SindhUniv. Res. Jour. (Sci. Ser.) Vol. 51 (04) 733-740 (2019)
http://doi.org/10.26692/sujo/2019.12.116
SINDHUNIVERSITYRESEARCHJOURNAL(SCIENCE SERIES)

An Appraisal of Population Growth Rate through ESDA in Bahawalpur District, Pakistan

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Received 08th April 2019 and Revised 26th October 2019

Abstract: Exploratory spatial data analysis (ESDA) is one of the recently developed techniques in GIS used to analyze the statistical characteristics and spatial heterogeneity of population data. Current research is focused on the examination of spatial patterns of population growth rate in Bahawalpur district of Pakistan. Based on census data at union council level of the district, the present study uses specific techniques of ESDA including spatial autocorrelation and Moran's Index to analyze the distribution and concentration of population. Keeping in view the research objectives, paper is divided in two sections. The first section deals with the analysis of spatial distribution of population growth rate at a specific interval size. The second part of the research deals with the application of spatial autocorrelation to examine the spatial clustering of population growth in the district. The results of the study show the spatial clustering of population growth rate in the northern part i.e. Bahawalpur city. The study concludes that uneven and non- random population distribution is not the result of random chance and is associated with various factors. The study can be beneficial for population planning authorities to identify the major clustered areas of high and low population growth for planning and regional development of the area.

Keywords: Population Growth Rate, Spatial Autocorrelation, Moran's Index, ESDA.

1. INTRODUCTION

Population growth is the major determining factor of regional development but growth rate and doubling time are not same everywhere and all the time (Debbarma, *et al.,* 2018). Every sector of government needs accurate information about past and present data of population and resources because population growth rate plays a central role in forecasting the trends of future population growth and become beneficial for urban planners (Sibly and Hone 2002). Based on the previous year size of population, it refers to per capita growth of population and represented by 'r' is used as a key for future projections (Sibly and Hone 2002; Apenteng 2009). (UN 2019) defines the term population growth as 'Average annual rate of change of population size during a specific period of time and expressed as percentage'. The estimation of population growth rate depends upon census or other demographic data. However, census method possesses significant statistical power for high density regions. (Wunsch, *et al.*, 2005). According to khan (2011) Globally population growth is measured by subtracting crude death rate from the crude birth rate. Relative population growth is measured in rate of growth or percentage. The most common measure of population growth is annual rate of increase or decrease. Natural increase or decrease rate is the difference between crude birth and death rate. Rate of natural increase can also be calculated by subtracting deaths from births and dividing by total population of that specific year (Clarke 1972). Relative population growth is expressed as:

$$\frac{Pt2 - Pt1}{Pt1 * n} \times 100$$

Where Pt2 is the population of previous year, Pt1 is the population of recent year. Net migration rate can also be added to the above formula for better results. Positive growth rate expresses population increment while negative growth rate indicated population decline. Moreover, it can also be zero which indicated same number of people at two time (Khan 2011). (Wunsch, *et al.,* 2005) describes that average growth rate of countries vary from -1% per annum +3.5% but within smaller regions growth rates can have many variations for several reasons in the form of rapid increase or decline. However, in less developed countries growth rates of cities is observed to be higher as compared to rural areas due to migration and may increase more than 4%. Likewise growth rate, population density of the regions also varies from region to region depending upon the scale of measurement. (Zhang *et al.,* 2014) also discusses scale as basic parameter to measure the population density because large spatial scale can only give a macro pattern of population distribution. Therefore selection of minimum spatial scale is very essential to understand the distribution of population. Researches explain county level to be more appropriate for analyzing population distribution rather than

