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Assessment of urban sprawl in Bathinda city, India

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1. Introduction

Urban sprawl denotes expansion of human population away from the central urban areas into low-density areas that are mostly car dependent communities. The exact definition of urban sprawl differs among researchers as the term lacks precision and sometime have negative connotation. While urban sprawl appears to be inevitable phenomena (Buzbee, 2000), it is criticized for causing environmental degradation (Seto, Fragkias, Guneralp & Reilly, 2011 and Wilson & Chakraborty, 2013) and undermining of existing urban areas as the margin expands. Batty, Besussi, and Chin (2003) defines sprawl as, “uncoordinated growth: the expansion of community without concern for its consequences in short unplanned, incremental urban growth which is often regarded as unsustainable”. In India, the unprecedented population growth and migration results in urban sprawl where the urban fringe towns and cities cope up with changing land use along the highways and in the immediate vicinity of the city for better space. Due to which, the dispersed development takes place, outside the compact urban and village, along highways and rural countryside (Theobald, 2001) and this growth of built ups outside the urban margins are termed as urban sprawl. Bhatta et al. (2010) argues, despite the dispute over a precise definition of sprawl, the general consensus of urban sprawl is characterized by “unplanned and uneven pattern of growth, driven by multitude of processes and leading to inefficient resource utilization”. Therefore, the methods of identifying urban sprawl is important in delineating the term from sub-urbanization using indicators (Ewing, 1997) rather than characteristics, as it is more flexible and less arbitrary. Five indicators (Hasse & Lathrop, 2003) proposed to examine the per capita consumption of land associated to sprawl includes: (1) density of new urbanization; (2) loss of prime farmland; (3) loss of natural wetlands; (4) loss of core forest habitat; and (5) increase of impervious surface. As in late 20th century, strong sentiment against urban sprawl has developed in the United States (Brueckner, 2000) that includes a lot of critics, alleging that excessive urban expansion have encroached farm land and open space. In western countries, urban sprawl is the consequence of suburbanization, and urban sprawl means excessive suburbanization (Mills, 2003) resulting into argument that urban sprawl is used synonymous with suburbanization in a pejorative way.

No matter what the consensus lies with the definition, urban sprawl becomes an inevitable event (Bhat, Shafiq, Mir, and Ahmed, 2017) when urban area experience ‘growth’. The growth that is fueled by increasing population, increasing economic land use and changing utilization of space (Meyer & Turner, 1992) and have great impact on the land use pattern that re-design the urban landscape. While addressing to the issue of urban sprawl, the spatio-temporal organization of a space (An, Tsou, Crook, Chun, Spitzberg & Gawron, 2015) becomes an important question. The city of Bathinda is one such case in Punjab state of India, the 5th largest city in the state of Punjab and the major urban settlement of LPA (Local Planning Area), with population of 2,17,256 persons in 2001 (Municipal Corporation). LPA Bathinda experienced growth rate of 22.79% and 26.96% during the year 1981–1991 and 1991–2001 respectively (BTD report, 2011). While the urban growth accounts for 28.82% and 37.73%, the rural growth accounts for 17.71% and 12.74% during the year 1981–1991 and 1991–2001 respectively. The shares of LPA Bathinda in relation to Punjab state is 1.40%, 1.43% and 1.51% in 1981, 1991 and 2001. The growth rate of Bathinda was 95.12 percent during 1971–1981 mainly due to the expansion of municipal boundary and establishment of two major industries; Thermal power plant National Fertilizer limited (BTD report, 2011). Considering the past record, the statistics reveals that the growth trend of Bathinda is not uniform as well as not rapid.

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Taking consideration of the population growth and changing land use, the main objectives of the study includes; a) Identification of land use land cover change resulted by buildup expansion between the year 1972–2016. Growth of built up area over the given time period highlights the changing landscape that explains the spatio-temporal organization. b) Analyzing the population growth between 1971–2011 (District population and city ward population). c) Study on worker's categories within Bathinda city and identifying section of population that has contributed to population growth. Therefore, the main question is how spatio-temporal change has impact on the land use and does changing demographic feature (particularly looking at the worker's classification) is the only factor of urban sprawl in Bathinda? This paper is an attempt to explain the process of urban sprawling by identifying land use change in relation to population change and make an effort to study the magnitude of sprawling and seek an answer to explain the spatio-temporal change over the space.

2. Methodology

The study include primary data of multispectral satellite image of Landsat ETM+ with 30 m spatial resolution for the year 2010 and 2016, Landsat TM with 30 m spatial resolution for the year 1990 that were collected from United States Geological Survey (USGS) and GPS point and digital photographs that are collected from the field. The study also include secondary data of topographical map of the study area of 1972 collected from Survey of India. The different year was selected considering the decadal changes occurred in the land use. Bathinda Ward map collected from Bathinda Municipal Corporation, Census Data for the year 2001 and 2011 collected from Census of India, Published Government reports collected at Bathinda municipal, Government of Punjab and many other Published and unpublished articles from various sources. Population data was collected from Census of India reports and Bathinda municipal office for the city wards population. Population census of the year 1971, 1981, 1991, 2001, and 2011 was considered for the study as images each images falls within the census decadal year.

