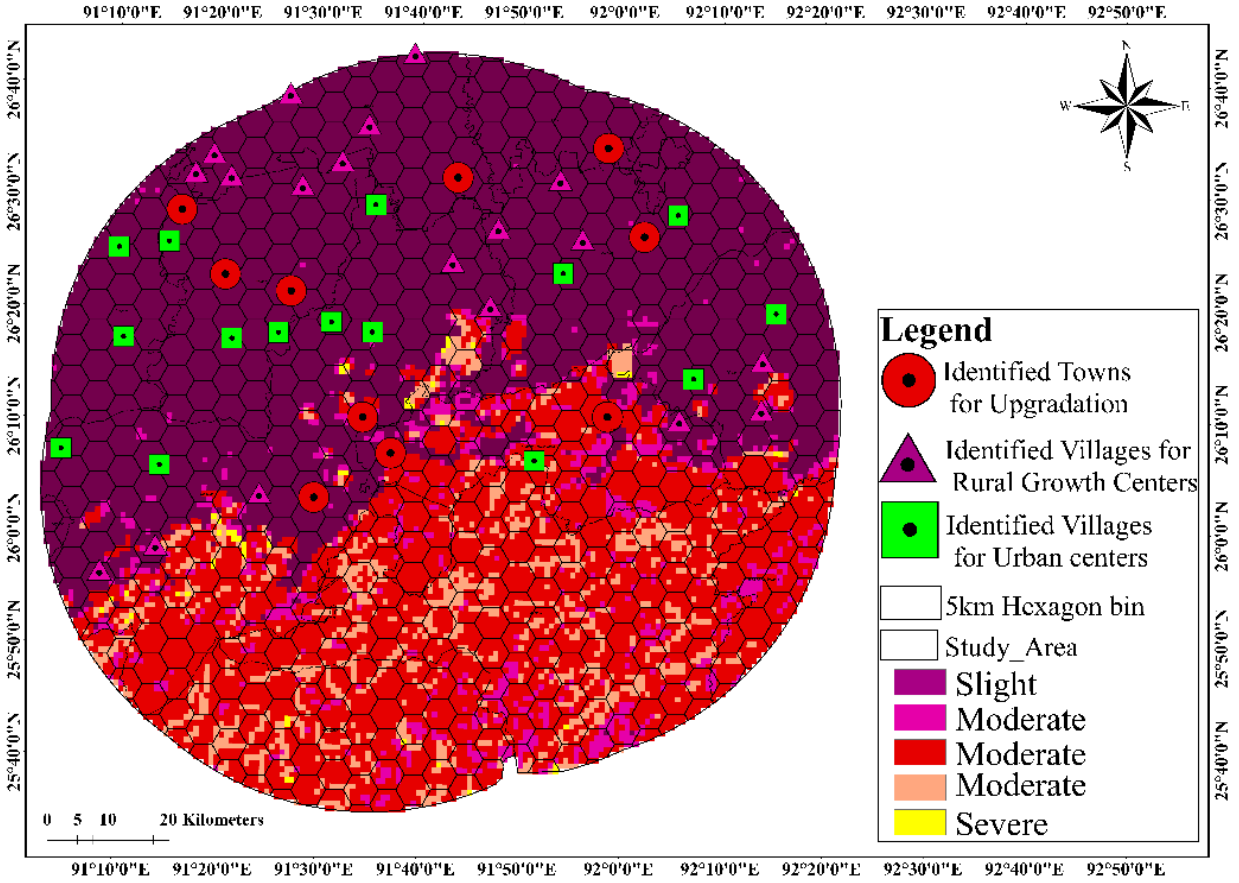

Figure 9. Identified Villages and Towns over Landslide zones (Stanley and Kirschbaum 2017)