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provincial units (Cai, *et al.*, 2011; Zhang, *et al.*, 2014). Traditional old methods of population data analysis lack the capability of integrating quantitative population data with modern graphic methods (Liu 2003; (Henneberg, *et al.*, 2016). Introduction of new methods in geospatial technologies has provided a new perspective of studying human population at macro and micro level (Salvacion and Macandog 2015; Debbarma, *et al.*, 2018).Selection of appropriate method for population data analysis is very essential for urban planners. According to (Salvacion and Macandog 2015) population data is spatial in nature itself because human beings are spread over geographic spaces and advancement in geographic information system has made it very easy to integrate population data with GIS techniques for further analysis (Liu 2003; Bagarinao 2015). Spatial analysis using GIS oriented programs like Arc GIS and Geoda provides a wide range of techniques from basic descriptive to advance modeling based on various inferential statistical methods (Anselin and Bao 1997). Exploratory spatial data analysis (ESDA) is one of the modern and being widely used method for analyzing the pattern of population spatial distribution (Liu 2003, Reyes 2013; Haixia, *et al.*, 2016). Application of ESDA includes various techniques used to identify spatial clusters and outliers, detecting the pattern of spatial association and suggesting the regimes of spatial heterogeneity or homogeneity (Bae, *et al.*, 2008). Spatial autocorrelation is significant method of ESDA used to determine the spatial relationship of population data over time. Morans I statistics is the spatial index of autocorrelation used to evaluate the degree of spatial association among population data observations (Anselin and Bao 1997; Haining 2003) Henneberg(2016) also provided a new perspective of studying population distribution within Spain's municipalities using spatial autocorrelation and Moran's Index. Krishna (2017) examined the spatial relationship between census data of population distribution in five different states of India applying spatial autocorrelation using Moran's and Geary's index.

The current study was aimed to analyze the spatial distribution pattern of population growth in Bahawalpur district of Pakistan. The exploratory spatial data analysis of population growth rate in GIS environment provides statistically significant proof of spatial heterogeneity of population distribution in the district.

2. STUDY AREA

The focus of current study is Bahawalpur district that lies between 70° 54´ to 72° 50´East longitudes and 27° 48´ to 29° 50´ north latitudes. The district is located on the Southern side of Punjab province **(Fig. 1)**. It is bounded on the north by Multan, Lodhran and Vehari districts, on the East by Bahawalnagar district, on the south and south east by India, on the west by Rahim Yar Khan and Muzaffargarh. The district covers an area of 24,830 Km^2 which makes it the largest district of the province. Administratively, the district is subdivided into 05 Tehsils, 108 Union Councils(UCs) and 1,216 mouzas (PCO 1999) (**Table 1).**Urban centers of the district embrace five major city headquarters including Hasilpur, Khairpur, Ahmadpur East, Yazman, and Bahawalpur. Two towns namely Samasatta in Bahawalpur tehsil and Uch Sharif in Ahmadpur Tehsil are also included in urban areas of the district. Urban areas are governed by five Tehsil Municipal Administration committees and two town committees.

Table 1: Tehsil Wise Characteristics of Bahawalpur District

Tehsil	Area (Km^2)	Population (1998)	Population Density	UCs
Bahawalpur	2,372	806,580	340	36
Ahmadpur	1,707	718,297	420	31
Hasilpur	1,372	317,513	231	14
Khairpur Tamewali	888	184,914	208	8
Yazman	18,491	405,787	21	19

Source: District Census Report Bahawalpur (1998).

Physically, a large portion of the district on the southern side comes under Cholistan desert and experiences very sparse population distribution. While the northern part of the district exhibits a good agriculture potential and presents a home to main urban population centers. The variation in physical land cover of the district makes it significant for studying the spatial pattern of population distribution.

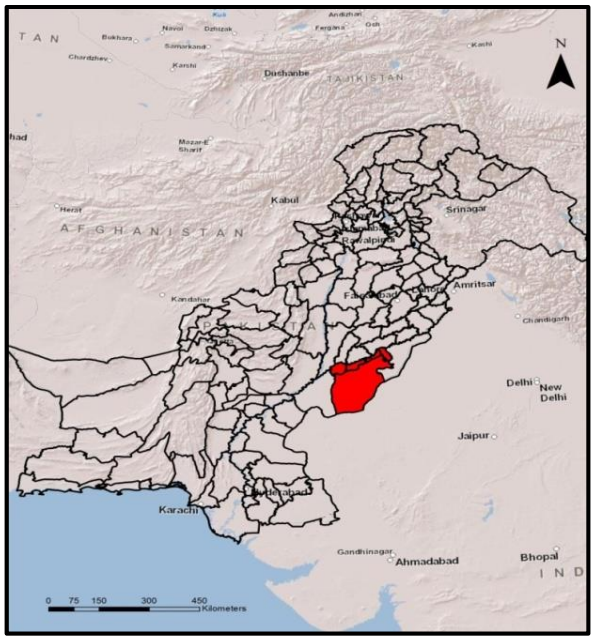

Fig1: Location of Bahawalpur District in Pakistan

3. DATA COLLECTION

Population data used for the current research was compiled and collected from District census report of Bahawalpur district for the years 1981 and 1998. Recent census data of year 2017 was collected from Pakistan Bureau of statistics **(Table 2).** Data was compiled at village or mouza level as mouza is the basic demographic unit for calculating population size in Pakistan. Villages falling in union council counted for whole district and total population of all villages for that union council was also calculated. Union council wise database was arranged and created in ArcGIS environment. As population in number of persons or individuals is not an accurate measure of examining population growth and distribution of any area. Therefore, spatial pattern of population growth and distribution was examined using indicators namely population growth rate. Inter census Population growth rates i.e from 1981 to 1998 and from 1998 to 2017were computed by applying following equation in Arc GIS.