Firstly, Survey of India toposheet was mosaic (the study area comes under 10 different toposheets) and geo-referenced (for extraction of boundaries and land use classification). Then city boundary was extracted from the toposheet by digitizing the boundary (information gathered from Town and Country Planning Office, Bathinda). Landsat satellite images downloaded from USGS (United State Geological Survey) was re-projected as the different agencies used different standards and references. The imageries have been stacked in order to get FCC imagery and supervised classification was carried out using ERDAS Imagine software. Different land use/cover classes (Agriculture, built up, Fallow land, vegetation and water body) were extracted for the years 1990, 2010 and 2016. To verify the quality and reliability of classification exercise, the accuracy assessment has done, with the help of GPS points. The Google earth is also used primarily to identify the doubt areas. A total of 18 GPS points are taken mostly identify and segregate fallow land from built up. For separation of vegetated areas from agricultural land, NDVI (Normalized Difference Vegetation Index) of each particular is generated and verification was carried out. The NDVI results range between -1 to $+1$. Class range between 0.34 to $+1$ is taken as crop land and a range from 0.12 to 0.34 are classified as vegetation cover and field verification was done in this regard.

The change matrix for the classes (Agriculture, built up, Fallow land, vegetation and water body) was calculated that identify changing land use pattern. The extraction of built up area were done to see the growth of economic activities as well as population that is correlated. The Bathinda ward map was also created using the population growth data for analyzing the growth within city urban limit. The population data along with worker classification were collected from census of India and Bathinda Municipal Board which clearly highlighted the demographic feature of the population growth. After examining population data and analyzing changing land use pattern, it was found that the retail and whole sale section of the working sector contributed highest population growth. So it was found necessary to study how the retail sector contribute or influence to the urban sprawling. Reilly's law of retail gravitation was used to find out the retail influence in Bathinda city and its peripheries, which in turn influenced the trade both retail and wholesale that in turn lead to the growth of retail as well as wholesale trade in the Bathinda city.

3. Result and discussion

3.1. Land use land cover change in Bathinda

The topographical map of 1972 is taken as a base map for extraction of built up areas and agricultural land. The geo-referenced topographical map is digitized in GIS platform and city boundary is over-lay over the topographical for creating urban boundary. The settlement area are digitized so that built up area could be extracted from the topographical map, that would be further over-lay with Landsat images to identify areal expansion of built up. From the estimation of land use land cover of 1972 (Fig. 1) it is found that around 65.45 square kilometers comprises the total built up of the study area, where as 1099.15 square kilometers comes under agricultural crop land. Another two important classes mentioned in topographical map is land with Kikar, classified as dense Kikar, open Kikar and Mixed Jungle. Total area comes under Kikar is around 13.01 square kilometers. Mixed jungle is 0.54 km^2 and water body is 0.75 km^2 .

Classification of 1990 (Fig. 2) image shows increase in built up areas and decrease in agricultural land. Other vegetation types considered in one class as vegetation that is around 199.88 square kilometers. Built up areas increase up to 124.1 km^2 , on the other hand agricultural land decreased up to 854.17 km^2 . Water body is 0.75 km^2 . The net changes in this two particular land cover are; 58.65 (increase) in built up areas and 244.98 (decrease) square kilometers concerning agricultural land.

The land use land cover classification of 2010 (Fig. 3) shows a gradual increase in built up area as well as agricultural land. Agricultural land is 929.07 km^2 , vegetation is 48.8 km^2 , built up is 199.87 km^2 , Fallow land 0.41 km^2 , water body 0.75 km^2 . There is a net change of 75.77 km^2 in built up areas and 74.9 km^2 in terms of agricultural land. There is area around

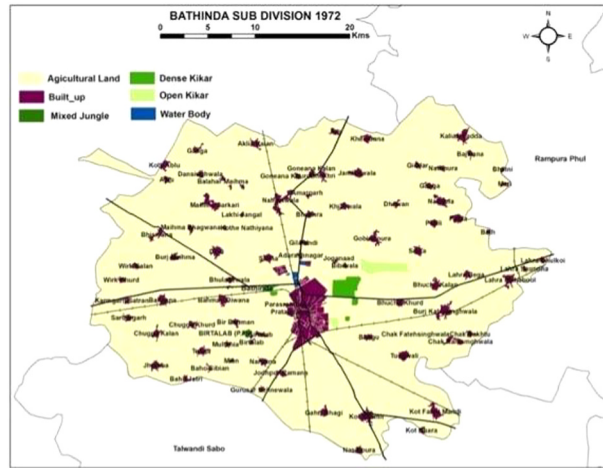


Fig. 1. Land use land cover of Bathinda, 1972.
Source: Topographical Map 1972 (Survey of India)

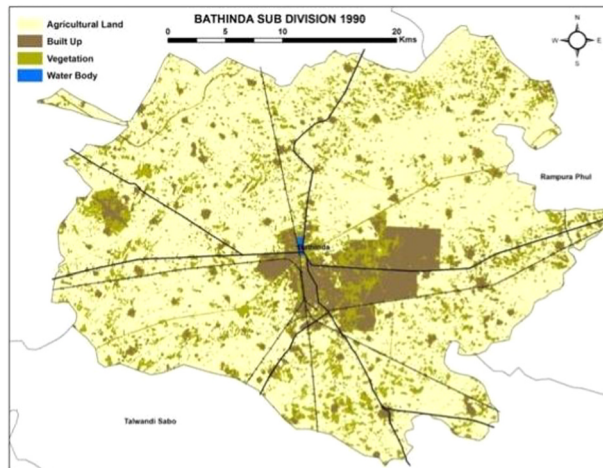


Fig. 2. Land use land cover of Bathinda, 1990.
Source: Landsat TM 1990 (USGS)

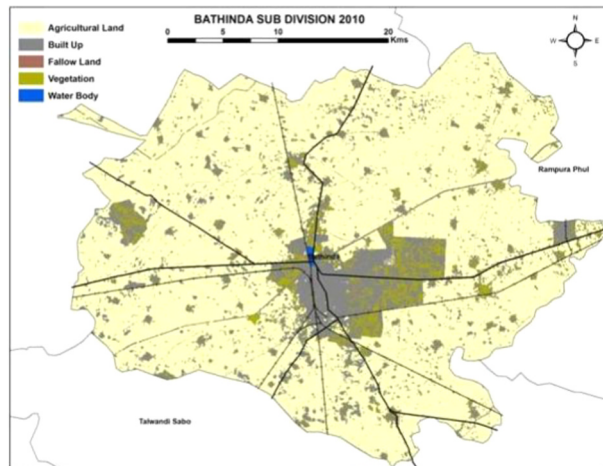


Fig. 3. Land use land cover of Bathinda, 2010.
Source: Landsat ETM+ 2010 (USGS)

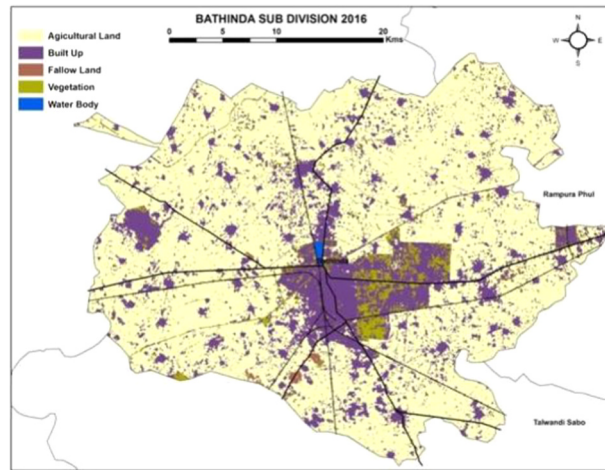


Fig. 4. Land use land cover of Bathinda, 2016.

Source: Landsat TM 2016(USGS)

0.14 square kilometers is identified as degraded land and thus classified as fallow land.

The classification of land use land cover for the year 2016 (Fig. 4) shows a gradual increase in built up areas and decreasing agricultural land. The vegetation cover also decreases up to 44.45 square kilometers. On the other hand, fallow land increases up to 3 square kilometers. Agricultural 864.81 km², built up 265.89 km², water body is 0.75 km². There is net change of 64.26 square kilometers in terms of agricultural land and around 66.02 square kilometers in terms of built up areas.

The land use land cover change in Bathinda reveals the expansion of built up area, where once agriculture area are transform into built ups and city margins/ peripheries have observed expansion of built ups.

3.2. Expansion of built-up in Bathinda (1972, 1990, 2010 and 2016)

The expansion of built up (Fig. 5) has taken place mostly along the NH (National Highway) 15 and NH 64, towards the north,

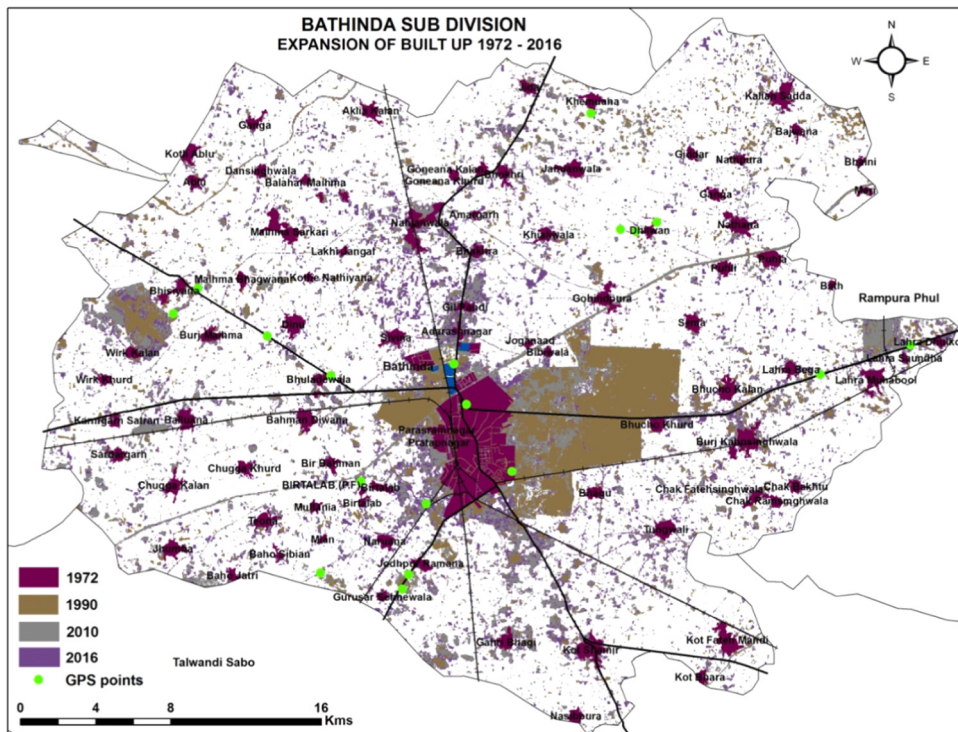


Fig. 5. : Expansion of build-up in Bathinda (1972–2016).

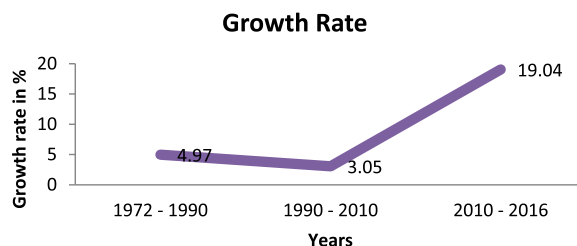


Fig. 6. Growth rate of buildup in Bathinda.

Source: Landsat TM (USGS)

eastern direction, constructing a linear pattern of sprawling. State high way connection Bathinda, Maur and Mansa also indicates liner pattern of urban sprawling. Thus the increasing built up indicate high rate of land consumption that were either fallow land or agricultural land.

Therefore, the annual growth rate of buildup is calculated with the help of Annual Land Use Change Rate (ALUCR), defined by Tian et al. as follows:

$$ALUCRa, t = \frac{(LUa, t - LUa, t - 1)/LUa, t - 1}{Nt - Nt - 1} * 100$$

where ALUCRt (%) is the land use change rate; LUa,t and LUa,t-1 are the total land area of land use class 'a' in kilometers at the time t (current year) and time t - 1 (former year); N is the total number of years from time 't' (current year to time t - 1 (former year)). Calculating the growth rate of expanding built up areas it is found that, during the year 1972 to 1990 the rate of growth was 4.97% (duration 18 years), between the year 1990 to 2010 the growth rate of built up was 3.05% (duration 20 years). Between the years 2010 to 2016 the growth rate of built up increase up to 19.04%. The ALUCR indicate a sudden expansion of built up areas during last six years (Fig. 6).

3.3. Change matrix of land use

For better understanding and analysis of land use land cover change, change matrix has been carried out for the years 1990 to 2016. The assessment of 2010 based on 1990 (Table 1) with the help of change matrix shows that the increase of 74.9 square kilometers in agricultural land is a conversion of vegetated land to agricultural land, as well as 75.77 square kilometers increase of built up land also showing the conversion of vegetated land to build up. More over around 0.14 square kilometers of fallow land also showing the same trend. Thus it is almost distinct that during the year 1990 to 2010 most affected land cover is vegetated land, considering all types of vegetation.

The assessment of 2016 based on 2010, (Table 2) the change matrix reveals that there is decrease of 64.26 square kilometers in agricultural land that is directly converted into built up areas. Mover over 1.76 square kilometers of vegetation cover again transformed into built up. Due this process 2.59 square kilometers of vegetation cover transformed into fallow land.

3.4. Population growth of the Bathinda city

According to census of India the population of Bathinda city from 1971 to 2011 (Fig. 7) shows gradual increasing trend in comparison to the total urban population of the state. Between the years 1971 to 1981 the percentage of Bathinda city population share against the total urban population of Punjab state has increased 0.71%. After which there was a constant decrease from 0.09% and 0.02% during 1981 to 1991 and 1991 to 2001. But in 2011 census there is an increase of 0.12%.

It can also be address from the decadal growth rate 1901–2011 (Fig. 8). 1961 to 1971 shows 14.05% rate of population growth and the census year 1981 shows a very high increase in population growth rate that 95.12%, which was the highest in the state.

Table 1

Change matrix 1990–2010.

2010 Assessment						
2010 Assessment	Agricultural Land	Built Up	Fallow Land	Vegetation	Water Body	Total 1990
Agricultural Land	854.17	0	0	0	0	854.17
Built Up	0	124.1	0	0	0	124.1
Fallow Land	0	0	0	0	0	0
Vegetation	74.9	75.77	0.41	48.8	0	199.88
Water Body	0	0	0	0	0.75	0.75
Total 2010	929.07	199.87	0.41	48.8	0.75	1178.9
Net Change	74.9	75.77	0.41	-151.08	0	

Table 2
Change matrix 2010–2015.

2016 Assessment						
2016 Assessment	Agricultural Land	Built Up	Fallow Land	Vegetation	Water Body	Total 2010
Agricultural Land	864.81	64.26	0	0	0	929.07
Built Up	0	199.87	0	0	0	199.87
Fallow Land	0	0	0.41	0	0	0.41
Vegetation	0	1.76	2.59	44.45	0	48.8
Water Body	0	0	0	0	0.75	0.75
Total 2016	864.81	265.89	3	44.45	0.75	1178.9
Net Change	-64.26	66.02	2.59	-4.35	0	

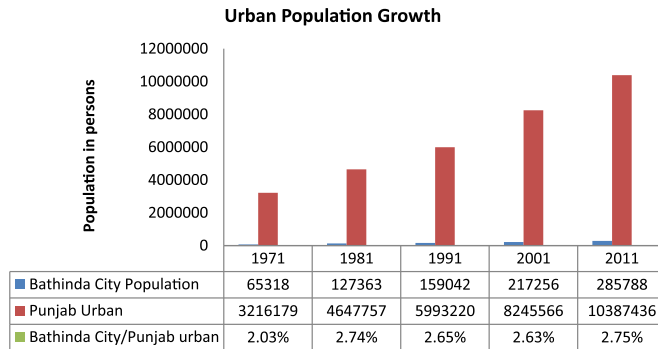


Fig. 7. Urban growth of Bathinda District and Punjab State, 1971–2011.
Sources: [BTD report 2011](#), Govt. of Punjab

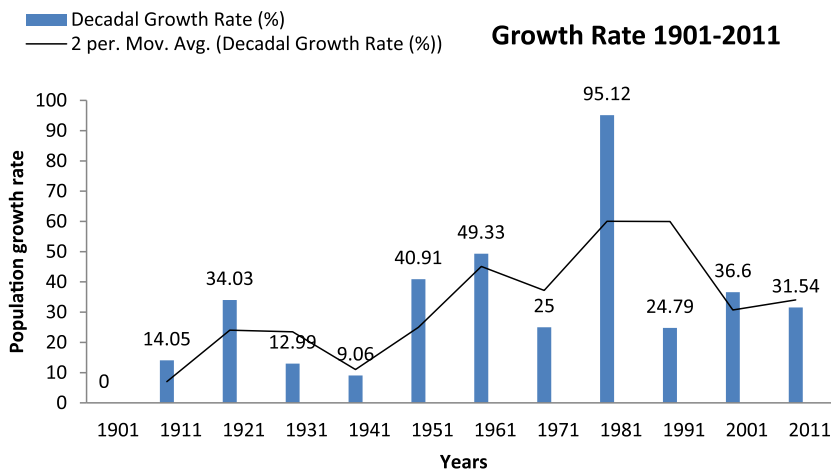


Fig. 8. Trend of Bathinda city population growth, 1901–2011.
Source: [BTD report 2011](#), Govt. of Punjab

During this period Bathinda was introduced with two major industries, Thermal Power plant and National Fertilizer Limited, causes established of Thermal Colony and NFL colony in 1973–74. It was also a major fact of First Town Planning Scheme, First Development Scheme, and First Urban Estate in 1973. In 2001 the Bathinda municipal expanded city area up to 67.87 square kilometers, the growth rate of population also raised up to 36.6 percent. In the Last census of 2011 population growth rate again shows drop down to 31.54 percent, in spite of Bathinda Municipal Corporation again extend the city area up to 68 sq.km.

According to BTD report of 2011 published under Government of Punjab, the area under Bathinda Municipal Corporation has expanded up to 68 square kilometers in year 2008 from 20.72 square kilometers (1971) and 67.87 square kilometers (2001). The density of population was 7675.77 persons/square kilometers in 1971 to 1991, which decreased to 3201.06 person/square kilometers in 2001 because of expansion in Bathinda Municipal boundary. Furthermore, the population density continues to rises up in 2011 to 4202.76 person/square kilometers, despite of expansion of Bathinda municipal that also resulted in numbers of wards from 35 to 50 (According to Census 2001 and 2011 respectively).

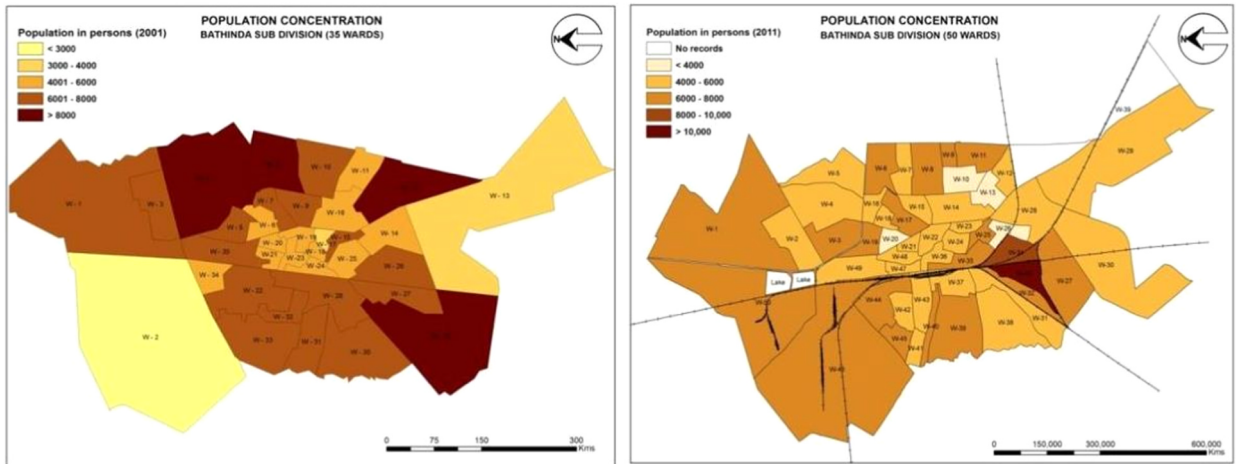


Fig. 9. Population concentration in Bathinda City Wards, 2001 and 2011.
Source: [BTD report 2011](#), Govt. of Punjab, File format: CAD

During the period of 2001 (Fig. 9), population concentration of the wards can be seen up to above 8000 persons. Ward number 8 had highest population concentration; 9150 persons followed by ward number 4, had 8868 persons, ward number 29 had 8798 persons and ward number 12 had 8113.

During the year 2011 (Fig. 9), population concentration rises up above 10,000 persons, as ward number 33 has highest population concentration that is 10,644 persons, followed by ward number 34 has 9070 persons.

3.5. Correlation between population growth and expansion of built up

The correlation is generated to show the relation between population growth and expansion of built up areas which shows a strong correlation. The R^2 value 0.979 established a positive relationship between populations and built up. In this particular scenario one can say that built up is a dependent variable upon population and thus as population increases, built up areas are also seen increasing (Fig. 10).

Spatial expansion is an inevitable event in the changing demographic feature in Bathinda. The process of peopling and the spatial re-arrangement is well documented thereby resulting in land use change. Previous studies reveals the in/out migration of people changes urban population structure as well as built ups. Labor migration, seasonal migrations are common issues in Bathinda. Migration of people as labourer and retailing start settling in open spaces (mostly city peripheries and urban margins) and this redesign the urban picture. Due to this reason, it has becomes an interesting to find out, what section of working class category contributes to the urban sprawl. There is no doubt that urban land should expand to accommodate the population and economic growth, but the problem is that low density and too much spatial expansion occurs, where “Population” and “Economic growth” play most important role in urban sprawl.

3.6. Occupational structure in Bathinda

Regarding economic growth, worker population is considered as occupational structure is believed to give insight about the

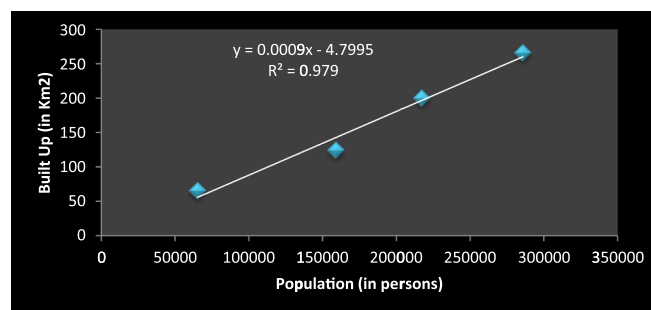


Fig. 10. Correlation between population growth and expansion of built up.

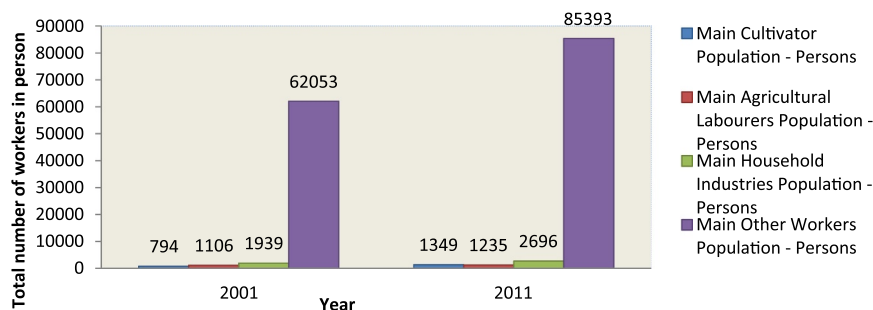


Fig. 11. Occupational structure of Bathinda City 2001–2011.

Source: Census 2001 and 2011

economic activities for increasing built up areas. Considering the last two decades the major worker population of Bathinda city it is found that in both decades the total population of other workers is highest as, 62,053 in 2001 and 85,393 in 2011 (increased by 23,340), followed by household industrial workers as; 1939 in 2001 and 2696 in 2011 (increased by 757). In both the decadal record working categories cultivators and agricultural laborers consume less number of working population. The occupational structure of Bathinda city for last two decades is given below in Fig. 11.

Among the total working population of Bathinda city 29.61% comes under public administration and other governmental services. On the otherhand 21.80% of working population comes under whole sale and retail trade, whereas only 11.80% comes under manufacturing, processing and repairs industry, 7.73% electricity, gas and water supply and 2.40% in household industries. Beside public administration and other governmental works, whole sale and retail trade is the second most influential factor in the economy of Bathinda. Depending upon this fact it can be say that during the last two decades retail trade and commerce is the prime sector that consumes highest working population, rather than other industries (Tables 3 and 4).

Retail trade and commerce is the prime sector that consumes highest working population, rather than other industries. The urban sprawl and expansion of built up in Bathinda largely influenced by whole sale and retail trade. The populations of sprawl area are largely related to retail trade and commerce. Thus the interesting relationship is built between retail sector expansion and urban sprawl in Bathinda urban areas taking the help of Reilly's Law of retail gravitation.

3.7. The retail sector of Bathinda

This is initiated to see retail influenced area of the Converse revision (Converse, 1949) of Reilly's Law of retail gravitation, known as Breaking Point Model. Reilly's Law defined the breaking point of trade between two urban centers that study the ability to attract trade between two city or urban centers or trade areas is in direct proportion to the square root of the populations of the two cities and in proportion to the distance between these two cities. Regarding this particular study, Muktsar, Faridkot, Talwandi Sabo and Rampura Phul four bordering urban centers are considered.

Table 3

Sub category wise occupational structure of Bathinda city, (Census 2001).

Source: BTD report 2011, Govt. of Punjab

Code	Type of worker	Number of workers	Percentage
A & B	Cultivators	771	1.17
	Agricultural laborers	1074	1.63
	Plantation, Livestock, Forestry, Fishing, Hunting and allied activities	1200	1.82
C	Mining and Quarrying	49	0.07
D	Household industry	1585	2.40
	Manufacturing processing and repairs industry.	7789	11.80
E	Electricity, Gas and Water Supply	5100	7.73
F	Constructions	4576	6.94
G	Whole sale and Retail trade	14385	21.80
H	Hotels and Restaurants	844	1.28
I	Transport, Storage and Communications	4327	6.56
J & K	Financial Intermediation; Real Estate Renting and Business Activities.	4748	7.20
	Public Administration and Others	19535	29.61
	Total	65,983	100

Table 4
Breaking points from Bathinda.

Urban	Population	Breaking point from Bathinda (in kilometres)
Bathinda	285,788	-
Muksar	116,747	32.63
Faridkot	87,695	25.17
Talwandi Sabo	20,589	19.80
Rampura Phul	51,023	14.64

This relationship can be expressed as;

$$Da \rightarrow b = \frac{d}{1 + \sqrt{\frac{Pb}{Pa}}}$$

Where: $Da \rightarrow b$ = the breaking-point from city 'a' measured in miles to city 'b', d = the distance between city 'a' and city 'b', Pb = the Population of city 'b', Pa = the Population of city 'a'

The breaking point model provides a basic formula for demarcation trade area boundaries. Though it is a widely accepted model, it does not take cultural differences into consideration. According to Anderson et al. (2010), Reilly's Law and Converse's revision based on two primary assumptions as follows; The two competing cities are equally accessible from the major road and the Population is a good indicator of the differences in the goods and services available in different urban centers. Regarding the present study area Breaking Point Model to demarcate the trade area boundary is acceptable (Figs. 12–14).

The breaking point shows the boundaries of trade area (area covers and direction of coverage) in regards to neighbouring points of Muksar, Faridkot, Rampura and Talwandi Sabo. These areas are emerging urban areas having trade centres at Bathinda. The breaking model shows trade expansion towards the eastern part which clearly depicts that western part, maybe, has another important urban centre. Thus Bathinda's influential area extends towards the eastern part in terms of trade area.

