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SMART CITIES CHALLENGES
SMART ENVIRONMENT FOR SUSTAINABLE RESOURCE MANAGEMENT

SMART CITIES CHALLENGES: SMART ENVIRONMENT FOR SUSTAINABLE RESOURCE MANAGEMENT 1 (2014)

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1 INTRODUCTION

Cities origin can be traced back to the river valley civilizations of Mesopotamia, Egypt, Indus Valley and China. Initially these settlements were largely dependent upon agriculture, however with the growth of population the city size increased and the economic activity transformed to trading. The process of urbanisation gained impetus with industrial revolution 200 years ago and accelerated with globalization in 1990's.

Urbanisation refers to the growth of the towns and cities due to large proportion of the population living in urban areas and its suburbs at the expense of its rural areas. In most of the countries the total population living in the urban regions has extensively accelerated since the Second World War. Current global population is 7,057,075,000 billion (Population Reference Bureau, 2005; United Nations, 2011). The rapid urbanization of the world's population over the 20th century is evident (Revision of the UN World Urbanization Prospects report, 2005) from the dramatic increase in global urban population from 13% (220 million, in 1900), to 29% (732 million, in 1950), to 49% (3.2 billion, in 2005) and is expected to increase to 60% (4.9 billion) by 2030 (Ramachandra and Kumar, 2008; Ramachandra et. al., 2012) and 9.6 billion in 2050 (United Nations, 2011). Urban population has been increasing three times faster than the rural population, mainly due to migration in most parts of the world (Girardet 1996; Massey et. al., 1999).

People migrate to urban areas with the hope of a better living, considering relatively better infrastructural facilities (education, recreation, health centres, banking, transport and communication), and higher per capita income. However, rapid unplanned urbanization has led to serious problems in urban areas due to higher pollution (air, water, noise) inequitable distribution of natural traffic congestion, development of shanty towns and slums, unemployment, increased reliance on fossil fuels, and uncontrolled outgrowth or sprawl in the periphery

The direct implication of such urbanisation is the change in land use and land cover of the region. Urban ecosystems are the consequence of the intrinsic nature of humans as social beings to live together (Sudhira, et al., 2003). The process of urbanisation contributed by infrastructure initiatives and consequent population growth and migration results in the growth of villages into towns, towns into cities and cities into metros. However, in such a phenomenon for ecologically feasible development, planning requires an understanding of the growth dynamics. Nevertheless, in most cases there are lot of inadequacies to ascertain the nature of uncontrolled progression of urban sprawls.

Urban sprawl refers to the dispersed development along highways or surrounding the city and in rural countryside with implications such as loss of agricultural land, open space and ecologically sensitive habitats. Sprawl is thus a pattern and pace of land use in which the rate of land consumed for urban purposes exceeds the rate of population growth resulting in an inefficient and consumptive use of land and its associated resources. This phenomenon is characterized by an unplanned and uneven pattern of growth, driven by multitude of processes evident from lack of basic amenities. Urban sprawl is thus a term often used variously to mean the gluttonous use of land, uninterrupted monotonous development, leapfrog discontinuous development and inefficient use of land that are influenced by a myriad of factors, including land features, infrastructure, policies, and individual characteristics. This is characterised by low levels of some combination of eight distinct dimensions such as density, continuity, concentration, clustering, centrality, nuclearity, mixed uses and proximity (Sudhira, et al., 2004; Ramachandra, et al., 2012a).

Process of urbanisation bring the development of a region (Verzosa and Gonzalez, 2010), which could be planned (in the form of townships) or unplanned (organic). Unplanned urbanization leads to the haphazard or irregular growth with the loss of green spaces and water bodies. Dispersed urban growth without proper infrastructure and basic amenities is often referred as sprawl (Yeh and Li, 2001; Sudhira et al., 2004; Verzosa and Gonzalez, 2010, Bharath H A et al., 2012, Bharath S et al., 2012) and this phenomenon is widespread in developing countries (Bhatta et al., 2010a; 2010b). Implications of sprawl are excess demand

on natural resources, improper allocation of basic amenities and infrastructure, (Ramachandra et al., 2012b), deteriorating water quality, an increased potential for harboring disease vectors, etc. Large scale land use and land cover (LULC) changes, such as the loss of forests to meet the urban demands of fuel and land (Ramachandra and Kumar, 2009) has led to the changes in the ecosystem structure, impacting its functioning and thereby threatening sustainable development (Yeh and Li, 1999; Ji et al., 2001; Chen et al., 2005; Xiao et al., 2006; Liu et al., 2007; Ramachandra et al., 2013).

Urban expansion is one of the most direct forms of land use change, and refers specifically to changes in land use patterns and urban space distribution resulting from the social and economic pressures (Pathan et al. 1989, 1991; Gillies et al., 2003; Alphan et al., 2009; Bhatta 2009; Ramachandra and Bharath, 2012a). Land cover changes involving the disappearance of ecologically vital natural systems is the major concern in developing countries (Taubenbock, 2009; Ramachandra et al., 2012a). This has necessitated the understanding of spatial patterns of urbanisation and quantification of changes. Several earlier studies have addressed issues relating to urbanisation in relation to energy, land use and climate (Roth et. al., 1989; Grimm et. al, 2000; Voogt and Oke, 2003; Bharath H. A et al., 2012, Vinay et al., 2012).