$Pt_2 - Pt_1 / Pt_1 \times 100$
Where
Pt_2 = recent year population size
Pt_1= previous year population size.

To get the average annual population growth rate, resultant figure was divided by the years interval size e.g. population growth rate from 1981 to 1998 was calculated by subtracting the 1998 population from 1981 population and dividing the subtracted value from 1981 population. The resultant value is multiplied with 100 to get the growth rate percentage. The final value was divided with n (year's interval size) to attain the average annual population growth rate percentage.

To meet the research objectives and to examine the spatial distribution of population growth rate and density over time, spatial data of Bahawalpur district was prepared in GIS environment in the form of Polygon feature class of Union Council boundary of district Bahawalpur and joined with geo database of attribute tables (**Table 2)**

Table 2: Types and sources of data used in study

Type of data	Source
Population 1981	District census report 1981
Population 1998	District census report 1998
Population 2017	Pakistan Bureau of statistics
Union council based map of Bahawalpur District	District Commissioner office, Bahawalpur (Census 2017)

4. DATA ANALYSIS

After processing the data spatial pattern of population growth rate was analyzed through ESDA in two GIS oriented programs i.e. Geoda and ArcGIS 10. Geoda basically provides a user friendly interface and was used to analyze the descriptive and inferential statistical analysis of population data (Anselin and Bao 1997; Anselin, Syabri and Kho 2006; Scott and Janikas 2010). ArcGIS was used to analyze the spatio temporal patterns of population growth rate in study area.

Simple statistical analysis of population growth rate was done through boxplot analysis of population growth rate in Geoda which provides a meaningful analysis of central tendency and standard deviation of population growth rate. While its spatial pattern was analyzed by making quantitative maps of population growth rate at a defined interval size of 2.5% for the two respective years in ArcGIS. Tehsil wise analysis of population maximum and average growth rates in every Tehsil of growth rate was also sorted to compute the minimum, the district. Furthermore, IDW spatial interpolation technique was also applied to predict the distribution pattern of population growth rate from low to high values across the whole district (Cai, *et al.*, 2011).

Spatial autocorrelation is one of the statistical methods of ESDA that is used to express the random, dispersed and clustered pattern of spatial distribution. In present study, Global Morans I statistics was used to calculate the spatial autocorrelation of population growth rate and computed the Morans Index value, z score value and p value (Wilson and Fotheringham 2008; Scott and Janikas 2010). Morans Index value ranges from -1 to +1. Resulting values greater than 0 and near to +1 create a clustered pattern, while less than 0 and near to -1, create dispersed pattern, and value equal to 0 shows random distribution pattern (Scott and Janikas 2010). Other than Global Morans I test, local Morans I test known as Anselin Local Morans Index was also used to identify spatial clustering of population growth at local scale with high or low values (Anselin and Bao 1997).

5. RESULTS

Spatial distribution of Population growth rate

Spatial distribution of population growth rate in Bahawalpur district from 1981 to 2017 was studied at union council level **(Fig 2)**. It was observed that high population growth rate was mainly found in urban UCswhile low population growth rate in rural UCs. (**Fig 2)** show the intercensus average annual growth rate from 1981 to 1998 and 1998 to 2017 at union council level in Bahawalpur district. Growth rate was analyzed with a defined interval of 2.5 percent in the district. It was observed that 20 UCs of the district experienced low growth rate of 1 to 2.5% from 1981 to 1998 and 38 union UCs experienced the same low growth rate from 1998 to 2017. 52 UCs of the district experienced the medium growth rate of 2.51 to 5% from 1981 to 1998 and 41 unoion councils experinced the same growth rate from 1998 to 2017. Moreover, 18 union coucils