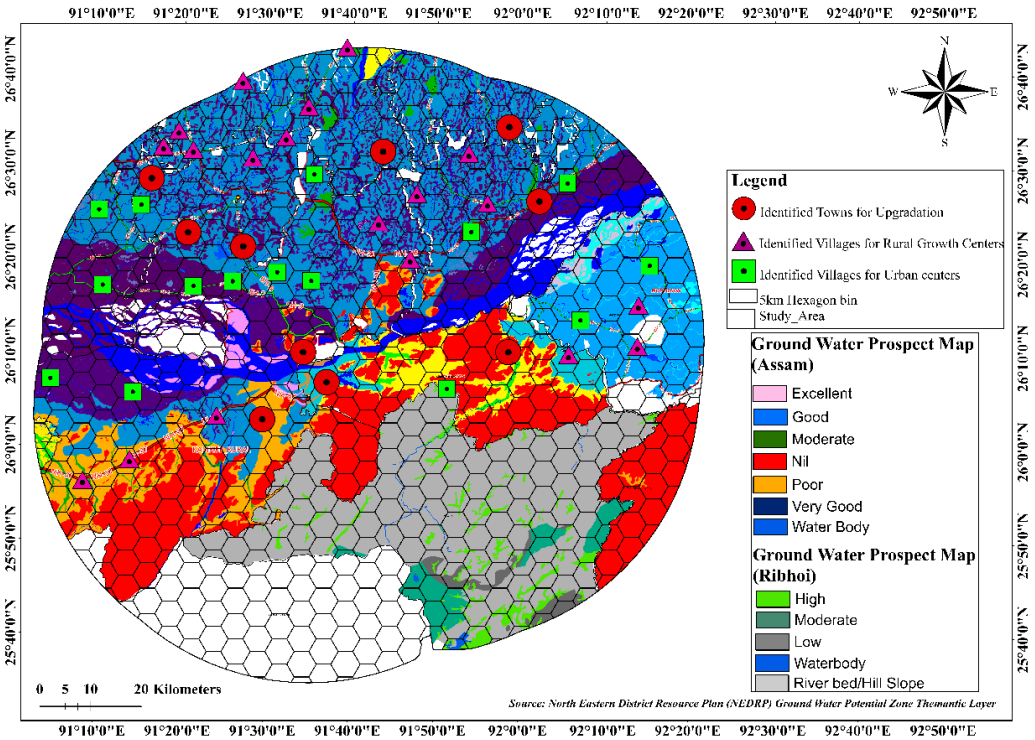

Figure 10. Identified Villages and Towns over Ground Water prospect zones (NEDRP)

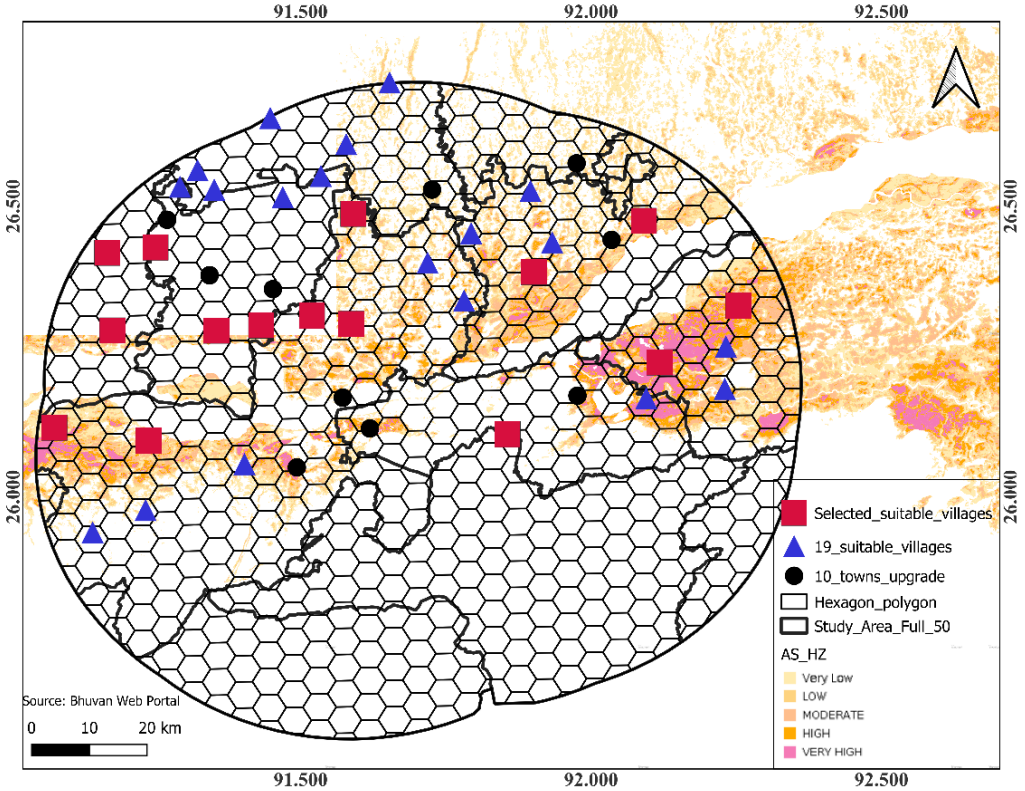

Figure 11. Identified Villages and Towns over Flood Hazard zones (Bhuvan)

From, Table 5 and Table 6, it is found that two village settlements namely Dhopguri and Dakua para from Kamrup rural district and one town namely Digaru Gaon (Digarubar Gaon) (CT) from Kamrup metropolitan district falls in poor ground water zones. Hence, these settlements were not proposed further for development of new rural growth centers and class upgradation. Finally, 15 urban centers and 17 rural growth centers along with nine towns of different hierarchical order were identified and overlaid on the nested hexagon (Figure 9). However, certain preventive measures are required to be taken and suggested for the proposed settlements from the purview of urban expansion which are as follows

Table 5. Settlements of different orders Proposed for Urban centre and Rural growth centre

AA	BB	CC	DD	EE	FF	GG	HH	II	JJ
Morigaon	Bhakat Gaon	1993	III	RGC	GD	MD	SL	AG/PTC	S
Darrang	Bhuktabari	5400	III	UC	VG	VL-MD	SL	AG/PTC	S
Kamrup (M)	Amerigog N.C.	5348	IV	UC	NL	VL	MD	BU/FFL	S
Morigaon	Burha Buri	5875	IV	UC	GD	VL-HH	SL	AG/PTC	S
Morigaon	Kalikajari	7266	IV	UC	GD	LW-HH	SL	WL/AG	S
Baksa	Kaljhar	2867	IV	RGC	VG	VL	SL	BU/AG/PTC	S
Kamrup_Rural	Khopani Kuchi	5244	IV	UC	GD	VL-MD	SL	AG/PTC	S
Nalbari	Khudra Makhibaha	5052	IV	UC	VG	VL-MD	SL	AG/PTC	S
Nalbari	Narayanpur	5748	IV	UC	VD	LW	SL	BU/ AG /PTC/WB	S
Darrang	Sanapatipara (Sentipukhuri)	1122	IV	RGC	VG	VL	SL	AG /PTC	S
Kamrup (R)	Tulsibari	7214	IV	UC	VG	VL	SL	BU/ AG /PTC /WB	S
Kamrup_Rural	Tupamari	10964	IV	UC	VG	VL-HH	SL	AG	S
Baksa	Baganpara	3211	V	RGC	VG	VL	SL	AG /PTC	S
Nalbari	Balitara No.4	1584	V	RGC	VG	VL	SL	AG /PTC /WB	S
Darrang	Bar - Satra	1095	V	RGC	VG	LW	SL	AG /PTC	S
Baksa	Bareigaon	2812	V	RGC	VG	VL	SL	AG /PTC /WB	S
Baksa	Bhalukdonga	2099	V	RGC	VG	VL	SL	BU/ AG /PTC	S
Baksa	Bhawraguri	1441	V	RGC	GD	VL	SL	AG /PTC /WB	S
Kamrup_Rural	Dakuapara	3016	V	RGC	PR	VL	SL-MD	BU/ AG/ PTC	US
Kamrup_Rural	Jajikona	1903	V	RGC	VG	LW	SL	AG /PTC/WB	S
Darrang	Khataniapara	5968	V	UC	VG	LW	SL	AG /PTC	S
Kamrup_metro	Maloibari Pathar	1521	V	RGC	GD	VL-VH	SL	AG /PTC /WB	S
Kamrup_Rural	Manah Kuchi	6290	V	UC	VG	VL-MD	SL	AG/ PTC	S
Nalbari	Niz-Namati	4784	V	RGC	VG	LW	SL	BU/ AG /PTC	S
Kamrup_Rural	Nowapara	3596	V	RGC	GD	VL-HH	SL	BU/AG/PTC	S
Morigaon	Sarubori	1350	V	RGC	GD	VL-VH	SL	AG	S
Nalbari	Bangaon	1409	VI	RGC	VG	VL	SL	AG/PTC/WB	S
Kamrup_Rural	Bezera	2434	VI	RGC	VG	VL-MD	SL-MD	AG /PTC	S
Kamrup_Rural	Dhopguri	3889	VI	RGC	PR	VL	SL	AG /PTC	US
Barpeta	Kawaimarikaragari Reserve	24581	VI	UC	VG	VL- HH	SL	AG	S
Nalbari	Loharkhatha	6384	VI	UC	VG	VL-MD	SL	AG/ PTC /WB	S
Barpeta	Muchalman Gaon	6385	VI	UC	VG	VL- MD	SL	AG/ PTC /WB	S
Darrang	Salikajhar	2032	VI	RGC	VG	VL	SL	AG/ PTC	S
Kamrup_Rural	Tukura Para	7166	VI	UC	VG	LW	SL	BU/AG	S