Analysis of the urbanisation process and provision of appropriate management strategies requires monitoring of the spatial extent of urbanisation with the location (Kong et. al., 2012). Availability of temporal data through space borne sensors with geographic information system (GIS) has aided in the understanding of spatial patterns and visualization of urbanization with environmental implications (Clapman, 2003; Sutton, 2003; Gillies et al., 2003; Martinuzzi et. al., 2007; Yang et al., 2003; Lopez et al., 2001; Ramachandra et al., 2012b). Remote sensing data provides a birds-eye view of urban land-use changes at regular intervals. Geographic information system (GIS) enables spatial analysis of temporal data, which aid in understanding land use dynamics. Land use (LU) indicates the socio-economic use of land (for example, agriculture, forestry, recreation or residential use), which implies the purpose for which land is employed (Codjoe, 2004) or activities humans undertake inducing a change or maintain it (Di Gregorio and Jansen, 1997; Jansen and Di Gregorio, 1998; Codjoe, 2004).

The spatial patterns elucidate the heterogeneity and complexity of the urban patches in the landscape (Uuemaa et al., 2009) that can be measured using spatial metrics that help in quantifying and monitoring the urban growth (Sudhira et al., 2003; Ramachandra and Bharath., 2012b; Ramachandra et al., 2012a). Landscape structure is a prime factor in analysing the pattern and effects the various natural processes (Molles, 2006), which is determined by size, shape, composition of land use patches within the landscape. The analysis of structure of the landscape is essential to understand the implications of land use changes. In this regard, spatial metrics with a robust mathematical framework help to understand and quantify the spatial patterns of urbanisation (Gustafson, 1998; Sudhira et al., 2004; Herold et al., 2003; Uuemaa et al., 2009; Bharath H.A et al., 2012). Spatial metrics can be computed using Fragstats and Patch Analyst. Fragstats is designed to compute a wide variety of spatial metrics to understand landscape dynamics (McGarigal and Marks, 1995). India has been experiencing urbanisation subsequent to globalisation and opening Indian markets during 1990's. Pune city is the eighth populated Indian city with higher economic growth, industrial development and IT sectors has been experiencing rampant land use changes. However, unplanned urbanisation in most cities in India including Pune has enhanced the environmental concerns in recent years (Bhaskar, 2012). Pune city with sprawl is facing lack of infrastructure and basic amenities such as sanitation, housing, improper drainages, transportation, etc. (Desai et al., 2009). This has necessitated the analysis of spatio temporal patterns of urbanisation for implementing appropriate policy measures to mitigate environmental consequences. The focus of the current paper is to understand the spatial patterns of urbanisation through (i) the analysis of land use dynamics, (ii) investigation of sprawl through Shannon's entropy and (iii) patterns of urbanisation through spatial metrics using gradient and zonal approach.

Fig.6 Urban growth pattern

Fig. 7 Shannon entropy index calculated

Number of Urban patches (NP) and Patch density (PD): These metric quantifies patches that helps to identify the level of fragmentation (Fig. 8a). Higher the number of patches, then the region is under fragmentation. Patch density analogous to NP reflects number of patches per unit area is given in Fig. 8(a) and Fig. 8(b). Highlights that Pune had clumped growth during 70's and 90's in all zones and confined to the core areas of the city. Post 2000 the city showed the signs of fragmentation especially in north-west and north-east directions with values reaching 500 patches in near periphery. Buffer zones also show similar trends with approximately 200 patches on an average, and 800 patches (2013) in all directions resulting in higher patch densities which indicates of sprawl in the region.

Total edges and edge density: Edges and edge density basically are indicator of fragmentation in the landscape. Edge density represents denseness of the patches/edges in the landscape. Edges in 1977 across all zones and circles indicates that the core of the city are clumped. Further, post 1992 edges have increased highlighting fragmented out growth. In 2013, Gradients covering the inner core are clumped in the north-east and north-west directions, and the outskirts are with large number of edges (~300000 edges) in NW and NE directions. Density of 1.5 signify higher edges. Fig. 8c and 8(d) represents outputs of Total edge and Edge density.

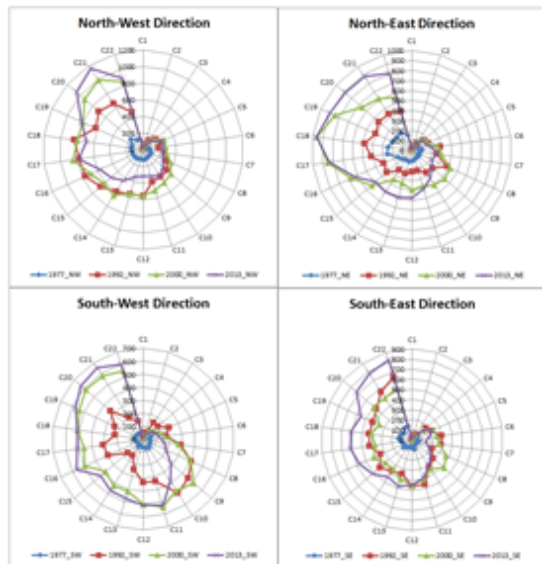


Figure 8(a) Number of urban patches

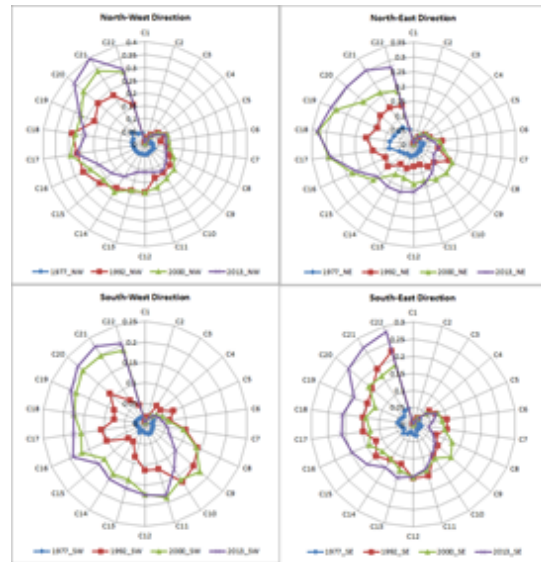


Figure 8(b) Patch density

Normalized shape index (NLSI): NLSI describes the shape of the particular class in the landscape. It is 0 when the landscape consists of a maximally compact patch and increases as the patch type becomes increasingly disaggregated and is 1 when the patch type is maximally disaggregated (Fig. 8(e)). The results of the analysis show that the gradients near the core with aggregations are forming a compact patch, whereas outer gradient in all direction with the spurt in urban activities show a value closer to 0.9 in almost all zones in the buffer zones indicating of sprawl as the shape of landscape is irregularly disaggregated and fragmented.

Cohesion index: Cohesion index implies the physical connectedness of the focal class and the value is 0 with the decline of the proportion of urban class in the landscape, which is indicative of fragmented outgrowth else increases monotonically, evident in Fig. 8f, indicating the emergence of urban sprawl in buffer zones and the decrease of the physical connectedness near the core similar to earlier metrics.

Clumpiness index (Clumpy) and Percentage of like adjacencies (Pladj): CLUMPY metric directly measure aggregation and disaggregation of the class in the landscape, equals -1 when the class is maximally disaggregated; and equals 0 when the class is distributed randomly, and approaches 1 when the patch type is maximally aggregated. PLADJ equals 0 when the focal class is maximally disaggregated and no like adjacencies and is equal to 100 when the focal class is a single patch is adjacent between same classes. These metrics are dependent on adjacent characteristics of the focal class in the landscape.

Fig. 8g and 8h shows that gradients reaching aggregation or single patch class from 1977 to 1992 in all zones. However, post 2000 the initiation of fragmentation value reaches 0 for Clumpy and Pladj signifying the fragmentation due to urban outgrowth. This phenomena can be mostly seen in the buffer zones and in regions under extreme pressures of sprawl.

Spatial metrics indicates of sprawl especially in the periphery and the buffer zones. These regions requires an immediate attention by the decision makers to provide appropriate infrastructure and basic amenities.

Metrics computed in each temporal gradients equip the decision-makers with fundamental information about the growth, the role of agents (for example policy decisions to setup industrial layouts, etc.), rate of growth, spatial patterns of growth and information about site specific details such as patches or clumpiness or shapes in the landscape.

This knowledge helps in visualizing the extent and patterns of future growth, which helps in adopting strategies to control or mitigate potential impacts on the sustenance of natural resources due to large scale land cover changes.

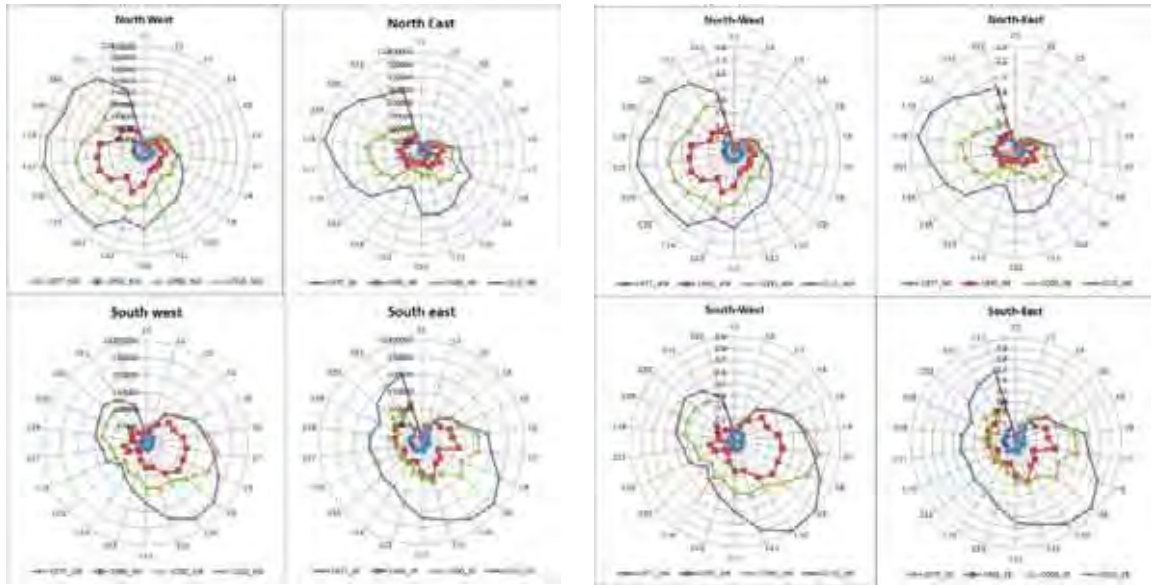


Figure 8(c) Total edge

Figure 8(d) Edge density

Spatial pattern dynamics elucidation throws light on the role of earlier government policies (Fig. 9) in urban sprawl or urbanisation process in the region. This also helps in assessing the effectiveness of earlier urban policy measures to address sprawl and development of a city. Integrated management of natural resources involves understanding the rationale of development and making decisions of placing the regions specific development trajectory while maintaining the urban open spaces (parks, lakes, vegetation, etc.), natural water drains and resources.

Localities such as Pimpri, Chinchwad, Kahdakwasla, Dhayari phata, Katruj, Yerwada, Pashan, Lavale, Warje, Baner, Khadki, Tharwade, Pirangut etc., in and around Pune are experiencing large scale land cover changes due to the government push for industrialization in 1990's are now facing the problem due to sprawl and associated problems such as lack of basic amenities, etc.

The spatial analyses establishes that gradient based metrics computation helps in understanding the spatial patterns of a dynamically evolving urban landscape (Keiner and Arley, 2007, Aguilera, 2008) like Pune given the momentum of growth and pressing need to characterize and plan in efficient manner. Fig. 9 illustrates the potential of gradient based spatial pattern analysis in understanding the land use dynamics due to policy interventions.

Pimpri Chinchwad was established in 1988 and developed to cater the requirement of industrial needs. This region is located in gradients 11, 12 and 13 in the north-west zone.

These gradients had higher vegetative cover in the pre-1990. But post 2000 it can be seen extensive conversion of vegetative area urban land use. Landscape metrics for this gradients show that the urban impervious surface were located as a continuous simple shape concentrated surface pre-2000 (Fig. 9a). Post 2000 these regions have experience significant land use change and conversion in to highly fragmented area. In 2013 these regions have changed into most fragmented gradients in North West zone.

Warje (Fig. 9b) is located close to periphery of the Pune municipal boundary. Gradient 6-9 represents this industrial region in the south west zone. The land use before 1990 was dominated by other land use class and post 2000 is dominated by the urban land use. Post 2000, the region formed a clumped simple patch, which indicates of prevalence of urban patch dominance.

Yerwada and Nagar road (Fig. 9c) is located in north east region of Pune and 7-8 gradient of North east zone and contribute about 10% to the industrial output of Pune. Landscape metrics of urban land use highlights that these gradients (post 2000) are in the verge of forming a single dominant urban class with simple shapes.

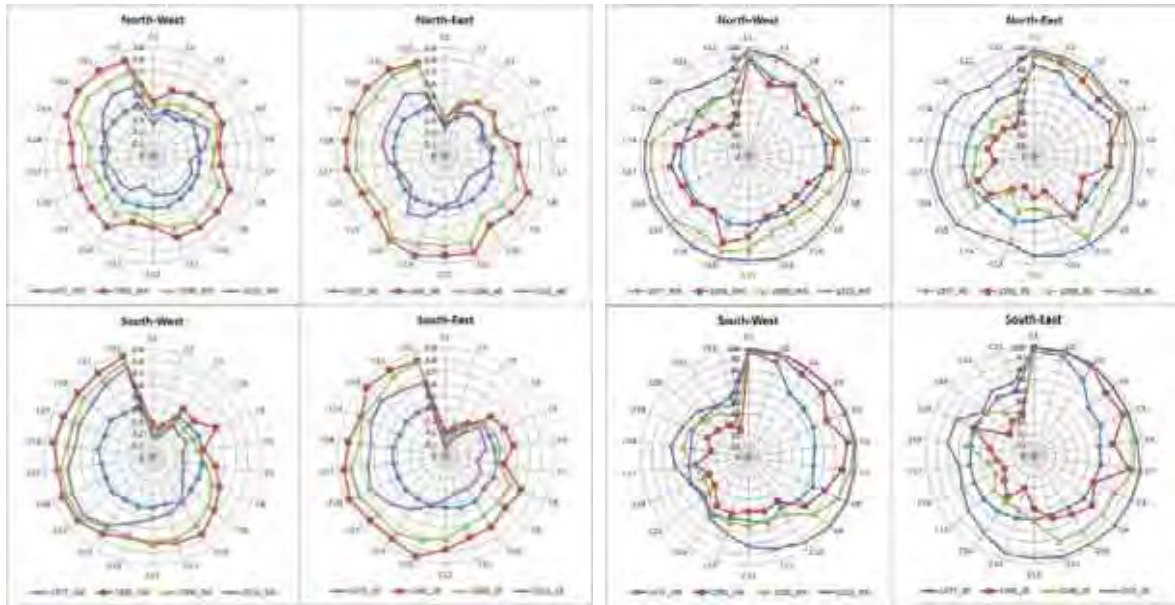


Fig. 8(e) Normalized landscape shape index

Figure 8(f) Cohesion index

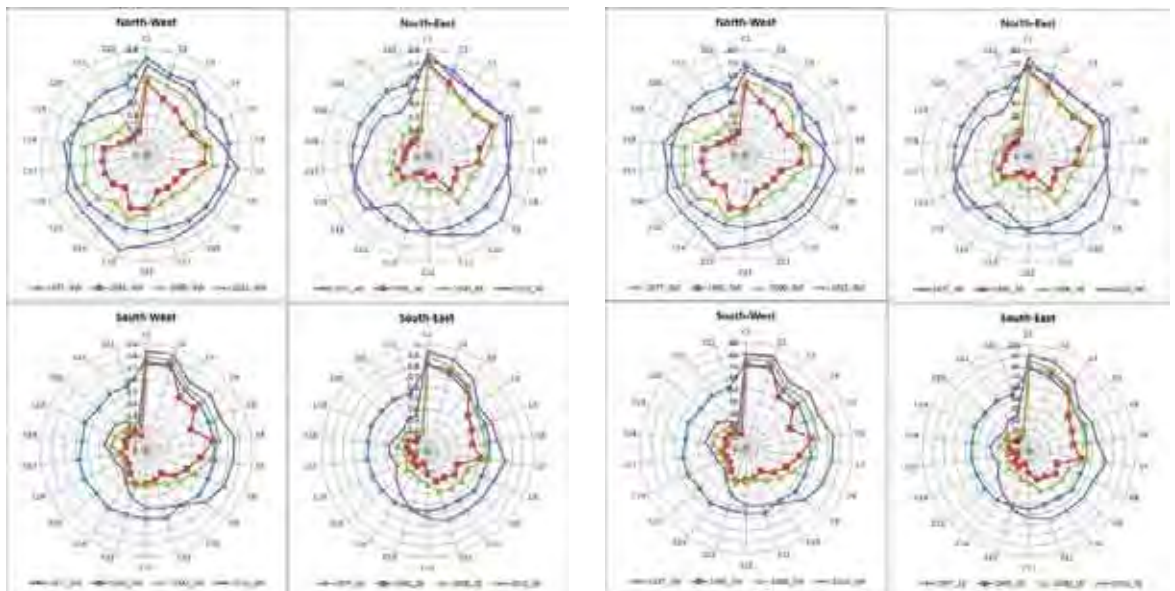


Fig. 8(g) Clumpiness index

Fig. 8(h) Percentage of like adjacencies

These spatial analyses confirm that policy and socio-economic factors fuel URBANIZATION. Urban planning require essential up-to-date knowledge of spatial patterns of land use changes to regulate and plan the city's expansion as well as infrastructure development. Access to consistent and integrated spatial information about land use dynamics aids in the strategic understanding of the region specific growth for formulating effective cognitive decision on natural resources management by city planners with all stakeholders. Location specific information enhances the planning process through multitude of factors having decisive role in the land use sustainability.

5 CONCLUSION

Spatial patterns of urbanisation and sprawl in Pune city with 10 km buffer has been analysed zone wise gradients using temporal remote sensing data through Geoinformatics and spatial metrics during 1977 to 1992 there was infilling in the core city area. During 2000 and 2013 the fragmentation was quite evident at city outskirts. Spatial pattern dynamics analysed through patch, contagion, edge and shape metrics.

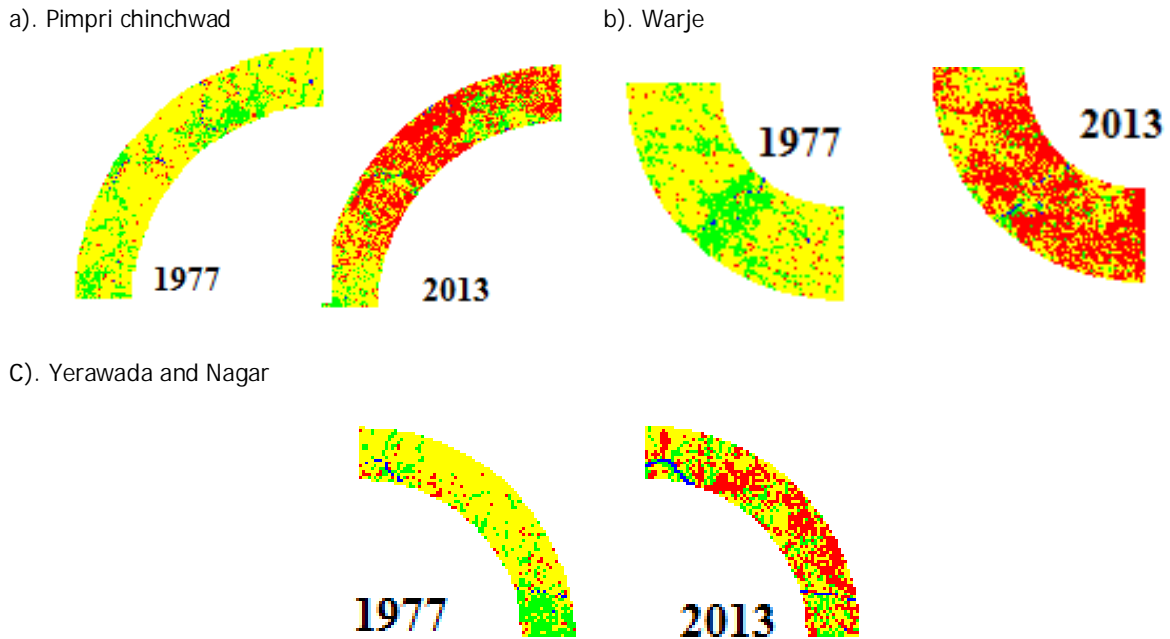


Fig.9 Spatial patterns of urbanization with industrialization in 1990's
The temporal pattern of the urbanization process of this region highlights the process of coalescence during the rapid urbanization decade (2000 to 2010). Results indicate the process of aggregation in the core compared to the periphery and the buffer zones. Globalisation and the reforms in the industrial sector during 1990's witnessed a spurt in urban growth, which is evident from the occurrence of large number of urban patches surrounded by other land uses, especially in industrial pockets such as Pimpri chinchwad, Warje, Yerawada, etc. Subsequent urban growth witnessed consolidation of fragmented patches with lower patch density and larger urban patch to form clumped urban pockets in NW and SE directions by 2010. Specifically, aggregation of patches is noticed in northwest at the outskirts and even at the buffer zone. Gradients with metrics provide vital information to the decision makers about level of urbanisation and the role of agents (policy issues, etc.). Information about the patterns of growth, rate of growth, patches, clumpiness etc. would help in evolving appropriate location specific strategies to mitigate environmental consequences. Visualisation of urban growth based on the behavior of agents with the temporal data help the city managers in help city planners and administrators to design towards achieving the goals of sustainable cities.

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REFERENCES

- Alphan, H., Doygun, H., & Unlukaplan, Y.I. (2009). Post-classification comparison of land cover using multi-temporal Landsat and ASTER imagery: the case of Kahramanmara angstrom, Turkey, *Environmental Monitoring and Assessment*, 151(1 – 4), 327 – 336
- Aguilera, F., 2008. Análisis espacial para la ordenación eco-paisajística de la Aglomeracion Urbana de Granada (Spatial analysis for the ecological landscape planning in the Metropolitan Area of Granada). PhD Thesis. University of Granada, Granada (in Spanish: English abstract).
- Bharath, S., Bharath, H.A., Durgappa D.S., & Ramachandra T.V. (2012). Landscape Dynamics through Spatial Metrics, *Proceedings of India Geo Spatial Conference*, Epicentre, Gurgaon, India, 7-9 February, 2012.

- Bharath, H. A., Bharath, S., Sreekantha, S., Durgappa D.S., Ramachandra, T. V., (2012) "Spatial patterns of urbanization in Mysore: Emerging Tier II City in Karnataka, Proceedings of *NRSC User Interaction Meet- 2012*, 16th & 17th, Hyderabad, February 2012.
- Bhaskar, P., (2012). Urbanization and changing green spaces in Indian cities (Case study – City of Pune), *International Journal of Geology, Earth and Environmental Sciences*, 2, 148- 156.
- Bhatta, B., (2009). Analysis of urban growth pattern using remote sensing and GIS: A case study of Kolkata, India. *International Journal of Remote Sensing*, 30(18), 4733–4746.
- Bhatta, B., Saraswati, S., & Bandyopadhyay, D., (2010a). Quantifying the degree-of-freedom, degree-of-sprawl, and degree-of-goodness of urban growth from remote sensing data. *Applied Geography*, 30(1), 96–111.
- Bhatta, B., Saraswati, S., & Bandyopadhyay, D., (2010b). Urban sprawl measurement from remote sensing data. *Applied Geography*, 30(4), 731–740.
- Census of India, available at <http://censusindia.gov.in>. Last accessed 10th June 2013
- Chen, H.Y., Ganesan, S. & Jia, B.S., (2005). Environmental challenge for Post-reform housing development in Beijing", *Habitat International*, Vol. 19, No. 3, pp. 571 – 589
- City Development Plan (2006-2012), Jawaharlal Nehru National Urban Renewal Mission.
- Clapman, Jr., W.B., (2003). Continuum-based classification of remotely sensed imagery to describe urban sprawl on a watershed scale, *Remote Sensing of Environment*, 86(3), 322 - 340
- Codjoe, S.N.A., (2004). Population and land use/cover dynamics in the Volta River Basin of Ghana, 1960-2010, *Ecology and Development Series No. 15*, Cuvillier Verlag, Gottingen
- Congalton, R. G., Oderwald, R. G., & Mead, R. A., 1983. Assessing Landsat classification accuracy using discrete multivariate analysis statistical techniques. *Photogrammetric Engineering and Remote Sensing*, 49, 1671-1678.
- Congalton, R.G., & Green K., (2009). *Assessing the Accuracy of Remotely Sensed Data: Principles and Practices*. CRC Press Taylor & Francis Group, Boca Raton, FL
- Congalton, R.G., (1991). A review of assessing the accuracy of classifications of remotely sensed data. *Remote Sensing of Environment*, 37 (1), 35-46.
- Desai C.G, Patil M.B, Mahale V.D., & Umrikar, B., (2009). Application of remote sensing and geographic information system to study land use/land cover changes: a case study of Pune Metropolis, *Advances in Computational Research*, 1, 10 – 13.
- Di Gregorio, A., & Jansen, L.J.M., (1997). A new concept for a land cover classification system, in *Proceedings of the Earth Observation and Environmental Information 1997 Conference*, held at Alexandria, Egypt, from 13-16 October, 1997
- Duda, R.O., Hart, P.E., Stork, D.G., (2000). *Pattern Classification*, A Wiley-Interscience Publication, Second Edition, ISBN 9814-12-602-0.
- Gillies, R.R., Box, J.B., Symanzik, J., Rodemaker, E.J., (2003). Effects of urbanization on the aquatic fauna of the Line Creek Watershed, Atlanta – a satellite perspective, *Remote Sensing of the Environment*, 86(3), 411 – 412
- Girardet, H. (1996). *The Gaia Atlas of Cities: new directions for sustainable urban living*, Gaia Books Limited, London. 1st Edition, ISBN: 1856750973.
- Global Land Cover Facility (<http://www.glcf.umd.edu/index.shtml>). Accessed on 10th January 2013.
- Grimm, N.B., Grove, J.M., Pickett, S.T.A. and Redman, C.L. (2000). Integrated approach to long-term studies of urban ecological systems, *BioScience*, 50(7), 571 – 584
- Gustafson, E.J., (1998). Quantifying landscape spatial pattern: what is the state of the art?, *Ecosystems*, 1, 143–156.
- Herold, M., Goldstein, N., C., Clarke, K., C., (2003). The spatiotemporal form of urban growth: measurement, analysis and modeling. *Remote Sensing of the Environment*, 86, 286–302.
- Jansen, L.J.M. & Di Gregorio, A., (1998). The problems with current land-cover classifications: development of a new approach, in *Land-cover and land-use information systems for European Policy Needs*, Office for the Official Publications of the European Communities, Luxembourg, 21 – 23

- Ji, C.Y., Lin, P., Li, X., Liu, Q., Sun, D., & Wang, S., (2001). Monitoring urban expansion with remote sensing in China, *International Journal of Remote Sensing*, 22(8), 1441 – 1455
- Kong, F., Yin, H., Nakagoshi, N., James, P., (2012). Simulating urban growth processes incorporating a potential model with spatial metrics, *Ecological Indicators*, 20, 82-91
- Lata, K.M., Sankar Rao, C.H., Krishna Prasad, V., Badrinath, K.V.S., & Raghava Swamy, (2001). Measuring urban sprawl: a case study of Hyderabad, *GIS Development*, 5(12).
- Lillesand T., Kiefer R., Chipman J. (2003). *Remote sensing and image interpretation*. Wiley, New York, Fifth edition.
- Liu, J., Dietz, T., Carpenter, S.R., Alberti, M., Folke, C., Moran, E. & Taylor, W.W., (2007). Complexity of coupled human and natural systems, *Science*, 317(5844), 1513 – 1516.
- Lopez, T. del M., Aide, T.M., & Thomlinson, J.R., (2001). Urban expansion and the loss of prime agricultural lands in Puerto Rico, *Ambio*, 30(1), 49-54
- Keiner M. and Arley K., *Transnational city networks for sustainability*, *Eur. Plann. Stud.*, 15 (2007), pp. 1368–1395
- Martinuzzi, S., Gould, W.A., & Gonzalez O.M.R., (2007). Land development, land use, and urban sprawl in Puerto Rico integrating remote sensing and population census data, *Landscape and Urban Planning*, 79(3 – 4), 288-297
- Massey, D. S., Arango, J., Hugo, G., Kouaouci, A., & Pellegrino, A., (1999). *Worlds in Motion: Understanding International Migration at the End of the Millennium*, Oxford university press, ISBN: 0199282765
- McGarigal, K., & Marks, B. J., 1995. FRAGSTATS: spatial pattern analysis program for quantifying landscape structure. USDA Forest Service General Technical Report PNW-351.
- Mitrakis, N.E., Topalogou, C.A., Alexandridis, T.K., Theocharis, J.B., & Zalidis, G.C., (2008). A novel self-organising neuro-fuzzy multi layered classifier for land cover classification of a VHR image. *International Journal of Remote Sensing*, 29, 4061–4087
- Molles, M., (2006). *Ecology: Concepts and Applications*, 4th ed. McGraw Hill, Boston, USA.
- Pathan, S.K., Jothimani, P., Pendharkar, S.P. and Sampat Kumar, D., (1989). Urban land use mapping and zoning of Bombay Metropolitan Region using Remote Sensing data. *J. Indian Soc. Remote Sensing*, 17(3), 11-22.
- Pathan, S.K., Shukla, V.K., Patel, R.G., Mehta, K, S., 1991. Urban land use mapping - A case study of Ahmedabad city and its environs. *J Indian Soc Remote Sensing*, 19(2), 95- 112.
- Ramachandra, T.V., and Kumar, U., (2009). Geoinformatics for Urbanisation and Urban Sprawl pattern analysis, In *Geoinformatics for natural resource management*, Chapter 19, 235 – 272
- Ramachandra, T.V., Bharath, A.H., & Durgappa, D.S., (2012a). Insights to urban dynamics through landscape spatial pattern analysis, *Int. J Applied Earth Observation and Geoinformation*, 18, 329-343
- Ramachandra, T.V., Bharath, A.H., & Sreekantha, S., (2012b). Spatial Metrics based Landscape Structure and Dynamics Assessment for an emerging Indian Megalopolis, *International Journal of Advanced Research in Artificial Intelligence*, 1(1), 48-57.
- Ramachandra, T.V., Bharath, H.A., & Vinay S., (2013). Comprehension of temporal land use dynamics in urbanising landscape., *Proceedings of User Interaction Meet - 2013*, Balanagar, Hyderabad, 21-22, February, 1-6.
- Ramachandra, T.V., Bharath, H.A., (2012a). Spatio-Temporal Pattern of Landscape Dynamics in Shimoga, Tier II City, Karnataka State, India, *International Journal of Emerging Technology and Advanced Engineering*, 2(9), 563-570.
- Ramachandra, T.V., Bharath, H.A., (2012d). Land Use Dynamics at Padubidri, Udupi District with the Implementation of Large Scale Thermal Power Project, *International journal of Earth Sciences and Engineering*, 5, 409-417.
- Roth, M., Oke, T.R., & Emery, W.J., (1989). Satellite-derived Urban Heat Islands from Three Coastal Cities and the Utilization of Such Data in Urban Climatology, *International Journal of Remote Sensing*, 10(11), 1699 – 1720
- Sudhira, H.S., Ramachandra, T.V., & Jagadish, K.S. (2003). Urban growth analysis using spatial and temporal data, *Journal of the Indian Society of Remote Sensing*, 31(4), 299 – 311
- Sudhira, H.S., Ramachandra, T.V., & Jagadish, K.S., (2004). Urban sprawl: metrics, dynamics and modeling using GIS, *International Journal of Applied Earth Observation and Geoinformation*, 5(1), 29 – 39

Sutton, P.C., (2003). A scale adjusted measure of "Urban sprawl" using nighttime satellite imagery, *Remote Sensing of Environment*, 86(3), 353 - 369

Taubenbock, H., Wegmann, M., Roth, A., Mehl, H., & Dech, S., (2009). Urbanization in India: Spatiotemporal analysis using remote sensing data. *Computers, Environment and Urban Systems*, 33(3), 179–188.

Uuemaa, E., Antrop, M., Roosaare, J., Marja, R., Mander, U., (2009). Landscape metrics and indices: an overview of their use in landscape research. *Landsc. Res.* 3, 1–28

Verzosa, L.C.O. and Gonzalez, R.M. (2007). Remote sensing, geographic information systems and Shannon's entropy: measuring urban sprawl in a mountainous environment, In: Wagner W., Szekely, B. (eds.): *ISPRS TC VII Symposium – 100 Years ISPRS*, Vienna, Austria, July 5–7, 2010, IAPRS, Vol. XXXVIII, Part 7A. Available at http://www.isprs.org/proceedings/xxxviii/part7/a/pdf/269_XXXVIII-part7A.pdf. Accessed on 1st Aug 2013.

Vinay, S., Bharath, H.A., Ramachandra, T.V., (2012). Spatio-temporal dynamics of Raichur City, LAKE 2012: National Conference on Conservation and Management of Wetland Ecosystems, 6-9th November 2012, School of Environmental Sciences Mahatma Gandhi University, Kottayam, Kerala.

Voogt, J.A., & Oke, T.R., (2003). Thermal Remote Sensing of Urban Areas, *Remote Sensing of the Environment*, 86, 370 – 384

World Urbanization Prospects revised, 2011. United nation department of socioeconomic affairs. Available at <http://esa.un.org/unup>. Last accessed on 04th Aug 2013.

Xiao, J., Shen, Y., Ge, J., Tateishi, R., Tang, C., Liang, Y., & Huang, Z., (2006). Evaluating urban expansion and land use change in Shijiazhuang, China, by using GIS and remote sensing, *Landscape and Urban Planning*, 75(1), 69 – 80

Yang, L., Xian, G., Klaver, J.M., & Deal, B., (2003). Urban land-cover change detection through sub-pixel imperviousness mapping using remotely sensed data, *Photogrammetric Engineering and Remote Sensing*, 69(9), 1003-1010.

Yeh, A.G.O., & Li. X., (1999). Economic development and agricultural land loss in the Pearl River Delta, China, *Habitat International*, 23(3), 373 – 390.

Yeh, A.G.O., & Li. X., (2001). Measurement and monitoring of urban sprawl in a rapidly growing region using entropy, *Photogrammetric Engineering and Remote Sensing*, 67(1), 83-90

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