experinced the growth rate of 5.1 to 7.5% and 17 UCs experineced the same from 1998 to 2017. Furthermore, 06 UCs experienced the growth rate of 7.5 to 10 % in 1998 and 07 UCs of bahawalpur city grew at the same rate from 1998 to 2017.Besides, high population growth rate of 10 to 12% was found in 04 urban UCs of bahawalpur city in year 1998. 4 urban UCs of the same city experienced the very highest growth rate of 12 to 15% in 1998. These UCswere explored as "upper outliers". After analysing positively high increase in population growth rate of the district, it was further examined that 04 UCs of the district i.e. 23 and 27 of tehsil Bahawalpur ,UC number 40 of tehsil hasilpur and99 of tehsil yazman experinced the negative growth rate of less than 0% in 1998 and UC number 30 of Bahawalpur tehsil, 66,67 and 88 of Ahmadpur East, UC number 42 of Hasilpur and 56 of khairpur experienced negative growth rate from 1998 to 2017 and called as "lower outliers". Negative growth rate observed in the district indicated rural urban migration in the district especially around the Bahawalpur and Hasilpur city.

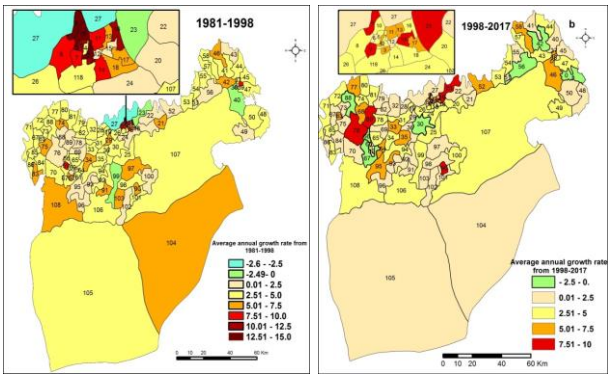

Fig 2: Spatial distribution of population growth rate in Bahawalpur District

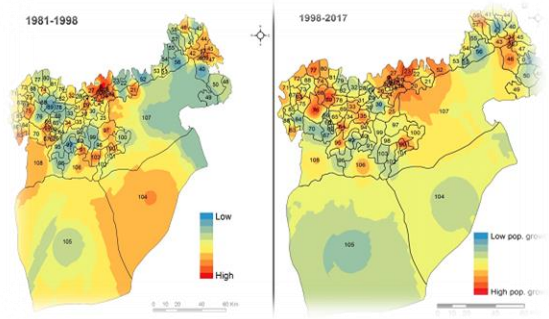

Fig.3. Spatial trend of population growth rate using IDW spatial

(Fig 3), displays the spatially interpolated growth rate of the district in two respective timeperiods. It shows the trend of growth rate distribution ranging from low to high values and revealing high population growth rate in the north of district reflecting more population pressure in Bahawalpur tehsil as compared to others. Furthermore, urban UCs of the tehsil Hasilpur and Yazman were also found growing at high rates. Other than urban UCs of the district, rural UCs of the district also showed significant changes in growth rate in two respective time periods. Some rural UCs of tehsil Yazman namely Chak 1/DNB, 117 DB and Basti Meerana showed high population growth rate from 1981 to 1998 but low population growth rate from 1998 to 2017. Similarly south eastern side of tehsil Yazman namely Channanpur showed high growth rate in 1998 and medium to low growth rate during 2017. Similalry, mid north west of tehsil Ahmadpur East namely kotla Musa Khan, Khurrumpur and Ali Khraik (UCs 68, 76 and 89) showed low growth rate trend in 1998 and high growth trend in 2017. Overall, highest growth rate centre was found around tehsil Bahawalpur reflecting more population pressure towards north of the district. (Table. 3) shows descriptive statistics of population growth rates showing minimum, maximum and average annual growth rate for every tehsil of the district. There was 15% maximum growth rate observed in the district accompanied by tehsil Bahawalpur followed by 8.8% for Tehsil Hasilpur, 8.1% for Tehsil Ahmedpur, 6.9% for Tehsil Yazman and 3.9% for Tehsil Khairpur from 1981 to 1998. From 1998 to 2017,maximum growth rate for Bahawalpur tehsil was observed to be 9.9%, followed by 8.8% for Tehsil Ahmadpur, 8.3% for tehsil Yazman. Exploratory spatial analysis of population growth rate from 1981 to 1998 and 1998 to 2017 are presented in box plot (Fig. 4). The red bar in the middle of box plot shows the median value that is 3.74 for 1998 growth rate and 2.9 for 2017 growth rate while green dot is showing mean value of growth rare and dark part is the interquartile range from 25th percentile to 75th percentile. Individual observations of population growth rate are shown as blue dots and observation above and below thin line are positive and negative outliers. Analysis shows that there are 2 negative growth rate values which are called as "lower outliers" and 9th positive growth rate values which are called as