Table 6. Proposed towns for upgradation to higher order from its current status class/order

AA	BB'	CC	DD'	EE'	FF	GG	HH	II	JJ
Darrang	Mangaldoi (MB)	25989	III	UG-II	VG	VL-MD	SL	BU/AG/ PTC	S
Kamrup	Sualkuchi (CT)	13898	IV	UG-III	VG	LW	SL-MD	BU/WB	S
Baksa	No.2 Goreswar (CT)	5631	V	UG-II	VG	VL	SL	BU/AG/ PTC	S
Kamrup Metropolitan	Azara (CT)	8780	V	UG-IV	GD	VL-HH	SL	BU/AG/WL	S
Nalbari	Belsor (CT)	8523	V	UG-II	VG	VL-MD	SL	AG/ PTC	S
Udalguri	Kalaigaon Town (Part) (CT)	5112	V	UG-III	GD	VL	SL	BU/AG/ PTC	S
Kamrup	Sanpara (CT)	4534	VI	UG-IV	GD	VL-VH	SL	BU/AG/ PTC	S
Kamrup (M)	Digaru Gaon (Digarubar Gaon) (CT)	3207	VI	UG-III	PR	VL	MD	FL/AG	US
Nalbari	Tihu (TC)	4599	VI	UG-IV	VG	MD	SL	BU/AG/ PTC	S
Nalbari	Marowa (CT)	4004	VI	UG-V	VG	LW	SL	AG/ PTC	S

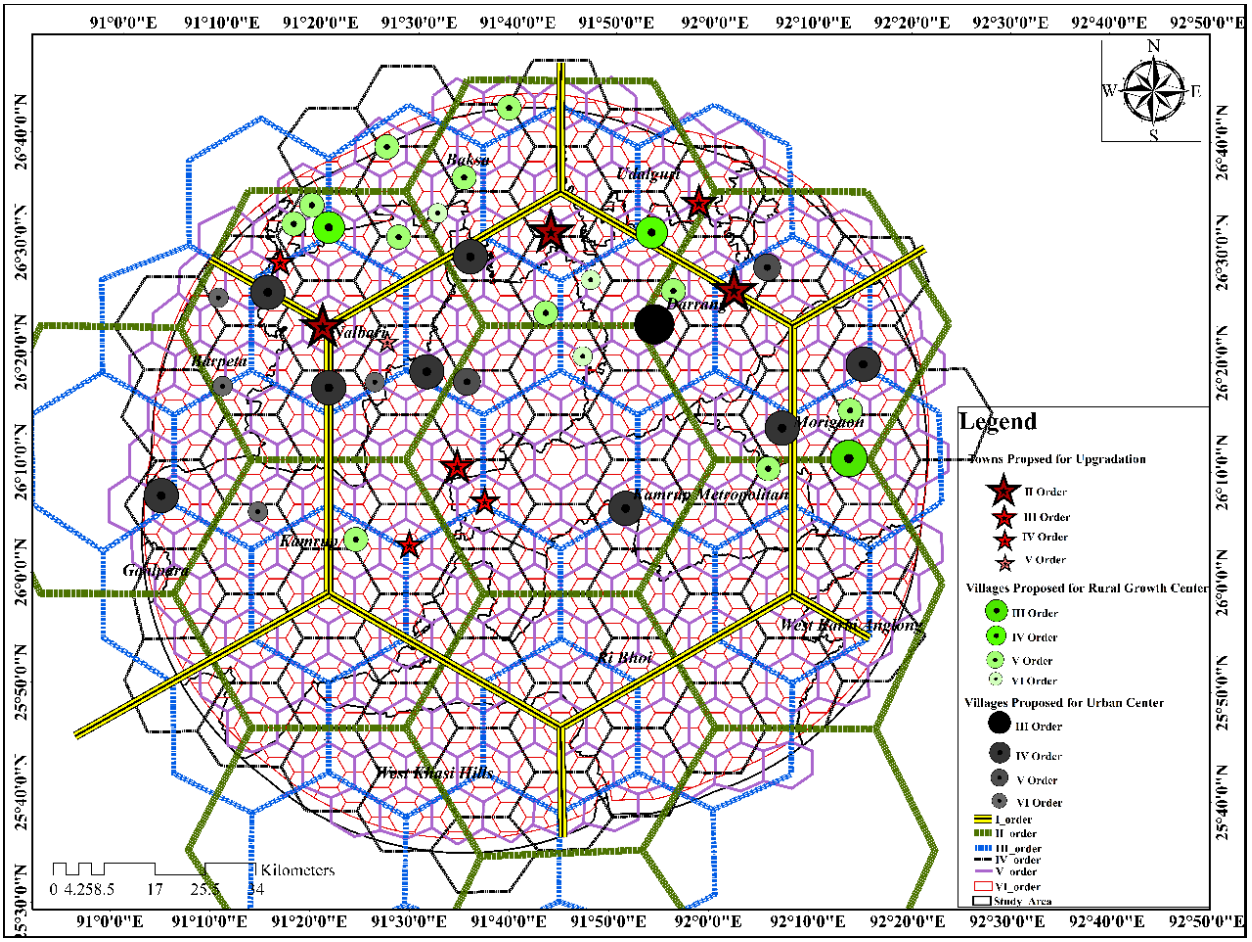

Figure 12. Hierarchy of settlements

i) Adequate vegetative and structural protection measures are suggested for the proposed URGC settlements which are having moderate to high flood prone and landslide susceptible areas.
ii) Expansion should be avoided in areas which are covered with wetlands.
iii) Rivers and streams need to be taken care of during expansion process.
iv) Adequate groundwater recharge structure and rainwater harvesting is suggested for the existing unsuitable settlements due to poor groundwater potential.
v) Settlements with available surface water supply from river and streams were proposed for urban centres within the study area.

5. Conclusion

This study identifies potential urban centers and rural growth centers using central place theory, nested hexagon model, GIS and remote sensing around the city of Guwahati for which multiple criteria were determined. The criteria although includes population of 5000 and above but for wider coverage of the study area villages with less than 5000 population is proposed for Rural Growth Centers. A total of 209 settlements were selected for identification of urban centers and rural growth centers. Further, based on multiple criteria, 34 villages and 10 existing towns were identified for the proposal of urban centers and rural growth centers and up gradation of towns to higher order. These selected 34 centers were further analyzed for suitability assessment by generating a 5km hexagonal bin which was overlaid on ground water potential zones, flood prone areas, land use land cover and landslides susceptibility of the area to assess suitability. After suitability assessment, out of identified 10 towns, nine towns have been selected and proposed for up gradation to higher order. Out of 34 village settlements, 15 villages were proposed for new urban centers and 17 villages were proposed for rural growth center within the study area for decentralized planning. After considering all the parameters and pre-determined criteria, two village settlements were not proposed since they were falling within poor ground water potential zones. Thus, a total of 32 settlements were finally selected for development as new urban centers and rural growth centers (URGC) within the study area. However, several suggestion and preventive measures were made which needs to be considered before initiating developmental expansion. In this study, an attempt has been made to identify potential urban centers and rural growth centers for decentralized planning with proper integration and co-relation between urban and rural sectors that will fulfill aspirations of people and achieve sustainable development of the region.

Abbreviations

***RGC*=**	**Rural Growth Centre**	**AA'=**	**District**
***UC* =**	**Urban Centre**	**BB=**	**Name of village settlement**
***VG* =**	**Very Good**	**BB′=**	**Name of Town settlement**
***GD* =**	**Good**	**CC=**	**Population**
***MD* =**	**Moderate**	**DD=**	**Hierarchical order as per nested Hexagon**
***NL* =**	**Nil**	**DD′=**	**Existing Orders as per Census data**
***PR* =**	**Poor**	**EE=**	**Proposed new Urban Centers/Rural Growth Centers**
***VH* =**	**Very High**	**EE′=**	**Proposed Towns for Upgradation to higher order as per Nested Hexagon**
***HH* =**	**High**	**FF=**	**Ground Water Prospect Zones**
***LW* =**	**Low**	**GG=**	**Flood Prone Zones**
***VL* =**	**Very Low**	**HH=**	**Landslide susceptible Zones**
***SL* =**	**Slight**	**II=**	**Land use/ Land Cover (within 5 km Hexagon zone)**
***SV* =**	**Severe**	**JJ=**	**Remarks**
***AG* =**	**Agriculture**		
***PTC*=**	**Patches of Tree Clad**		
***FFL* =**	**Forest Fringe Land**		
***FL* =**	**Forest Land**		
***BU* =**	**Built-Up**		
***WL*=**	**Wetland**		
***WB*=**	**Waterbodies**		
***S* =**	**Suitable**		
***US* =**	**Un-Suitable**		
***UG* =**	**Upgrade**		

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