4. Conclusion

The urban sprawl is unprecedented in Bathinda city due to the growth of the city centers, which reflect the growth of economic activities i.e., retailing and wholesale that is predominant in the city and the peripheries. While the demographic growth is observed, an un-uniform trend during the study period, the growth in economy and establishment is quite significant in Bathinda and its surrounding areas. The demographic features of rural and urban have shown changes tremendously as urban agglomeration has caused new economic establishments near highways. On a closer look using Reilly's law of gravitation, the influential area is prominent in the western and northern side where economic establishments and land-use changes are very significant. While the eastern and southern part growth/extension of city is few or not seen due to the presence of army cantonment acting as a barrier for growth. Thus it is significantly found that, while many studies on city sprawl or extension address the demographic change due to migration or the rural-urban or vice versa migration, the study here in Bathinda reveals that the growth of retail and wholesale has significantly contributed to urban sprawl.

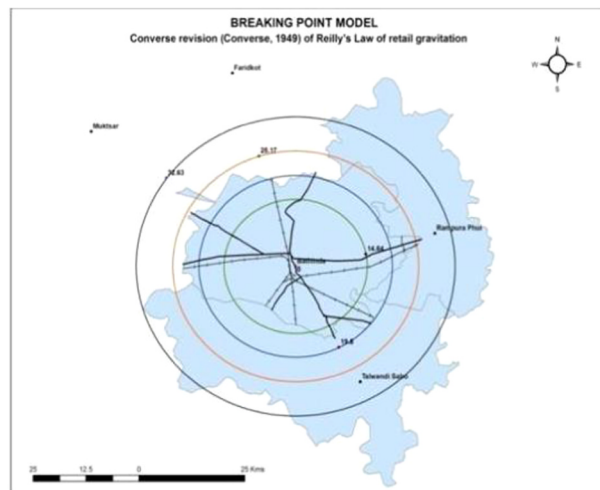


Fig. 12. Breaking Point Model I.

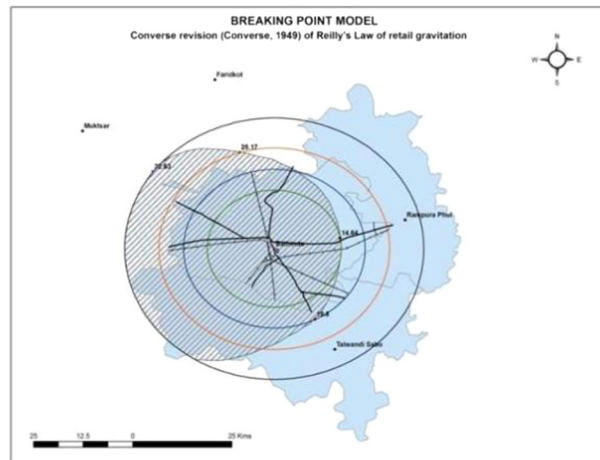


Fig. 13. Breaking Point Model II.

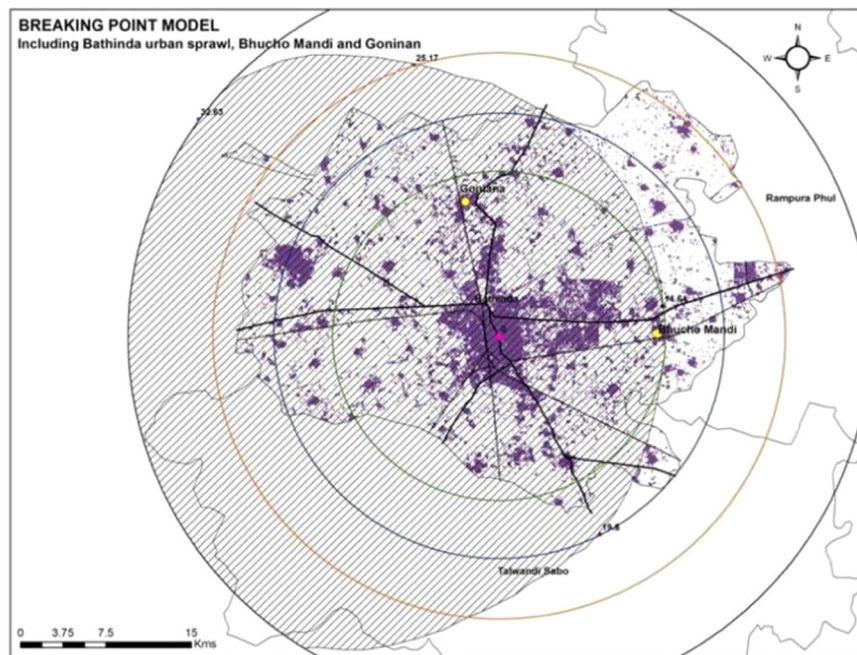


Fig. 14. Breaking Point Model III.

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