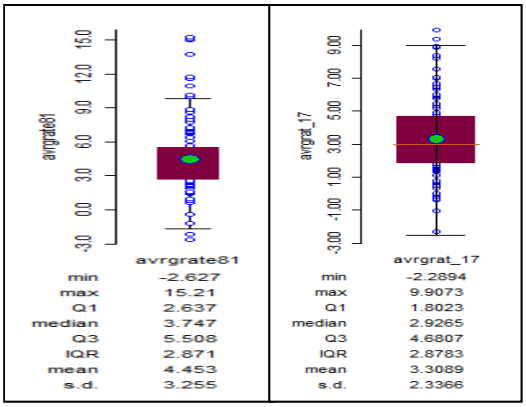

Fig. 3: Boxplot of PGR (1981-998, 1998-2017)

Table 3: Summary Statistics of Population Growth

Indices	Population growth rate (1981 to 1998)			Population growth rate (1998 to 2017)		
	Average	Minimum	Maximum	Average	Minimum	Maximum
Bahawalpur Distt.	4.3%	-2.6%	15%	3.3%	-2.2%	9.9%
Bahawalpur tehsil	6.1%	-2.6%	15%	4.1%	-0.3%	9.9%
Hasilpur tehsil	3.9%	-0.3%	8.8%	2.7%	-1.9%	6.0%
Khairpur tehsil	2.5%	0.9%	3.9%	3.01%	-0.3%	6.4%
Ahmadpur tehsil	3.7%	0.9%	8.1%	3.1%	-2.2%	8.8%
Yazman tehsil	3.6%	-2.0%	6.9%	2.6%	0.4%	8.3%

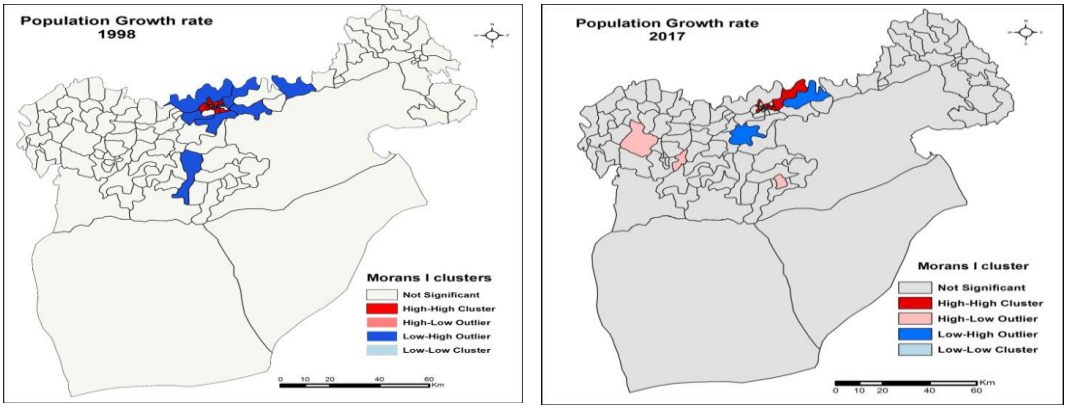

Fig. 4: Cluster and Outlier analysis of Population growth rate in two respective years

"upper outliers" in box plot of 1998 population growth rate while there are 2 " upper outliers" in the box plot of 2017 population growth rate. From rest of observations 25% to 75% lies in the growth rate from 2.2 to 5.51 in two respective years. **(Fig. 5**) shows the cluster and outlier analysis of population growth rates using Anselin Local Morans I test in arcgis detecting the high and low clusters with similar growth rate values. High High clusetrs reprensts UCs with highest similar growth rates and Low low clusters represents lowest similar gorwth rates. While low high outliers represnts UCs with low growth rates surrounded by high growth rate UCs. Analysis displays that 14 UCs making high high cluster are present in the northern side of the district where Bahawalpur city is located and it is surrounded by 9 low high outliers with low growth rates for the year 1998. Similalry growth rate analysis of year 2017 shows that there are 7 union councisl making high high cluster of population growth rate exactly in the north of district followed by 3 HL outliers and 3 LH outliers.

Table 4 shows the summary statistics of spatial autocorrelation using Global Morans I test. Positive Moran Index value of 0.5 for growth rate of 1998 and 0.009 for growth rate of 2009 shows that significant (p value < 0.001) clustered pattern is present at UC level in Bahawalpur district. High z score and small p values clearly reflects that there is very small probability that spatial pattern of population growth rate and density could be the result of random process. High high distribution clusters and low high outliers reveals moderate to high level clustering of population distribution within Bahawalpur District.

Table 4: Spatial autocorrelation of PGR using Global Moran's I

Year	Observed	Expected	variance	Z score	P-value	Pattern
1998	0.5569	-0.0092	0.000788	20.165	<0.001	Highly clustered
2017	0.0995	--0.0091	0.000803	3.835	<0.001	Moderate clustered

Table 5 shows the list of UCs making low high clusters for two respective years of population gorwth rate in Bahawalpur District.

Table 5: List of UCs making high and low cluster (Cluster-Outlier Analysis)

Population Growth rate	
High High cluster	**Low High clsuter**
Bahawalpur Urban 1	Bahawalpur Urban 12
Bahawalpur Urban 2	Bahawalpur Rural 20
Bahawalpur Urban 3	Bahawalpur Rural 22
Bahawalpur Urban 5	Bahawalpur Rural 23
Bahawalpur Urban 6	Bahawalpur Rural 24
Bahawalpur Urban 7	Bahawalpur Rural 26
Bahawalpur Urban 8	Bahawalpur Rural 27
Bahawalpur Urban 9	Khairpur Rural 52
Bahawalpur Urban 10	Yazman Rural 99
Bahawalpur Urban 11	
Bahawalpur Urban 13	
Bahawalpur Urban 14	
Bahawalpur Urban 15	
Bahawalpur Urban 16	
Bahawalpur Urban 17	
Bahawalpur Urban 18	

6. DISCUSSION

Spatial analysis of population growth rate changes in (**Fig.6)** shows that many UCs of the district experienced neative growth rate change from minimum -0.04% to -12%. 44 UCs of the district experinced slight low neagtive growth rate change of -0.01% to -2.9%. Out of these 44 UCs 14 belongs to thesil Ahmad pur East, 13 from tehsil Bahawalpur, 7 from tehsil Hasilpur, 9 to tehsil yazam and 2 from Khairur. Afterwards, 20 UCs from tehsil Bahawalpur, Yazman and Ahmadpur experienced a neagtive growth rate change of -3% to -5.9% from 1981 to 2017. High neagtve growth rate change of more than -9% is found in 4 UCs of Bahawalpur city. Spatial Autocorrelation analysis also proved that intensity of popualtion growth clustering decreased from 1998 to 2017. High Moran's Index value of 0.5 in 1998 predicted high clustered pattern while decreased index value of 0.099 in 2017 predicts moderate level of population clustering in the district.

Alongwith negative growth rate change, the district also experienced some positive change in population growth rate during 1981 to 2017 **Fig.6)** shows that 20 UCs of the district experienced a slight positive increase in growth rate of 0.07% to 2.9%. Most of the UCs of this category were from thesil Yazman and Bahawalpur and Ahmadpur. Futhermore 04 UCs of tehsil Ahmadpur, 02 from tehsil yazman, and 03 from Ahmadpur experinced a positive growth rate increase of 3.01% to 6%. The highest positive growth rate change of more than 6% was observed in 04UCs of the district.

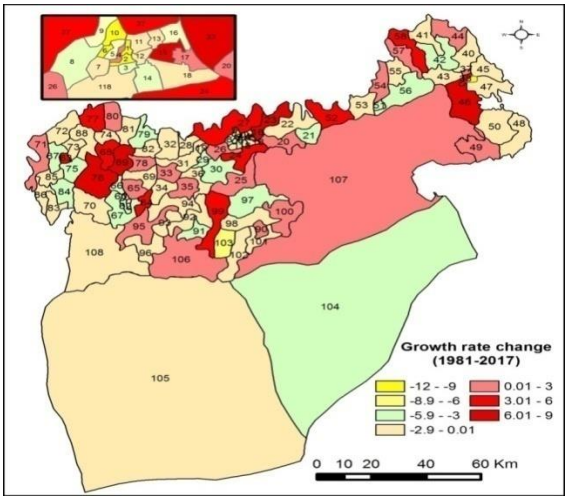

Fig. 5: Spatial pattern of population growth rate change in Study area

This changing pattern of population gorwth rate in the district is associted with many factors including social and economic development, improved infrastructure of the cities, rural to urabn migration for the sake of education and employement oppertunities, