REMOTE SENSING FOR SETTLEMENT PATTERNS IN METROPOLITAN REGIONS: THE CASE OF NATIONAL CAPITAL REGION (NCR) OF DELHI, INDIA

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ABSTRACT:

The author earlier conducted a research, attempting to make two models, one for understanding, monitoring and describing settlement patterns in metropolitan regions, dependant primarily on remotely sensed data; and the second, for predicting settlement patterns in such regions, using National Capital Region (NCR), of Delhi, India, as a case study. As part of the model, a transferable approach of the 'Continuously Built-up Area' (CBA) was adopted, which allows identification of settlements at different levels of generalization. With the capability of providing frequent and synoptic views over large areas, remotely sensed data (e.g., satellite images) proved to be a useful base for carrying out macro-analyses of settlement patterns, at frequent intervals. The model for prediction was applied for the target year of 2001. About 10 years have passed by since the base year of data collection. While the region has changed tremendously during these years, recent data (Census of India, 2001) pertaining to the then target year (2001) is also now available. The moment is also apt, keeping in mind that the *Regional Plan – 2001 National Capital Region* has now expired and the *Draft Regional Plan - 2021* has just come in. This paper reviews the models for 2001.

It has been found that the predictions made by the model with regard to settlements becoming 'towns', CBAs and couples have largely come true. It also confirms the role satellite images can play in reasonably predicting settlement patterns in metropolitan regions.

1. INTRODUCTION

1.1 Modelling Settlement Patterns

Analysis of settlement patterns is useful in making decisions about the location of new investments, and about the potential for clustering services and facilities in new ways to increase the capacity of human settlements to stimulate development in their areas. Settlement patterns in and around metropolitan regions become all the more important when considering the pace with which the urban settlements are increasing, both in number and size. In addition, in developing countries, there is a new category: increasingly large numbers of spontaneous human settlements are coming into existence on the urban fringes.

Left to 'natural' processes, these phenomena produce inefficient as well as ineffective settlement patterns. To reduce the social, economic and environmental cost of inefficiency, management is introduced to address problems arising from the processes. An attempt was made earlier, by this author to suggest a model for describing the settlement pattern, and for exploring alternatives for the management of the future development of that pattern.

No sufficiently comprehensive methods exist for defining and recognizing spatial patterns. The methods available (e.g., the spatial autocorrelation) are generally for point patterns, which are best analyzed partly visually and partly manually. Cluster analysis techniques are also not suitable for spatial clusters.

A number of theories and models have been put forward to describe and understand human settlement patterns. One important conclusion that can be drawn from a review of these models is that they all help in analyzing the existing patterns. Most of them help, in a limited way, in predicting settlement patterns and rarely, in planning settlement pattern changes. Moreover, the prevalent models consider settlements as point locations when analyzing their spatial distribution. The size of the settlement, not in terms of the population it holds but in terms of the area it covers on ground, or its shape, is hardly ever considered.

1.2 Continuously Built-up Area

In considering urban growth, one of the first questions to be resolved was how to identify the changing extent of the settlements. In response, a transferable approach of the 'Continuously Built-up Area' (CBA) was devised, which allowed identification of settlements at different levels of generalization. On the images at a scale of 1:250,000, the minimum curtilage for delineation of CBA was 4mm x 4mm (terrain 1km x 1km or 100 ha) and a minimum width of 2mm (terrain 500m) was adopted. An `exclusive' definition was applied: meaning that in case of doubt, it was decided to be non built-up. The concept encompassed suburban settlements, industrial complexes, airports, etc. In this approach, the reality of the moving urban edge rather than municipal, administrative or political boundaries is seen (e.g., through satellite images), recorded and continuously updated so as to provide real time information to support decision-making. The strength of the tool (i.e., the concept of CBA, applied to remotely sensed data) is that it may be calibrated to any level of generalization, corresponding to different scales of mapped information and decision-making.

Another conclusion drawn is that most quantitative models of settlement patterns rely heavily on assumptions such as isotropic planes and rational economic behaviour. The geometrically and statistically guided models do not really work in the light of 'urban managerialism', political climate and planning behaviour. Thus, methods will have to be developed which are flexible not only in the conceptual

context (e.g., CBA) but also in their application to model settlement pattern in a region. Satisfactory techniques are not available for performing a 'formal' spatial pattern analysis exercise. The methods developed have to be based on a partial visual/ manual analysis.

Methods based on traditional concepts require accurate, sophisticated and timely availability of data, both spatial and attribute, on variety of subjects. The level of detail required for information on many functions changes frequently and is difficult to update on a regular basis, more so in developing countries. Models lose their sophistication when outdated data are fed into them. Further, in many urban and regional systems it is important to ascertain the overall situation. But the information we usually have, or are likely to have, relates, by and large, to individual decisions.

With the capability of providing synoptic views over large areas, remotely sensed data (e.g., satellite images) can be a useful base for carrying out macro-analyses of settlement patterns, at frequent intervals. It not only provides information more efficiently than field surveys; it also offers a new perception and a new understanding of human settlements.

2. MODELS

Model(s) were developed for describing and making predictions and recommendations for settlement patterns based on the new understanding of settlements. Through a flexible approach in defining human settlements, and the use of images from satellites, the model(s) are easily applied in 'data-poor' situations and with not well-established practices of settlement pattern planning, as is the case in many developing countries. It literally provides a tool for better defining and comprehending the term 'local', in the context of the 74th Amendment to the Constitution of India, designed to strengthen the role of urban local bodies in promoting local and economic development, and in improving the environment. The two models, one for understanding, monitoring and describing settlement patterns in metropolitan regions, dependant primarily on remotely sensed data (Fig. 1); and the second, for predicting settlement patterns in such regions (Fig. 2) were developed. Both the models are suggested to be recalibrated each time the results of a new census become available or when a new plan for the region is being prepared. However, parts of the models that are dependant on remotely sensed data are suggested to be adjusted more frequently. The models were then applied to the National Capital Region (NCR) of Delhi, India, as described below.

3. NCR OF DELHI

National Capital Region (NCR) of Delhi, India is a complex entity, covering an area of about 33,578 sq. km. lying between $27^0 03$'N and $29^0 29$'N latitude and $76^0 07$'E and $78^0 29$'E longitude. It is a complex planning and administrative system. More complex is the planning for settlement pattern for the region, with human settlements in population sizes ranging from less than 500 persons to over 14 million people. The Region surrounds and includes the city/ state of Delhi (formally known as National Capital Territory of Delhi or the NCT Delhi). It also covers parts of the states (provinces) of Haryana, Rajasthan and Uttar

Pradesh. It is the biggest and generally accepted to the best-defined metro region in India. The region accommodated a population of more than 37 million people (in 2001), of which about 14 million lived in Delhi alone. Density of population of the region is about 1,200 persons per sq. km, with Delhi being the highest at more than 9,000 persons per sq. km. About 56 per cent population of the Region is urban, accommodated in 110 towns, including three metropolitan cities, viz., Delhi, Meerut and Faridabad. The city of Ghaziabad together with Loni is also emerging as a metropolitan complex. Besides, there are about 7,950 rural settlements, accommodating a rural population of 16.4 million. Plan policies for the Region (2001) were covered under three Policy Zones, viz. NCT Delhi, Delhi Metropolitan Area (DMA) and the Rest of the NCR. However, the *Draft Regional Plan – 2021* redesignated the DMA as Central NCR and added Highway Corridor as another policy zone.

3.1 Application of the Models on the NCR

The models as described in 2 above were applied to the NCR (as in 1991). Extensive use of satellite images from IRS-1A and 1-B (LISS-I and LISS-II) at resolutions 72.5m and 36.25m was made for the purpose. The images covered two time periods, e.g. 1990-91 (corresponding to the Census year) and 1993-94 (corresponding to the ground truth year). All products were standard CCT, 6250BPI, BSQ format. The image interpretation was primarily visual, as indicated in the models above. The models, drawing heavily from the operational definition of `CBA', examined the images for identifying existing `assemblage' of human settlements, `couples', `insular' settlements likely to join an assemblage or to form a new assemblage/ couple, existing villages with a potential to become urban by 2001 and existing and potential towns that were likely to stay as `insular'. While predicting a scenario for the year 2001 (target year for the then Regional Plan), 4 `assemblage' settlements, 11 `couple' settlements, 3 `functional couple' settlements and 65 `insular' settlements were identified. Population for these settlements was also projected for the year 2001, primarily using the `CBA' as interpreted on the satellite images and supported with their present (then) population, etc.

The population figures now announced by the Census for the year 2001 and the analysis of the settlement pattern as presented in the Draft Regional Plan for the year 2021 provided encouraging results and confirm many of the predictions made by the models. Satellite images from IRS-1C/1D (LISS III + PAN) of the year 1999, as interpreted by the NCR Planning Board, were also used for making these observations. The results are described in following paragraphs.

4. APPRAISAL OF THE MODELS

4.1 Potential Towns

As per the definition adopted by Census of India, towns are places with a municipal corporation, a municipal committee, a town committee, a notified area committee or a cantonment board; also all places having a population of more than 5,000 persons, a density of population of 400 persons per sq. km., pronounced urban characteristics and at least three-fourth of its adult male population employed in pursuits other than agriculture. A town can be declassified, however, if one of

criteria is not met subsequently. As described in 3.1 above, the villages (in 1991) having a potential to become towns (in 2001) were identified. The decision was based on their (then) population, growth rate, population density, percentage of male working population in non-agricultural activities, besides `CBA'. This list included the (then) villages of Dharoti Khurd, Salarpur Khadar, Nahri, Ladrawan, Ramgarh, Dunda Heda, Rewari (rural), Kishangarh, Asan Khurd, Pinagwan, Sidhrawali, Khandsa, Tapookra, Sahoti, Mohiuddinpur, Tilpat, Aminagar (excluding the villages within the NCT of Delhi, which were all expected to be urbanised by 2001). In addition, a few combination of villages were also expected to become urban, purely on the basis of `CBA', although they failed miserably in atleast one criteria essential for declaring a settlement `town' by the Census. These were of Atseni, Bait and Bihuni; Uchagaon and Amargarh; Bahin and Kot; Bahalgarh and Rathdhana; and Shahajahanpur.

It is very encouraging to note that 15 of the above 22 rural settlements indeed became `towns' in the year 2001. Out of the remaining 7, four did join other `urban agglomerations' and therefore did not appear as separate towns. The remaining 3 did not become towns as they were predicted purely on the basis of `CBA', as interpreted on the image and no consideration to other data was given.

4.2 `Assemblage' Settlements

The models also predicted four `assemblage' settlements to be there in 2001. The first `assemblage', primarily of NCT Delhi included the settlements of Loni, Western Ghaziabad, Noida, Tilpat, Faridabad, Gurgaon, Bahadurgarh, etc. The combined population for the assemblage was projected at 15.5 million by the year 2001. Another `assemblage' was that of towns of Eastern Ghaziabad, Dasna and Dunda Heda,
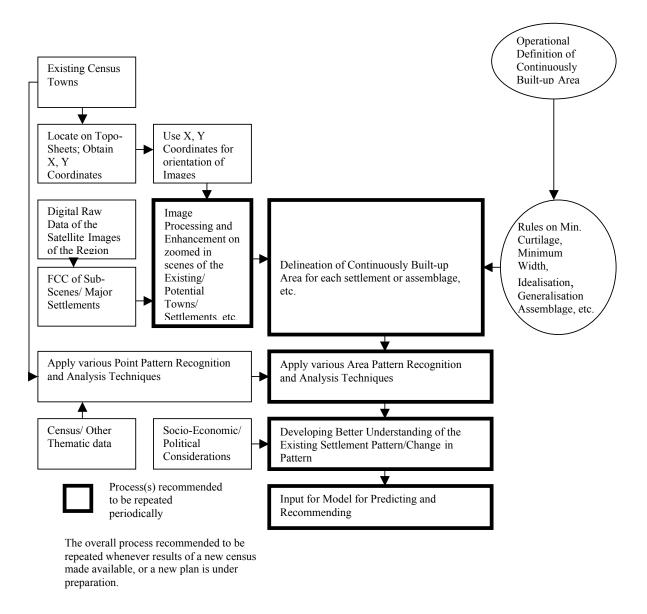

Fig. 1   Model for Understanding, Monitoring and Describing Settlement Patterns

Digital raw data of the satellite images of the region → FCC of Sub-Scenes/ Settlements

Rules of Assemblage, Couple, etc.

Definition of Towns → Criteria of Population, Density, Workforce, Economic Importance, Function etc.

Existing Census Villages

Operational Definition of Continuously Built up Area

Existing Census Towns

Potential Towns for future period

Potential `Settlements' for future period

Locate on Topo Sheets; Obtain X, Y Coordinates

Use X, Y Coordinates for orientation of Images

Locate on Topo-sheets, Identify the Settlements; Obtain X,Y Coordinates; Obtain relevant attribute data for existing towns

Digital Raw Data of the Satellite Images of the Region

FCC of Sub-Scenes/ Major Settlements

Image Processing and Enhancement on zoomed in scenes of the Existing/ Potential Towns/ Settlements

Delineation of Continuously Built-up Area for each settlement or assemblage, etc.

Rules on Min. Curtilage, Min. Width, Idealisation, Generalisation Assemblage, etc.

Apply various Point Pattern Recognition and Analysis Techniques

Apply various Area Pattern Recognition and Analysis Techniques

Input from Model for Understanding, Monitoring and Describing

Census/ Other Thematic data

Socio-Economic/ Political Considerations

Take policy decisions regarding Continuation/ Modification/ Alteration of the Settlement Pattern

Process(s) recommended to be repeated periodically

Generate a pattern of Continuously Built-up area/ Assemblage/ Couples, etc.

Rules for potential CBAs/ Assemblage/ Couples

The overall process recommended to be repeated whenever results of a new census made available, or a new plan is under preparation.

Re-aggregate relevant attribute data; Assign settlement hierarchy, population, functions, services, etc.
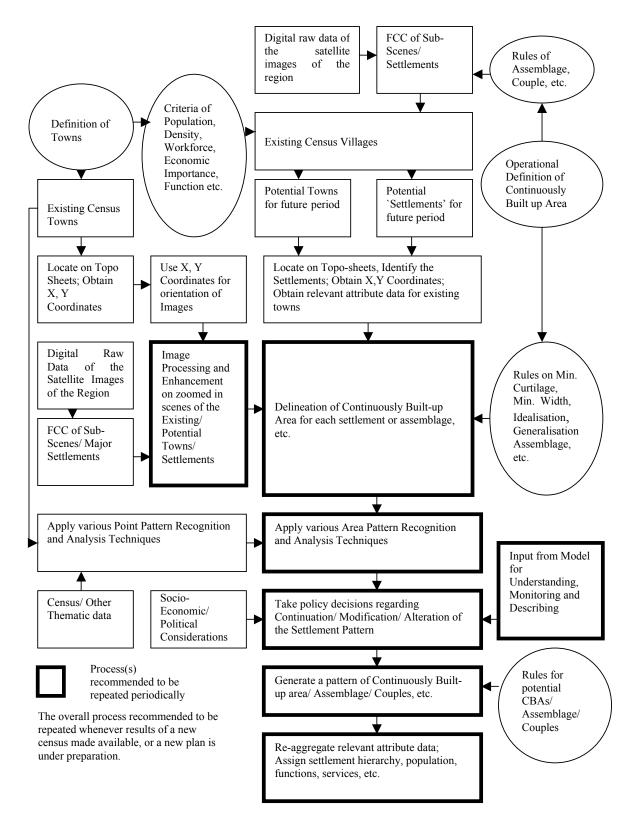
Fig. 2   Model for Predicting and Recommending Settlement Patterns

with a combined projected population of 0.4 million. It may be noted that, in reality, there is no entity as Western or Eastern Ghaziabad. The distinction was made by this author only for the fact that river Hindon makes the division with only one bridge to join the two parts. If the division by the river is ignored, these `assemblages' will make one large assemblage with a combined projected population of 15.9 million persons in 2001.

It is heartening to know that the settlements for the above assemblage now total up to 16.5 million. Moreover, the settlements are primarily being treated as Central NCR (erstwhile DMA). These settlements mainly compose of Ghaziabad, Modinagar, Noida, Faridabad, Gurgaon, Bahadurgarh, Sonepat and Kundli. It may also be noted that the division between these settlements among themselves and with NCT Delhi is, in reality, an administrative and political one and they in fact constitute one large `CBA'.

4.3 `Couple' Settlements

As stated earlier, the models also identified a few `couple' settlements. These included the couples of Alwar-Ramgarh, Hapur-Babugarh, Surajpur-Kasna, Sonipat-Bahalgarh, Baghpat-Agarwal Mandi, Kithor-Shahajanpur, Khairthal-Kishangarh, Hailey Mandi-Pataudi, Tikri-Doghat, Daural-Lawar and Bahsuma-Hastinapur. Functional couples of Modinagar–Mohiuddinpur/ Rori – Meerut, Sikandrabad-Bulandshahar–Khurja; and Rewari–Dharu Hera/ Bhiwadi were also identified.

Images for the year 1999 (nearly corresponding to the year of Census, 2001) confirm the above couples taking place. It is very satisfactory to note that the *Draft Regional Plan – 2021* indeed proposes to develop many of these as `integrated complexes'. They include Baghpat-Baraut, Ghaziabad-Loni, Faridabad-Ballabgarh, Bulandshahar-Khurja, Behror-Shahjahanpur-Neemrana, Rewari-Dharuhera-Bawal and Sonepat-Kundli. Proposed Land Use plan for the year 2021 also indicates the willingness of the NCR Planning Board to accept these assemblages, couples, etc., except for the fact that these are still separate entities for the purpose of administration as well as Census.

5. CONCLUSIONS

From the above review, it may be concluded that the models, depending heavily on the remotely sensed data, as applied to the concept of `CBA' provide an excellent framework for understanding, monitoring and describing existing patterns, and for making predictions and recommendations. Moreover the methods provide for periodic revisions and updates corresponding to availability of two major sources of data (i.e., the census and the satellite images). An important learning from the review is that the identification of rural settlements having potential to become urban may not be guided totally by the `CBA' as seen on the images. At the same time, this strengthens the concept of CBA rather than discriminating the settlements as `towns' or `villages'. The use of satellite images, as illustrated in the case of NCR, also confirms that the settlements will continue to grow irrespective of their `administrative' jurisdictions.

The concept of CBA, supported with tools such as remote sensing and GISs, enables planners, administrators and decision makers to gain better understanding of this complexity, in a way that can be impartially, and with consistency, executed by technicians.

An interesting finding was that working at the metropolitan regional scale, images with low spatial resolution are actually more useful than images with higher resolution. The remotely sensed data with spatial resolution of 72.5m is found appropriate for the purpose of this task (e.g., modelling settlement patterns), providing a synoptic view of the entire region under study. Specifically, its comparatively low resolution performs the otherwise difficult task of determining the 'built-up' pixel out of a mix of 64 pixels (of 10m resolution compared to 80m) in reality.

It may be noted that although, in principle, the method can be extended to rural settlements too, it will require higher resolution data and detailed ground truth. Similarly, the need for support from other traditional data sources cannot be totally ruled out as the images fail to deduce functions and interaction between human settlements.

REFERENCES

Bolt, D., 1996. An urban community strategy for implementing decentralisation and devolution policies. *ITC Journal,* 1996-1, pp.18-28.

Census of India, 2001.

Mahavir, 1996. *Modelling Settlement Patterns for Metropolitan Regions: Inputs from Remote Sensing.* ITC, Enschede, The Netherlands.

NCRPB, 1988. *Regional Plan – 2001.* National Capital Region Planning Board, Ministry of Urban Development, Government of India, New Delhi.

NCRPB, 2004. *Draft Regional Plan – 2021.* National Capital Region Planning Board, Ministry of Urban Development, Government of India, New Delhi.