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Effective management of slums- Case study of Kalaburagi city, Karnataka, India

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ABSTRACT

As urbanization grows, we may expect that slums will tend to grow even faster. Kalaburagi is a second tier city and an important commercial hub for the Hyderabad-Karnataka region located in the north eastern part of Karnataka state. It attracts the rural folk from neighbouring districts and the city is undergoing rapid changes in terms of population growth as well as in the degree of urbanization due to which the slum population is increasing. There are 60 slums that account for 11% of city's population. This study aims to contribute some sustainable methodologies for better execution of slum development programs to advance the living conditions of slum dwellers.

Slum ontology has been built to identify slums from very high-resolution satellite data that will benefit all stakeholders. The developed ontology was validated with field survey and the help of field photographs, the physical and socio-economic conditions were documented. As per the slum ontology, basic inputs for the Cellular Automata (CA) model were identified and criteria maps with scores were generated. The suitability map was created by giving appropriate weight to the factors. When the slum map prepared based on slum ontology was overlaid on the final results, the CA model output has given reliable results regarding current slum distribution and also a hint of the possible occurrence of slums in the future. Since the proposed land use plan for 2021 has been finalized by the Urban Local Body (ULB), the suitable area for developing affordable housing stock was suggested for preventing slums from arising. The Spatial Decision Support System (SDSS) was built for selecting slum development options. The design and running of the SDSS model were demonstrated with one case study – Borabai nagar slum to enable the ULB to apply the approach to other slum areas for effective implementation of slum development programs.

1. Introduction

1.1. Urbanisation and growth of slums

Globally, today, more people live in urban areas than in rural areas. In 1950, 30% of the world's population was urban, but by 2050, 66% of the world's population is projected to be urban. (WUP, 2014). Continuing population growth and urbanization is projected to add 2.5 billion people to the world's urban population by 2050, with nearly 90% of the increase concentrated in Asia and Africa. Just three countries—India, China, and Nigeria— are expected to account for 37% of the projected growth of the world's urban population between 2014 and 2050. India is projected to add 404 million urban dwellers, while China will add 292 million and Nigeria 212 million. According to UN HABITAT (2010, 2011), the world's slum population is expected to reach 889 million by the year 2020.

Cities and towns are centres for agglomeration economies, investment, technology, innovation, economic growth, and tertiary jobs. They represent the hopes of millions of migrants from rural hinterlands. The National Sample Surveys of India for 1999–2000 and 2007–2008 record the increase in both inter and intrastate migration to urban areas (Bhagat and Mohanty, 2009). As the Census of India shows, taken together inter and intrastate migration increased from 98 million in 2001 to 139 million in 2011. On the one hand, poverty, drought, unemployment and lack of good medical and educational facilities push rural migrants to urban centres. On the other hand, job opportunities in informal sectors and the greater range of urban amenities attract village populations to urban

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areas. Push and pull factors operate together to increase rural to urban migration which in turn increases the pressure on the existing urban infrastructure. The poor migrants who are unable to afford urban housing, find themselves in squatter settlements and slums, developed mostly in vacant plots and open areas along canals, riverbanks or railway lines.

Due to the influx of rural populations into urban areas in search of subsistence, slums are continuing to increase and the quality of housing to decline. As cities grow, so do their slum populations. This is mainly because of failure to plan cities in ways that address people's needs. Inequities in access to basic services and insecurity of tenure are the other important factors contributing to the growth of slums. In these circumstances the formation of slums becomes inevitable with rapid urbanization.

Slum-identification studies focus on the persistence and expansion of existing slums as well as the emergence of new slums, particularly in the southern world where rapid slum development is linked to the failure of formal land markets and inadequate planning (Kuffer, Pfeffer, and Sliuzas, 2016). Though there have been some improvements worldwide in the situation of slum-dwellers as a result of local and global efforts, the number is still estimated to grow by an average of 6 million every year globally. According to the 2011 census of India, about one in six Indian city residents live in an urban slum with unsanitary conditions that are unfit for human habitation.

In India, not only metropolitan cities but even second-tier cities are facing serious slum problems and these problems will only get worse in the future. The present study looks at the slum situation in a second-tier city, Kalaburagi and offers a feasible method to manage that city's slums, both today and in the future.

1.2. Need and importance of the research

Housing is one of the basic needs of human beings, next to food and clothing. It is an essential element in the overall socio-economic development of a country and its citizens, and for the satisfaction of social and cultural aspirations of people. The problem of housing shortage confronting us today seriously threatens to upset the political and social order since, with each successive Five Year Plan, the gap between demand and supply has only been widening (M/oHUPA report). It is expected that by the year 2051, the population of India will be almost equally distributed between urban and rural areas, with major cities and metro cities attracting a major portion of the country's rural population, thus aggravating the demand for urban housing.

As the report of the Technical Group shows, the shortage of housing is most acutely felt by the lower economic strata of the population. According to the report, the estimated housing shortage works out to be 10.49 million for Economically Weaker Section (EWS) households, which is 56.18% of the total housing shortage in urban India. Similarly, for Low Income Group (LIG) households, the shortage works out to be 7.36 million, which constitutes 40% of the total shortage (Table 1). In order to improve the quality of life in urban areas, it is of critical significance that the housing stock is improved through urban renewal, in situ slum improvement and development of new housing stock in existing cities as well as new townships.

As urbanization grows, the projected share of urban households rises in the next two decades from the current 28%–50% of the country's population, one may, therefore, expect that slums will tend to grow even faster. This is a consequence of urbanization in developing countries. Unless this possibility is consciously taken note of, and corrective action is initiated early, it could lead to serious crippling of the productive capacities of a growing number of people by the denial of basic services, shelter and security, increasing inequity and retarding the Gross Domestic Product (GDP) potential of urban areas.

The Millennium Declaration of the United Nations, to which India is a signatory, specifically recognizes the need to improve the lives of slum dwellers. Recognizing the gravity of the issue, and their commitment to both their own people and the global community, the Government of India has launched a major programme for improvement of the lives of slum dwellers. However, it has been found that the design of this programme is severely constrained by the paucity of data, not only regarding the living conditions in Indian slums but even the magnitude and dispersion of the slum population (Report of Slum Committee, 2010). In this scenario, the urban local body has to obtain answers (given in the brackets) to questions that include: where are the slums in a city? (data pertaining to location, the neighbourhood of slums); what is the size of the slum? (updated slum map with actual spatial boundaries); what is the current slum situation? (Population, type of housing, available infrastructures such as drinking water, roof and floor type, access to road, health facilities etc.); how to improve the existing slum? (in-situ, rehabilitation, upgradation); how to prevent the future occurrence of a slum? (future planning); where to construct affordable houses for slum dwellers? (identifying suitable areas) and how to implement slum development programmes successfully? (constructing a slum Spatial Decision Support System or SDSS). These and other questions need answers in order to accomplish the national mission of a “Slum Free India”.

The present study seeks to answer such questions for the slums in Kalaburagi, a fast urbanizing non-metropolitan city and suggest

Table 1

Distribution of housing shortage among economic category.

Source: Report of the Technical Group on Urban Housing Shortage (TG-12) (2012–17)

Category	DISTRIBUTION OF HOUSING SHORTAGE AMONG DIFFERENT ECONOMIC CATEGORIES AS ON 2012	
	No (in Millions)	in Percentage
EWS	10.55	56.18
LIG	7.41	39.44
MIG and above	0.82	4.38
Total	18.78	100.00

possible efforts to manage and improve that situation. Using traditional methods, such as household surveys, to collect information on slums suffer from a lack of spatial information and certain preconceptions. Updating this type of information is often costly and time consuming. Therefore, there is a need for a reliable source of spatial information which can be updated regularly and relatively cheaply. In this context the use of geospatial technology which includes remote sensing, Geographic Information System (GIS) and Global Positioning System (GPS) can help us to collect, map and analyze data on slums.

This study will help the urban poor in general and slum dwellers in particular by creating a reliable database about their location by using geospatial technology and helping them to improve their living conditions and also help planners and administrators by modelling possible areas of future growth of slums and building a SDSS for better implementation of Government of India (GOI) projects on slums.

1.3. Review of literature

In order to carry out the urban planning and development tasks necessary to improve living conditions for the poorest worldwide an adequate spatial database is needed (Mason & Fraser, 1998) and this is best obtained through the analysis of remote sensing data (Hofmann, 2001, 2008a and b). Since traditional methods demand a great deal of labour, money and time, alternative methods that include sophisticated techniques to extract the information from remote sensing data of very high resolution (VHR) could reduce subjectivity, time and labour (Naga Jyothi, Babu, & Murali Krishna, 2008) thereby providing more reliable data.

Many studies have used census and field survey data as the basis for studying slums and building databases for GIS-based mapping (Joshi, Sen, & Jane, 2002). Recently very high-resolution remote sensing-based methods for mapping slums have become popular within the scientific community (Mason & Fraser, 1998; Sliuzas, 2008; Sliuzas, Kerle, & Kuffer, 2008a; Sliuzas, Mboup, & Sherbinin, 2008b; Hofmann, 2001; Kohli et al., 2011), but there are only a few such studies based on the Indian situation (Sur, Jain, & Sokhi, 2004; Jain, Sokhi, & Sur, 2005; 2007; Kohli, Kerle, & Sliuzas, 2012; Shekhar, 2012; Swadesh Kumar et al., 2014).

In most of the remote sensing-based studies visual interpretation of data has played a major role in the identification of slums (Angeles et al., 2009; Baud et al., 2008, 2010; Sliuzas, 2004; Sliuzas & Kuffer, 2008). Visual interpretation performed by interpreters familiar with local conditions provides a flexible and useful approach to slum mapping, though it does have shortcomings for repetitive surveys of very large cities due to difficulties in controlling quality over time and between interpreters. Later pixel-based image classification began to be widely used in slum analysis and it also helped with understanding the patterns over time and space (Jain, 2007; Jain et al., 2005; Weeks, Hill, Stow, Getis, & Fugate, 2007). With the advent of Object-based Image Analysis (OBIA), the last decade has seen lots of research identifying slums using very high resolution data (Hofmann, 2001; Hofmann, Strobl, Blaschke, & Kux, 2008b; Herold, Scepan, & Clarke, 2002; Van Der Sande, De Jong, & De Roo, 2003; Benz, Hofmann, Willhauck, Lingenfelder, & Heynen, 2004; Kohli et al., 2011; 2012; Shekhar, 2012).

Spatial decision making is often complex and requires information produced from many sources and interpreted by a variety of decision-makers in relation to different goals and objectives (Sugumaran & Degroote, 2010, p. 507). Many spatial problems are semi-structured, where the decision-makers fail to define the problem precisely and do not articulate their objectives (Gorry and Marton, 1971, pp. 56–70; Alter, 1980; Hopkins, 1984 as stated in; Densham, 1991). Slum development is one such semi-structured spatial problem, where the objectives of the decision-maker and the problem itself cannot be fully or precisely defined. Often solutions to semi-structured problems are obtained by generating a set of alternatives and selecting from amongst them, those that appear to be viable using a SDSS.

Though SDSS has been widely used in various fields (Barton, Parolin, & Weiley, 2005; Katpatal et al., 2011; Kelly, Tanner, Valley, & Clements, 2012; Ramachandra and Kumar, 2008; Sreekanth, Soam, & Kumar, 2013; Sugumaran & Degroote, 2010), very few works are concerned with slums and slum planning (Shekhar, 2014).

2. Materials and methods

2.1. Study area

'Kalaburagi' (Formerly Gulbarga), which means a stony land in Kannada, is a growing city situated in the north-eastern part of Karnataka State (Fig. 1). It is the administrative headquarters of Kalaburagi District. Kalaburagi city has an area of 64.00 km².

Kalaburagi is known for its historical monuments built during the reign of the Bahamani kings. More importantly it is a commercial hub for the Hyderabad-Karnataka region. It serves as a regional market and service centre for the district in addition to being an educational centre. Since the city is located in an economically underdeveloped region, it has become a nodal centre for many developmental activities that started attracting rural folk from neighbouring districts. The city is undergoing rapid change both in terms of population growth as well as in degree of urbanization and the slum population has started to increase numerically as well as spatially. Thus, slums have become an integral part of Kalaburagi city and this has led to many slum related problems.

As recorded in the Census of India (2011), the population of Kalaburagi is 532,031; its urban/metropolitan population is 541,617 of which 277,357 are males and 264,260 are females. Kalaburagi is governed by the Municipal Corporation situated in Kalaburagi Urban Region (Census of India, 2011; GCC, 2012). Currently, 11% of the city's population is living in slums. There are 60 slums, covering an area of 1.48 km² spread over central and local government and private land. Out of these 60 slums, 42 slums are notified (All notified areas in a town or city notified as 'Slum' by State, UT administration or local government under any act including a 'Slum Act'- Census 2011) and the remaining 18 are Non-Notified (All areas recognised as 'Slum', which may have not been formally notified as slum under any act- Census, 2011). Most of these are built on land under the ownership of the Urban Local Body. Over 30% of

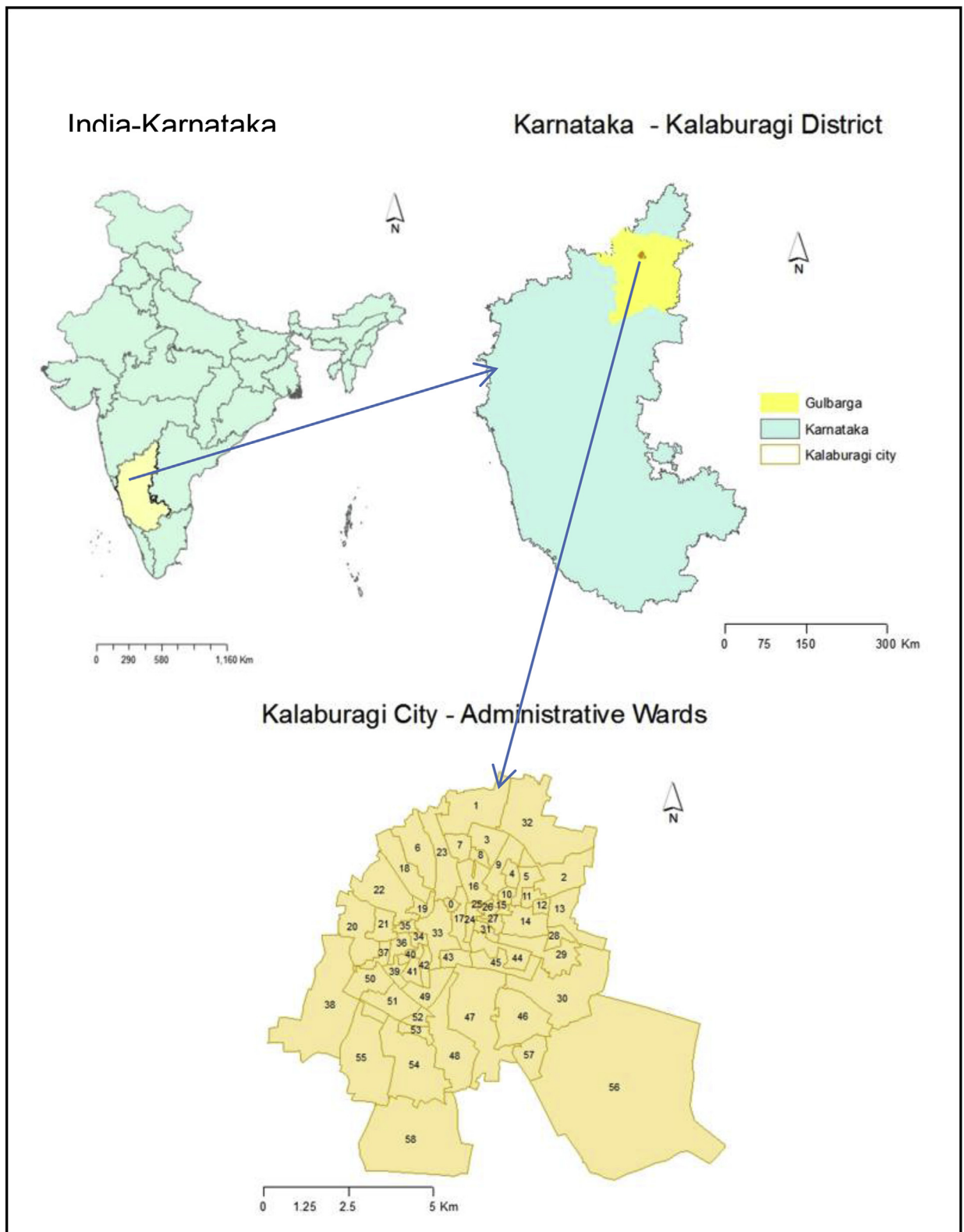


Fig. 1. Study area.

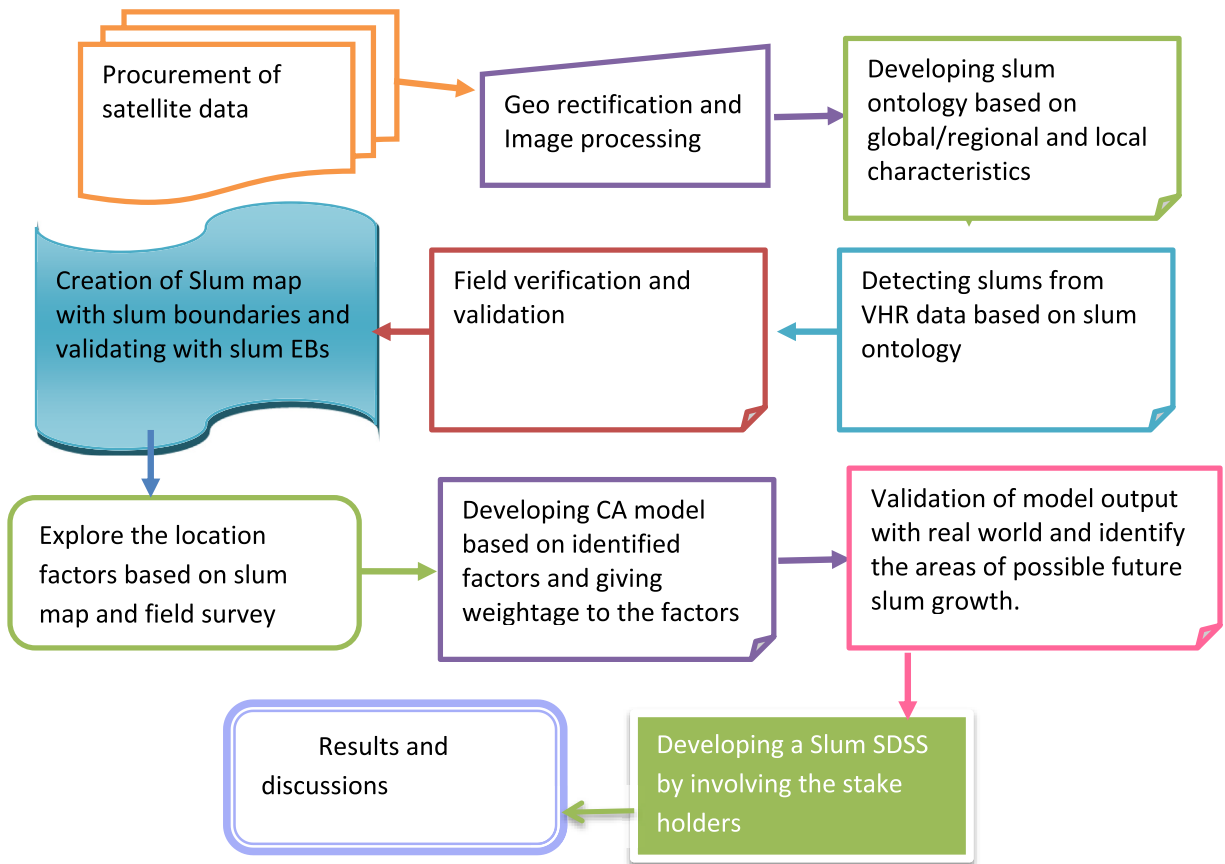


Fig. 2. Overall methodology.

slums have existed for more than 10 years in the city due to the fact that Kalaburagi has been one of the oldest continuously inhabited cities of India (Slum free city plan of action report, 2013). 47% of the slums are secured and have access to basic amenities and are in possession of certificates while 53% of slums are not, and are in need of regularization.

2.2. Database and methodology

The database used in the present study includes primary data collected through questionnaires, GPS surveys, field observations and secondary data collected from the Karnataka Slum Board, Census of India, National Sample Survey-Urban Frame survey maps. The Geo eye satellite data (2012) procured from NRSC is the base for the slum map but other satellite images, downloaded from Google Earth, were also used for updating the slum map.

There were three major steps involved in this study. The first step included ontology-based slum detection from very high resolution (VHR) data, the second step used cellular automata coupled with Multi-criteria evaluation techniques to model the slums and the third step was to build a Slum Spatial Decision Support System (Slum SDSS). The combined methodology is shown in the flow chart (Fig. 2).

2.2.1. Methodology for slum mapping based on ontology

Describing slums involves social economic and geographical components. One way to elucidate the amount of information needed is to create a knowledge model called an ontology (Agarwal, 2005; Gruber, 1993) that allows us to organize an extended database, relating all the above components. After analysing existing approaches, and knowing that urban planning is an extensive domain with several sectors, only the slum domain was selected with the main objective being to build a “slum ontology” in order to identify slums from high-resolution satellite data. In this study (with few alterations), the enterprise ontology developed by Uschold and King (1995); Uschold and Grüninger (1996), as stated in Fernández López and Gómez-Pérez (2002) and the specification, conceptualization & implementation process methodology developed by Fernández López and Gómez-Pérez (2002), along with a generic slum ontology developed by Kohli et al. (2011; 2012) were used to build our slum ontology.

Once one has an idea of what one wants to cover one can list some of the important terms needed. These can include basic concepts, properties they might have, or relationships between them. This knowledge can originate from domain experts, text mining and database metadata for example. The knowledge extracted has to be structured. Textual definitions have to be defined by referring

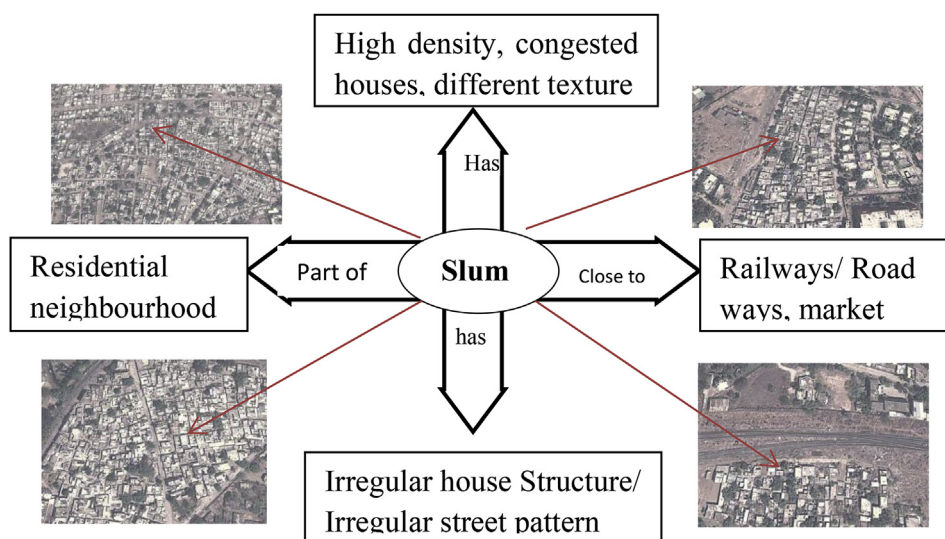


Fig. 3. Identifiable Slum characteristics from High resolution data.

to other terms and including notions such as class and relation for example.

In this case, the knowledge of fifty domain experts from India has been used to build our slum ontology along with excerpts from recent publications on ontology. This is known as ontology capture (Falquet, Métal, Teller, & Tweed, 2011). For a basic understanding of the concepts concerning slums, among various alternatives, the questionnaire method was used. The domain experts were asked to identify the slums from very high-resolution data (Table 3) pertaining to Kalaburagi city (Fig. 3).

Having understood these basic features of a slum from the experts' survey and other published sources, the next steps were -

1. **Conceptualization:** Conceptualization structures the domain knowledge as meaningful models at the knowledge level. The slum characteristics which can be identified from high-resolution data were defined in order to delineate slums from non-slums. The experts' views were summed up and grouped under various headings and the same were verified with data from major cities. Some of the slums were visited and field observations were compared with experts' opinions (Table 2).
2. **Formalization:** This is the transformation of the conceptual model into a formal or semi-computable model. It is also expressed as "Coding" which involves explicitly representing the acquired knowledge in a formal language, which will help in the detection of slums, in high-resolution data. The next step was to identify the variables which can distinguish between slum and non-slum areas in high-resolution satellite data.
3. **Implementation:** This is the building of computable models in a computational language. It also includes basic preparations and integration of existing ontologies.
4. **Evaluation and documentation:** This is similar to the maintenance of methodology (after Fernández López, 1999) which updates and corrects the ontology. The developed ontology was evaluated by interpreting high-resolution data of different cities in general and GeoEye data for Kalaburagi city in particular. Also, using the GPS survey and with the help of field photographs, the physical and socio-economic conditions were documented.

Table 2

Slum Characteristics to build ontology.

SLUM CHARACTERISTICS		
Indicators	From Experts Questionnaire survey	On Field survey
Building Characteristics	Variable size, Often lacks high-rise structure, Varies in brightness value in comparison to non-slums	Very small to moderate size Roofs: slates/stones, concrete, tin sheets Single story structure Dilapidated condition Lack of sanitation and hygiene
Building density	High density Often lacks vegetation and shadows	Crowded together with very narrow lanes
Layout	Irregular, haphazard street pattern	No layout, Kachcha internal roads
Location information	Close to railway line, canals, river, nallah, major roads, Airport boundary, coastal line	Along the railway line, Major roads and nallah, outskirts of airport area, coastal area
Neighbourhood characteristics	In between big apartments/high-rise structure Close to Market area, Bus stand	Close to high and middle income class residential area Adjacent to informal employment opportunities

Table 3
Detecting Slums from Very High Resolution data.

DETECTING SLUMS FROM VERY HIGH RESOLUTION DATA		
Indicators from Conceptual model	IMAGE INTERPRETATION ELEMENTS	
	For real stakeholders (visual interpretation)	For geospatial technology experts (Image analysis software)
Building Characteristics	Shape and size of the image objects	Shape and size of building foot prints (after segmentation in OOA) Brightness value, Spectral Mean, Standard deviation value of various bands. Texture measures of various bands (GLCM values)
Building density	High density of image objects	High density – Patch density, area, Compact measurement, lacunarity (spatial metrics and spatial statistics values)
Layout	Irregular Less vegetation Small/Nil shadows	Geometry, Shape index, symmetry Green index, NDVI, customized index
Location information	Association Close to railway lines, Major roads, river, nallah, coast	Shadow measurement- in relation with the image objects Creating buffers
Neighbourhood characteristics	Close to Bus stands, Market areas, high residential areas, labour intensive Industrial areas	Distance to other image objects, Relation with image objects

Table 4
Ontology based factors with their scores.

SELECTED FACTORS	SUITABILITY (to attract slum)SCORES		
	MOST - 3	MODERATE - 2	LEAST - 1
Distance from Lake	Less than1000m	1000–3000m	Above 3000m
Distance from Road	Less than1000m	1000–3000m	Above 3000m
Distance from Rly Line	Less than1000m	1000–3000m	Above 3000m
Distance from Nodal points	Less than1000m	1000–3000m	Above 3000m

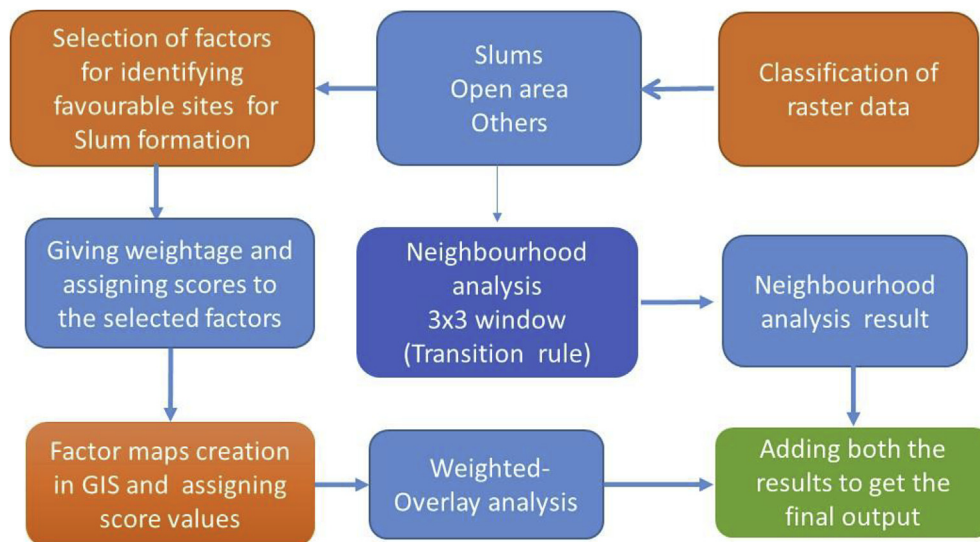


Fig. 4. Development of CA model.

2.2.2. Modelling slum development by using cellular automata

Cellular automata (CA) comprises five elements - cell space, cell state, time step, transition rule, and neighbourhood. In CA, the state of the cell itself and the states of its neighbouring cells at a previous time step determine the state of a cell in the future. If a cell has a strong propensity for development and it can get support for such development from its neighbourhood, then development will occur to that cell. However, not all the cells in the urban system develop at the same time or at the same speed. There are various conditions under which the change (transition) from one state to another state can take place. These conditions can be either physical, socio-economic, or institutional or any combination of these (Liu & Phinn, 2001). For instance, if a cell has a propensity for

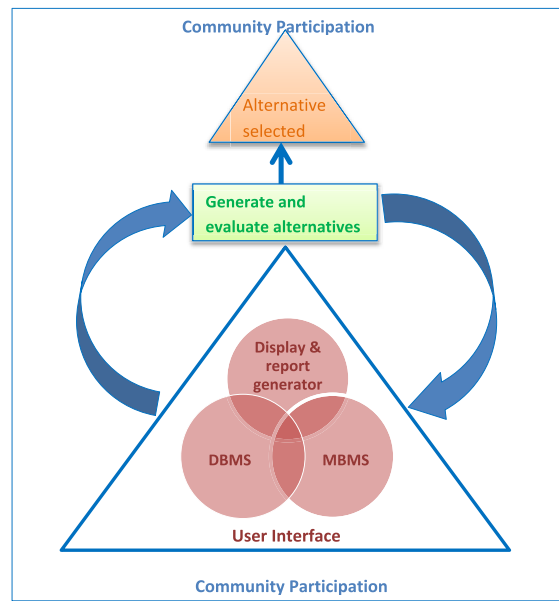


Fig. 5. SDSS for Slum development.

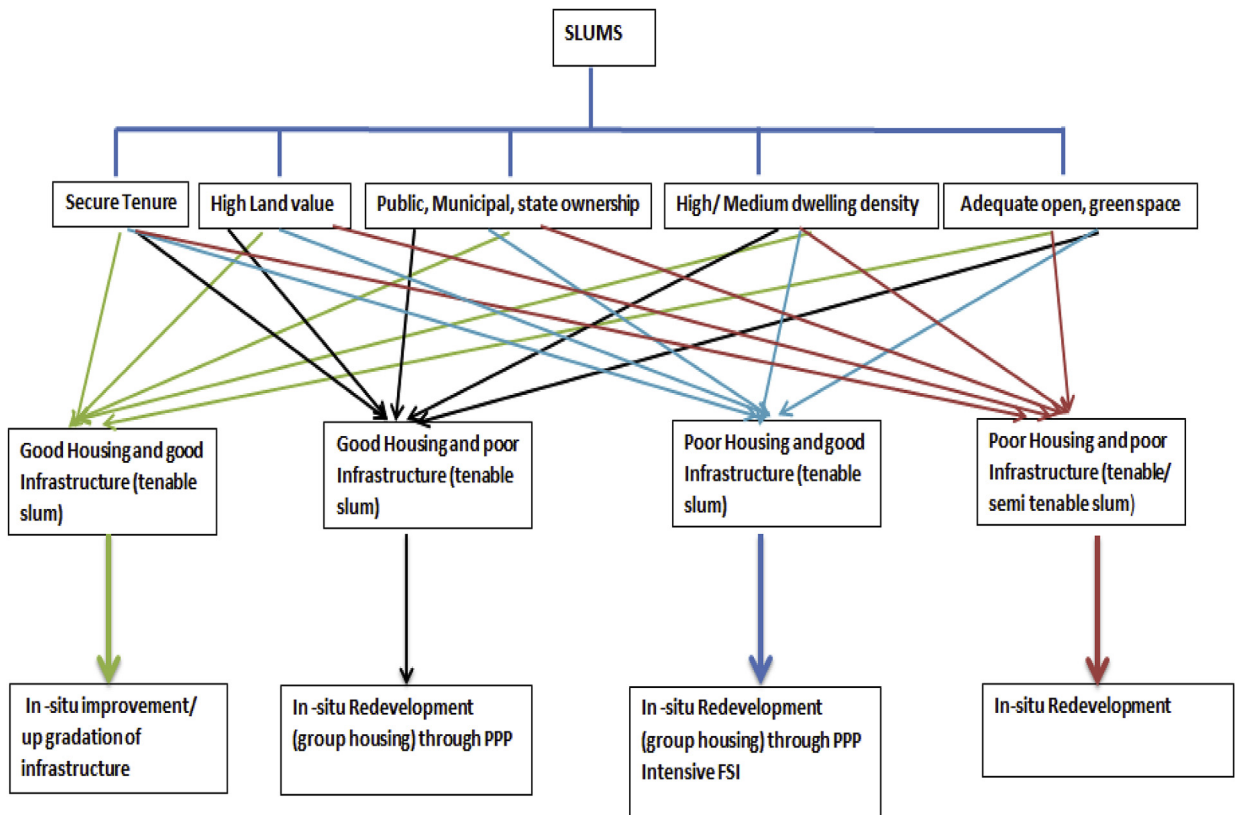


Fig. 6a. Slums for improvement, up-gradation and redevelopment (secure-slums).

development but it cannot get sufficient support from its neighbourhood, development could be slowed down. This slow development can also occur if the cell is located in a high terrain or a steep slope area. With the support of transportation networks, development might be expedited. Cells, which are sited in water bodies, such as lakes or rivers, cannot be developed. This information can be modelled to find the suitability of a particular land parcel or cell to become the site of a slum using Multi-Criteria Evaluation (MCE).

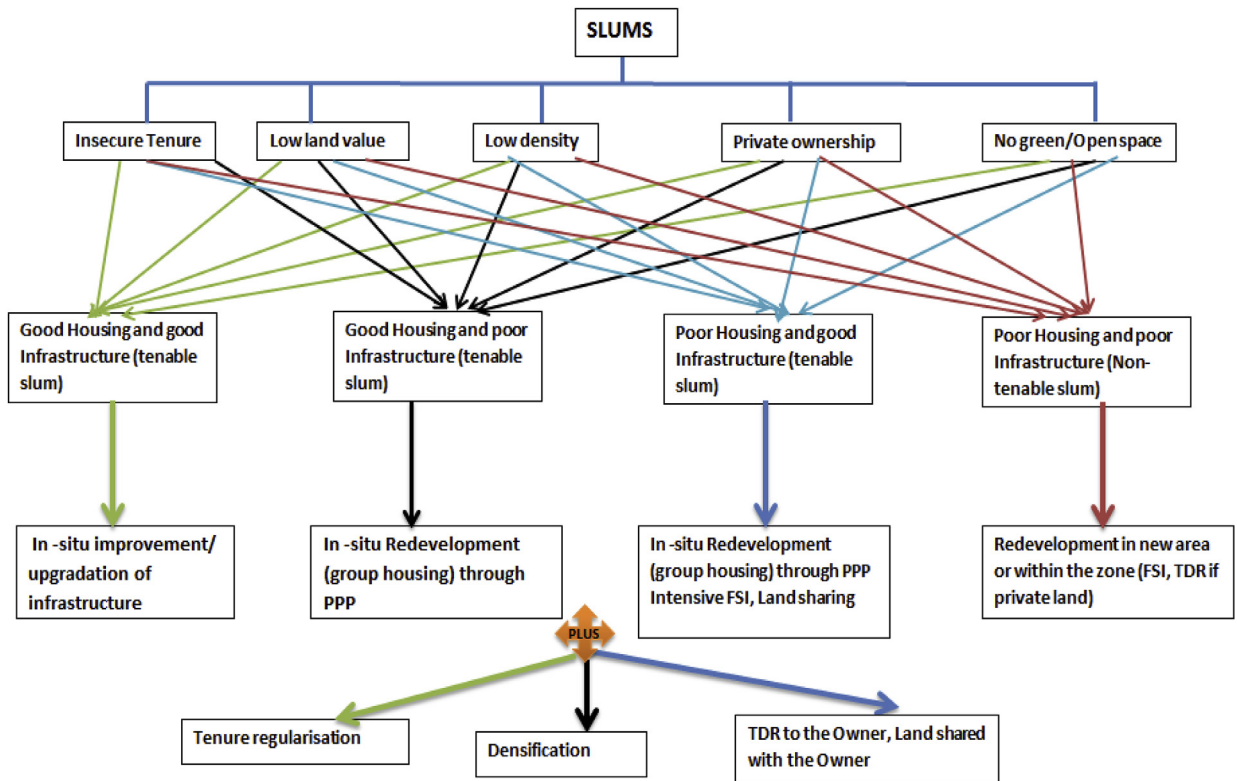


Fig. 6b. Slums for improvement, up-gradation and redevelopment (insecure-slums).

These factors or conditions were determined through a review of the pertinent literature, as well as through consultation with experts in the field. These can be divided into - factors that can be assessed by their relative suitability and factors that are either suitable or unsuitable in some absolute sense. However, in this model, factors were assessed by their relative suitability for slum growth. Cell space represents a subset of the geographical area, and the land use represents the status of a cell. The transition rules are built to address the selected factors responsible for the different growth processes of a cell. The state of the cell (S) at x, y (Location of the cell) in time ' $t+1$ ' is the function of the status of the cell at x, y in time ' t '.

$$S_{t+1xy} = f(S, t, xy)$$

In this study, the base map for the neighbourhood analysis was prepared with 2 states which were open space and slums. The conversion of one state to another state will take place only among these two in a linear direction, and the conversion of any cell is possible only from open space to slum. With the help of MCE, all the candidate cells (those available for slum development) can be given a score (Table 4) on the basis of the weighting applied to the factors. The final score should be the integration of the scores (S_c) obtained by the factors and the neighbourhood influence (N). Thus, the final score (Final score = $S_c + N$) determines the probability of the cell for slum growth. As per the transition rules, if the status of a cell is " Z " (Z = slum or Z = open space) in time t , then in time $t+1$, it will remain as " Z " only if the cell is surrounded by all " Z " cells in its neighbourhood. The second rule is that if the status of a cell is open in time t , then in time $t+1$, it will change into Slum if the cell is surrounded (Majority) by Slum cells in its neighbourhood. These rules will be applied using a 3x3 matrix and Moore's neighbourhood with "Majority" option, and the output is a neighbourhood map (N). The conceptual model (Fig. 4) was built using a model builder in ArcGIS.

2.2.3. Methodology for slum SDSS

Conceptually, an SDSS can be thought of as an integrated set of flexible capabilities: the implementation of such a system can be achieved using a set of linked software modules (Armstrong, Densham and Rushton 1986; Armstrong, Densham, Lolonis, Rushton and Tewari, 1990). The number and exact description of components mentioned in the SDSS literature vary from - three components as stated by Lolonis (1990) and Malczewski (1999); four components as designed by Densham and Goodchild (1989); to five as stated by Armstrong and Densham (1990). In this paper, slum SDSS was designed based on the Armstrong, Densham, and Rushton (1986) architecture.

The SDSS for slum development has been designed (Fig. 5) by taking into account the recent developments in information and communication technology, computer hardware and software and the general usage of high-end gadgets. Hence this design has some alterations to the basic model of Armstrong et al. (1986).

Once the conceptual design was developed, it was transferred into an actual Spatial Decision Support System using ArcGIS and

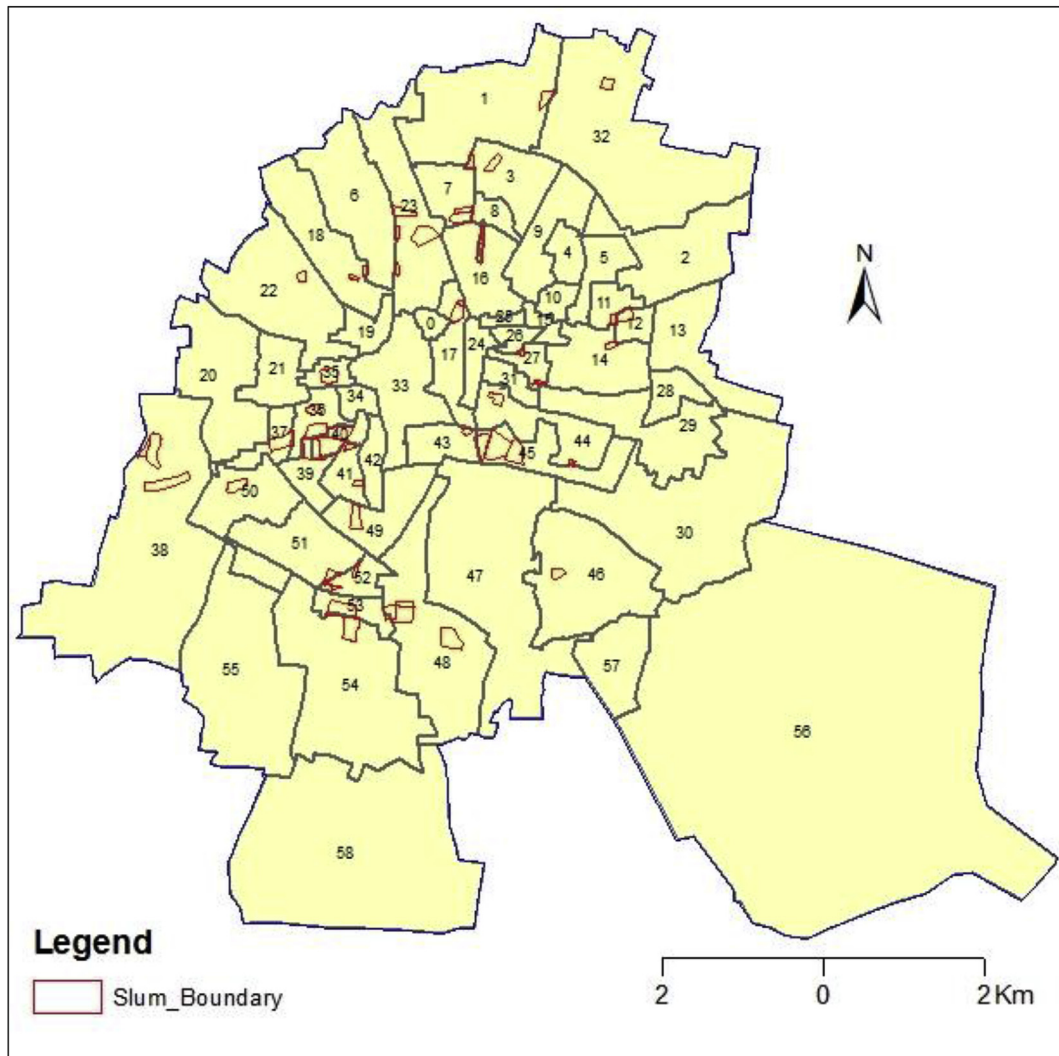


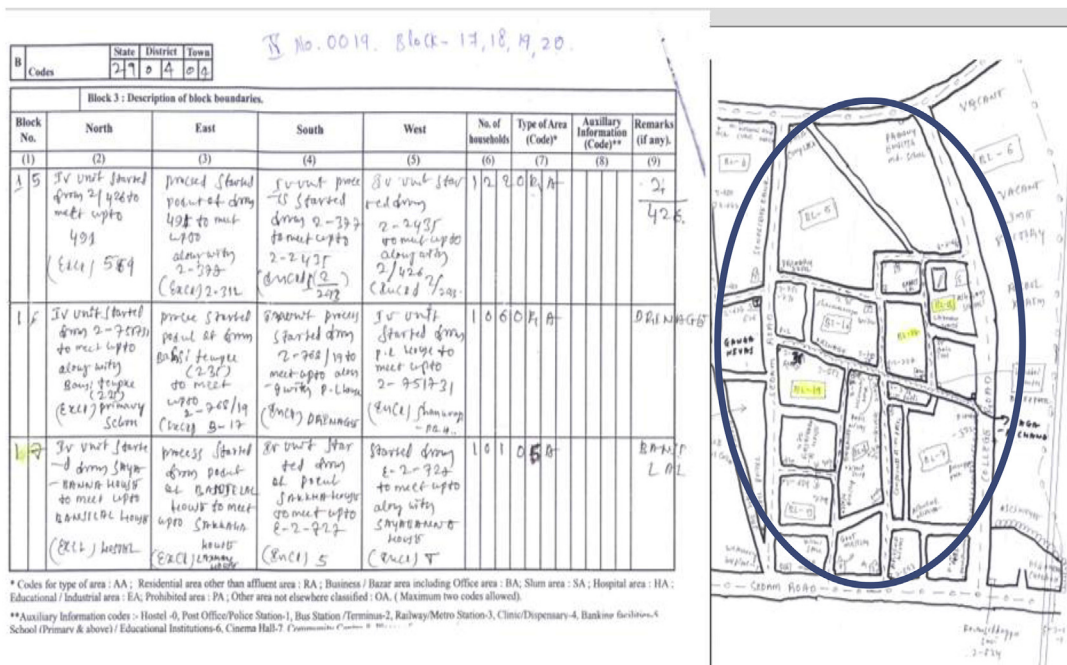
Fig. 7. Slum Map of Kalaburagi city.

CommunityViz software. CommunityViz planning software is an extension for ArcGIS Desktop. A GIS-based decision-support tool, CommunityViz “shows” the implications of different plans and choices to the decision-makers. Hence it was used in scenario planning, sketch planning, 3-D visualization, and suitability analysis (placeways.com).

2.2.3.1. Database management system (DBMS). The database for slum development has been stored in a File Geodatabase. It contains slum information in the form of point, line and polygon features. The geo-referenced GeoEye satellite data provided other necessary spatial information both at slum and city level.

2.2.3.2. Model base management system (MBMS). There were five major indicators used to identify the suitability of a particular slum for improvement, upgrading or relocation. These indicators were slum density (Total population of a slum divided by the total area of the slum); land ownership and tenure (Government or Private, Secured or non-secured); existing infrastructure (Availability of safe drinking water, Toilet facility, Sewage/Drainage facility, Electricity, Road, Public space/Community space); housing condition (Durability of the house structure, Number of households in good condition) and accessibility (Closeness to amenities such as Schools, Health Centres, Working place, Bus stand, Market area).

2.2.3.4. Graphical display and report generation. Based on the database created with the help of slum dwellers (Community participation), accessibility to facilities and suitability for slum redevelopment was checked through various analyses. With their input, alternative scenarios were generated for evaluation. The decision made would take into consideration the concern of all stakeholders by evaluating alternative scenarios. Demonstrating the scenarios in 3D by using Arc Map and Community VIZ would certainly help the stakeholders to decide the most suitable scenario for slum development.



Source: Urban Frame Survey maps

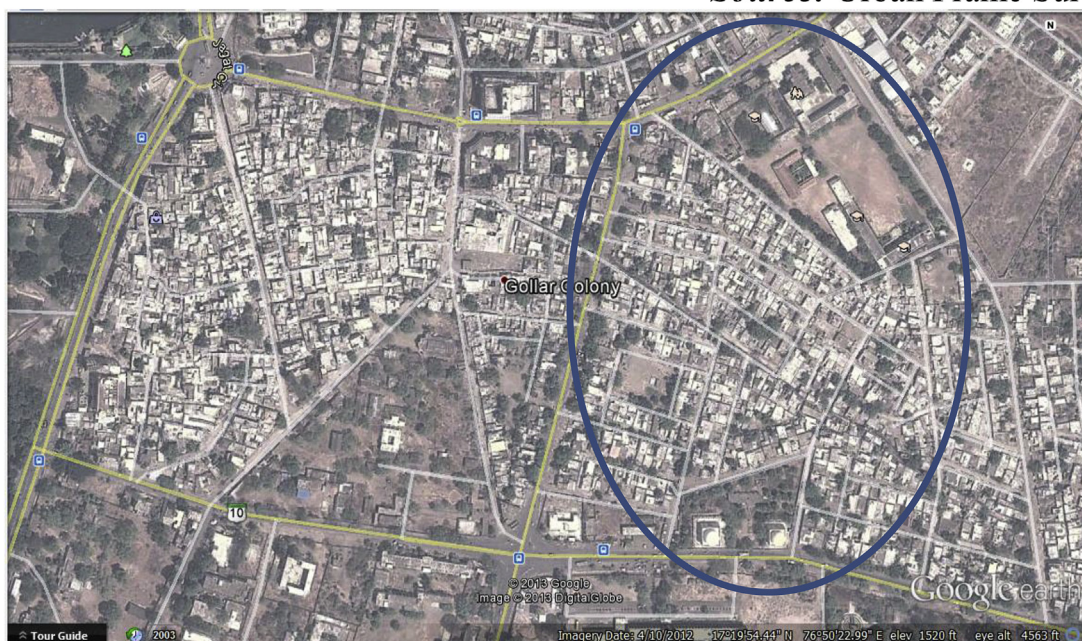


Fig. 8. Validation of slum with UFS and Google earth

Source: Urban Frame Survey maps.

In order to understand the efficiency of Slum SDSS, a slum area (Borabai Nagar) was chosen as a case study. After deciding the slum development method (Fig. 6a and b), in this case, in-situ development, the next step was selecting the housing structure with the consent of slum dwellers. The slum details such as availability of open space, number of households needing upgrading/improvement/complete renovation/reconstruction in a new site were decided with the help of all stakeholders (Slum board, Municipal body, Corporator, NGOs, slum dweller association, residents).

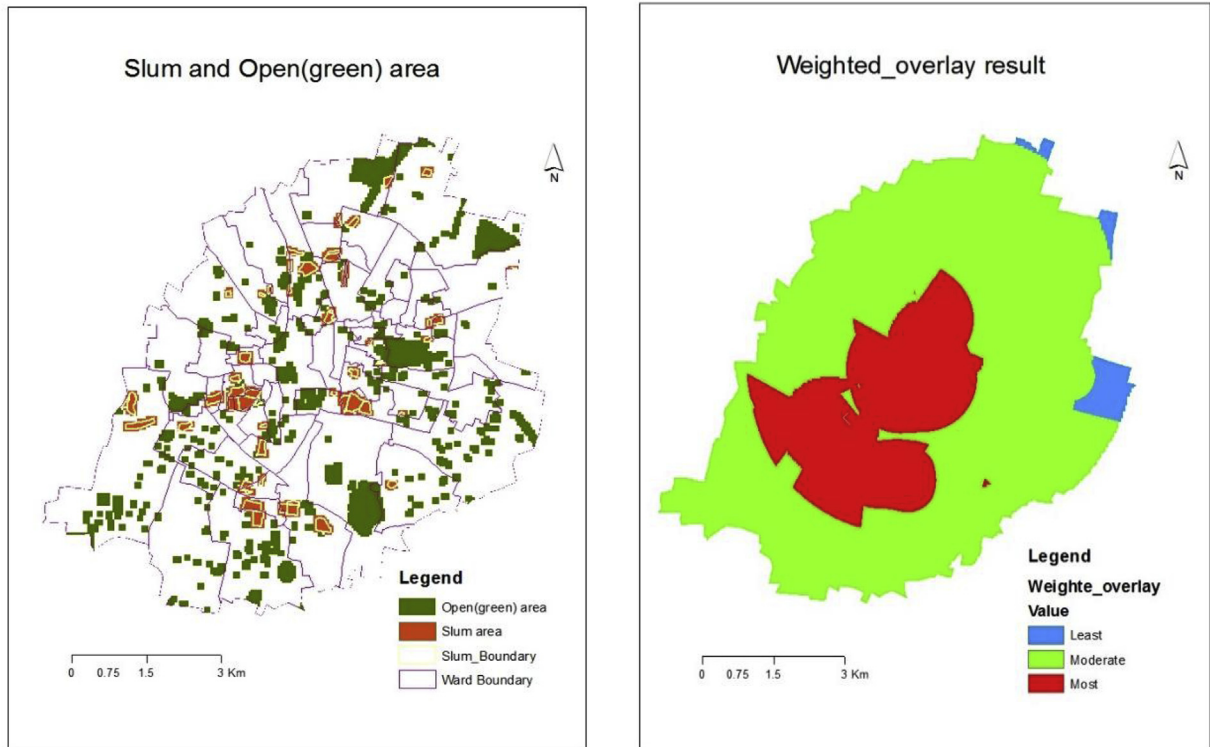


Fig. 9. Result of Neighbourhood analysis and weighted overlay.

3. Results

3.1. Slum map preparation and validation

It has been proven that a knowledge-based approach is effective in the identification of slums, particularly for non-geospatial experts i.e., the actual stakeholders who will be using this spatial information for slum improvement and renewal programs. The government of India's efforts to create a slum-free India needs community participation at all levels in slum development programs. Does the slum dweller actually know where he/she is living? And by identifying how far away they are from necessary infrastructure facilities, they will be able to make better decisions for improving the current situation on their own. Hence the knowledge-based approach is used here as the basis for spatial decision support and successful implementation of planning programs.

Based on the slum ontology, the slums were identified (both visual and object-based analysis) and the slum map was prepared (Fig. 7). The same was validated (Fig. 8) with the UFS (Urban Frame survey) map. The UFS maps were purchased from the National Sample Survey, Hubli. These maps were used by the enumerators at the time of collection of census data, and are of actual Enumeration Blocks.

14 UFS maps were purchased from NSSO and they were compared with Google Earth maps. Slum enumeration block maps were prepared based on field observation. This included not only notified and non-notified slums but also identified slums based on the census definition. Hence validating with the enumeration block map is important in order to assess the reliability of the map prepared by this project. The following snapshots (Fig. 8) show the matching of UFS maps with Google Earth display for initial understanding and later the same was compared with our slum map.

3.2. Modelling slum development

The classified GeoEye image with open areas (excluding agricultural land with crops and hill slopes) and slums was used as an input for the CA model. The other base layers used in the analysis were multi-criteria maps such as proximity maps to roads, to water bodies, to railway lines and to nodal points. The suitability map was created by giving appropriate weights to these factors (Table 4). The final map was prepared in the ArcGIS environment by adding a suitability map with a neighbourhood map.

As slum growth can speed up or slow down due to factors that include proximity to transportation networks and human decision-making behaviour, using linguistic variables such as “the Most”, “Moderate” and “the Least” can give us different scenarios of slum growth. Therefore, the locations which are favourable for the occurrence of slums are classified as “most attractive”, “moderately attractive” and “least attractive” zones for slum development (Fig. 9).

When the slum map was overlaid on the model output, (Fig. 10), it was shown that in Kalaburagi city, 97% (1.5 km²) of slum areas

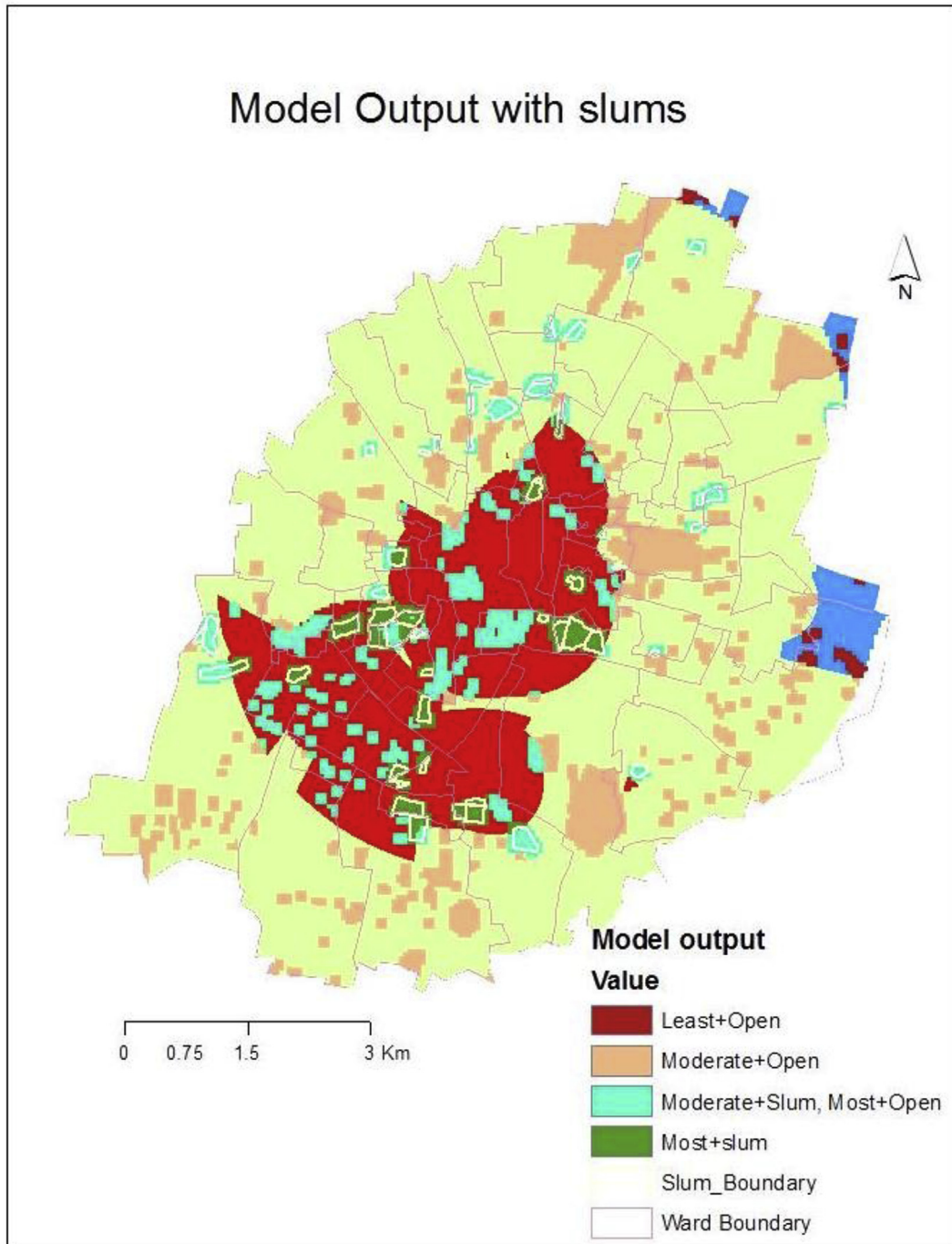


Fig. 10. Result of CA model.

are present in the most attractive zone for slum development whilst the remaining 3% of slum areas are located in the moderately attractive zone for slum development.

In Kalaburagi, slum expansion is due to the poverty of the rural migrants entering the city and arises mostly on un-used, un-protected and un-suitable government land, along roads, railway lines and near the lake. It has been observed that a large number of slums exist in the central part of the city (within the *most* attractive zone category), but there is a strong possibility of further slum expansion in moderately attractive zones along linear features such as roads and railway lines in peripheral areas of the city. This is because more than 8.7 km² of open land, such as agricultural land without crops and barren land, is present in the moderately attractive zone and only 1.5 km² of open land is present in the most attractive areas for slum growth. Moreover, since the latter areas

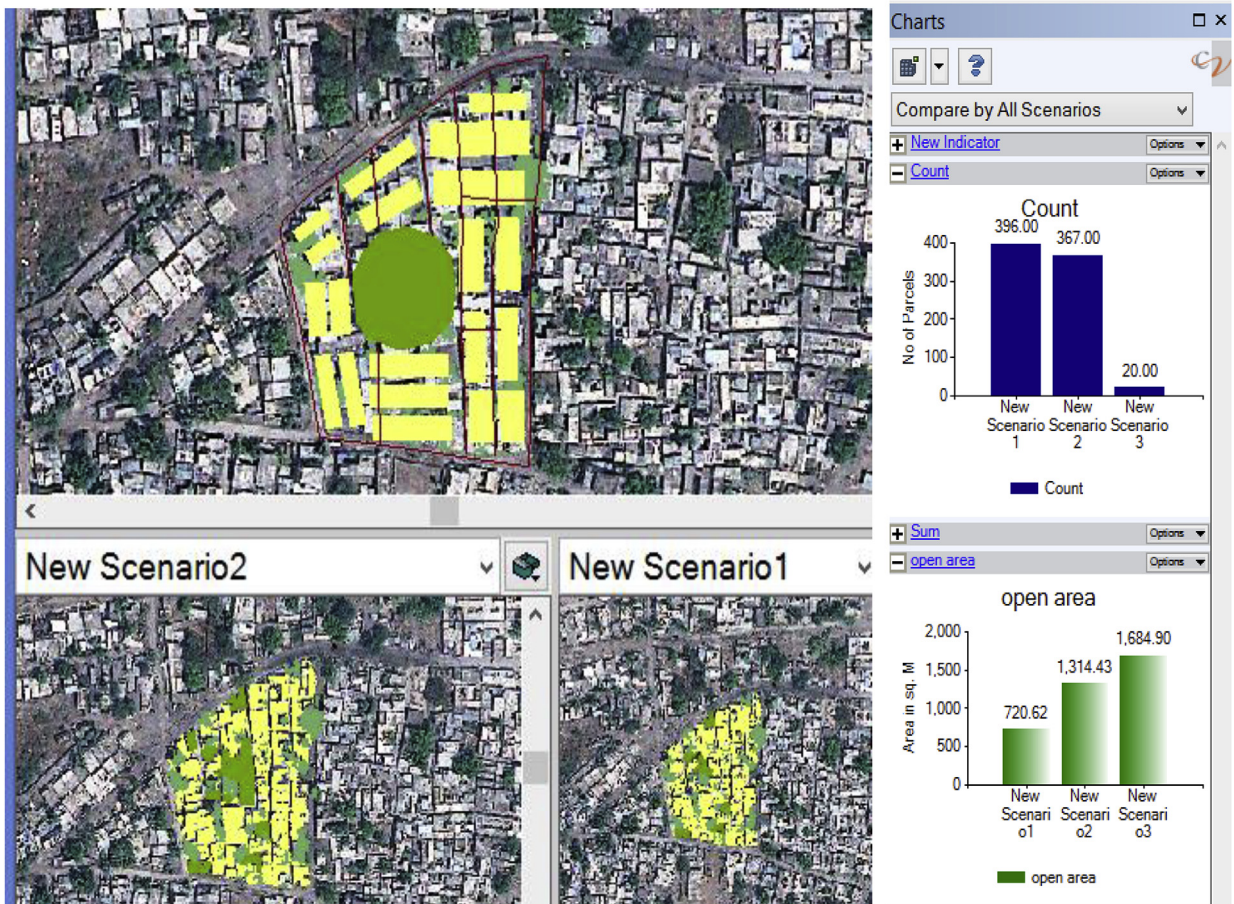


Fig. 11. Scenarios in CommunityViz.

are under planned green cover, moderately attractive areas will attract more slum growth than those open areas present in the most attractive category.

3.3. Slum SDSS

Once the slum development method (slum improvement/upgradation, slum redevelopment and in-situ development) had been decided based on the ownership of land, housing structure, population density, availability of open space and land value, then accessibility to facilities such as schools and hospitals and distance to transportation facilities was examined through various analyses. In the present case, in-situ development was recommended based on the open area available, land value, ownership, the density of the slum population and accessibility to basic facilities.

Housing structure (such as whether single floor or double-storey structures were needed) was decided in line with residents' needs. The structure of housing layout and house structure for a particular slum can be created in Arc MAP with the help of Community Viz. They are created for different scenarios and a 3D model displayed to help with visual understanding (Fig. 11). This will help residents to better understand the advantages (and disadvantages) of each development scenario and to decide the best development for them. The following figure shows three possible scenarios generated (just for the purpose of the study and not with the consent of slum dwellers) for a particular slum with the help of Community Viz along with their graphical display in the form of bar charts.

This interactive display can help planners to change scenarios to better meet residents' requirements given the availability of land for green infrastructure, the availability of open areas for expansion and so forth. Further, it can be improved through the display of a 3D structure for enhanced visualization. The housing structure is shown in Fig. 12 also includes sample structures (3D format) for demonstration purpose.

4. Discussion

In India, migration has played an important role in accelerated urban growth which concomitantly attracts rural migrants to the

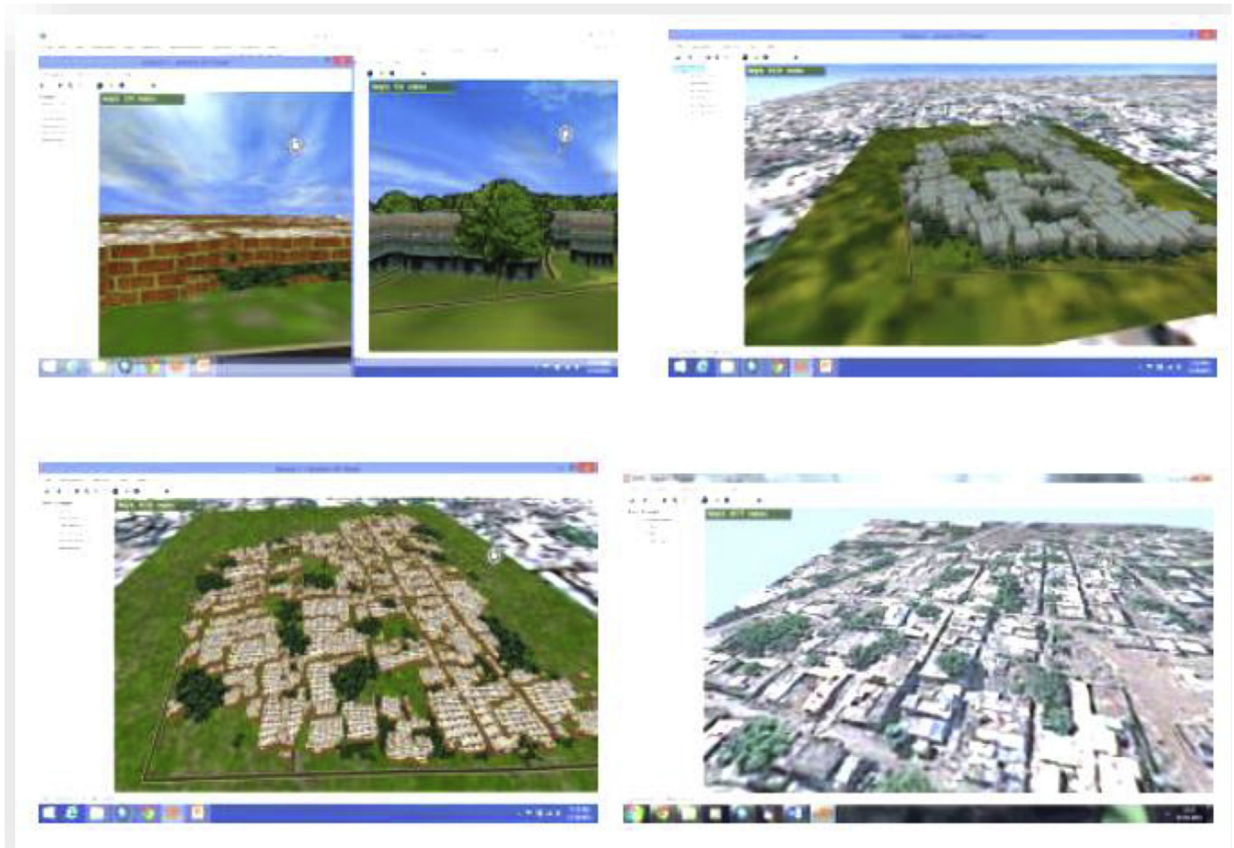


Fig. 12. 3D Scenarios with various housing structure generated in CommunityViz.

urban areas for economic reasons regardless of the fact that physical infrastructure in terms of housing, drinking water supply, drainage and sanitation for example is not adequate. Displacement of the labour force from the rural economy and their absorption in urban sectors has created serious stresses on cities and towns. The capacity of the cities and towns to assimilate the migrants by providing employment, access to land and basic amenities for example is limited. The problem has acquired severity as migrants have shown high selectivity in choosing their destinations mainly linked with the availability of employment opportunities leading to the growth of slums. The quality of life thus suffers due to the continuous influx of migrants and consequently widens the gap between the demand and supply of essential services and other infrastructure in urban areas.

The CA model was based on the physical location of slums and while it takes into account the spatial expansion of slums in certain conditions, it does not include population size or household size and these will need to be included when seeking to evaluate the future growth of a slum. The model assumes that there are certain areas that are generally attractive for the settlement of poor migrants and thus these areas have a high probability of becoming the slums of the future. These areas are linked with the availability of employment opportunities and the availability of vacant land. Once identified, these areas will be helpful for planning as well as preventing the formation of future slums.

The output of the model has not only taken into account open area (green area under proposed land use) that remains open in the current land use scenario but also areas that will remain open when implementing a proposed land use plan. Any current vacant land, which is designated for residential use under a proposed land use plan has been taken for developing a future stock of affordable housing.

The current vacant land (residential use in proposed land use) depending on its closeness to employment opportunities has been taken into consideration for affordable housing. The affordable housing should be at least within 1500m from the existing ring road. This will ensure connectivity and affordability for travel to work and other movements.

The houses should be distributed in such a way that they are accessible in all directions from the City Centre. The housing layout plan should have adequate space for further expansion and green areas (park). Schools and hospitals should be within an approachable distance from the new stock of houses.

Land values (both residential and commercial) should be taken into consideration before deciding the location of affordable housing. Fig. 13 shows the possible sites for affordable housing to prevent future slum formation and to manage the proposed land use plan towards inclusive planning. The details of possible sites for affordable housing are given in Table 5. The identified sites were earmarked for residential purpose in the proposed land use plan and there was no separate allocation of residential use for EWS.

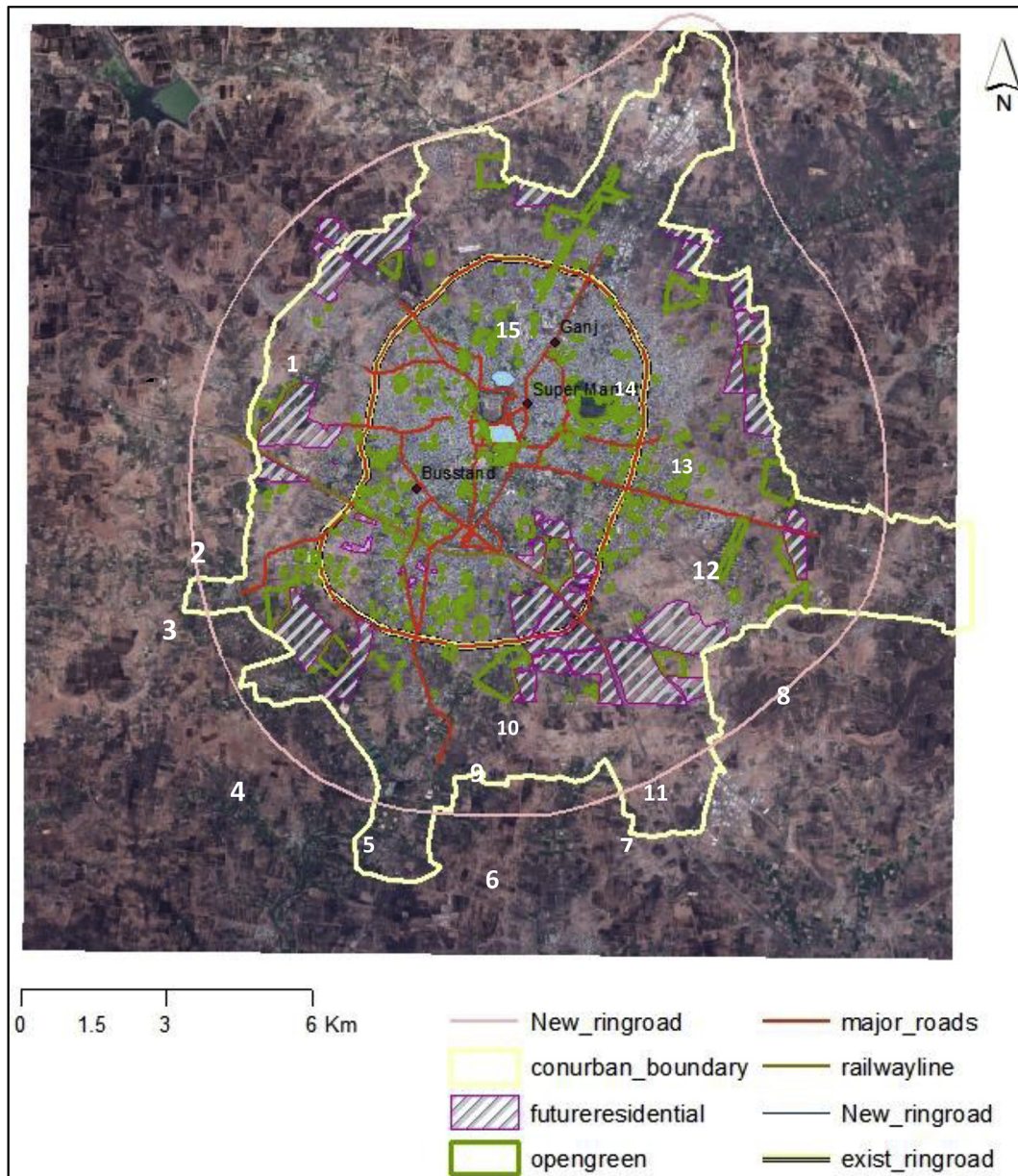


Fig. 13. Affordable sites for future Planning

The details of possible sites for affordable housing are given below.

1. Between Pallapur and Agricultural Research Centre
2. An area surrounded by Azmir colony, Heera nagar and central warehousing corporation.
3. Next to central warehousing corporation.
4. Between Mahanteswara layout and Udnoor road to Minajagi
5. Left side of Laxminarayan colony, BL Nagar, Satyam layout.
6. Left side of Police training centre and road to Khanadal
7. Right side of Police Training Centre
8. Right side of the University towards Sedam road side.
9. Area close to Dhariyapur and Krishna Nagar
10. Near Polytechnic college.
11. Close to Rajapur, Pavana Ganaga Colony, GDA layout
12. Close to Azadpur
13. Close to Arfadh colony, Aman nagar and Sonia Gandhi colony towards Kotnoor.
14. Area between Vidya Nagar and Malagatti
15. Towards the right side of Karnataka Reserve Police battalion.

Table 5
Possible sites for affordable housing.

Site ID	Location of possible sites as shown in the Fig. 13
	The area between Pallapur and Agricultural Research Centre
	The area surrounded by Azmir colony, Heera Nagar and central warehousing corporation.
	Next to central warehousing corporation.
	The area between Mahanteswara layout and Udnoor road to Minajagi
	The left side of Laxminarayan colony, BL Nagar, Satyam layout.
	The left side of the Police training centre and the road to Khanadal
	The right side of the Police Training Centre
	The right side of the University towards Sedam roadside.
	The area close to Dhariyapur and Krishna Nagar
	Near Polytechnic college.
	Close to Rajapur, Pavana Ganaga Colony, GDA layout
	Close to Azadpur
	Close to Arfadh colony, Aman Nagar and Sonia Gandhi colony towards Kotnoor.
	The area between Vidya Nagar and Malagatti
	Towards the right side of Karnataka Reserve Police Battalion

Hence, there is a chance that proposed sites for affordable housing might be used for other residential activities. It depends on the decision of ULBs.

Slum upgrading should be a process rooted in consultation, discussion and agreement with slum residents with regard to design, implementation schedules and the division of responsibilities between government agencies, residents and their community organizations, and chosen consultants and agreed contractors. This might seem time-consuming to a government structure that focuses too much on quantitative outputs, but it is likely to reduce or remove community hostility and make implementation easier and quicker.

The new mission of GOI, Prime Minister Awas Yojana (PMAY) may (can) be successfully implemented if they apply a participatory approach and, involve all the stakeholders. This research shows this very clearly.

Based on personal experiences and grounded in reality, this article provides a sincere attempt to solve the major problems of the stakeholders involved in slum development. These stakeholders vary from geospatial experts at GIS cells of national, state or municipal corporation level to the poor slum dwellers themselves. The knowledge model, incorporating slum ontology, basically helps in the understanding of domain concepts and facilitates communication between stakeholders. We think that this is why this approach will give good results. By refining the ontology further and also offering additional training to the local community, even better results can be obtained. This will really help in the better implementation of slum development programs, and thus the benefits of science will reach the common man, in improving their standard of living.

The slum map prepared also has information with respect to their location, area, population and so forth. Any further information required can also be added to the spatial database. This will be very useful for the urban local body in many aspects. The affordable housing stock was planned in such a way that, the proposed areas have proper access to all facilities and are close to formal residential areas and have appropriate land value. Thus it aimed for inclusive city planning.

5. Conclusion

This study is the first of its kind in many ways. This is the first time that a slum ontology was developed to identify slums from very high-resolution data acquired from the stakeholders with the help of input by experts and using published sources. This was tested with slum dwellers, slum development board officials and domain experts. The slum boundaries were created using a participatory approach (involving the slum community to map their own boundary with a GPS survey). The following paragraphs sum up all three tasks - mapping, modelling and managing the slums of Kalaburagi in brief.

The slum map was prepared and even validated with the help of urban frame survey map (UFS), procured from NSSO. UFS maps are the only source of information about slums at the city level. It has even taken into consideration small enumeration blocks with 20–25 houses which have slum characteristics.

The output of the CA model has given reliable results regarding the current slum distribution. The model also gave a hint for the possible occurrence of slums in future. It suggests that the open areas which are present in the moderately attractive zone will be the zone of future slum occurrence.

The building of the slum SDSS can improve the implementation of slum development programs such as PMAY. The design and running of the SDSS model were demonstrated with one case study which will be very useful for the proper management of resources in a sustainable way.

Thus the research work is successful as it is relevant to society and capable of being applied to solve societal problems.

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Useful Web Sources:

- http://mhupa.gov.in/W_new/Slum_Report_NBO.pdf.
- <http://pib.nic.in/newsite/pmreleases.aspx?mincode=63>.
- <http://mhupa.gov.in/ministry/housing/pdf>.
- <http://mhupa.gov.in/ray/DPRpreparationmodule.pdf>.
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- <http://timesofindia.indiatimes.com/india/17-of-urban-India-lives-in-slums-Census/articleshow/19118219.cms>.
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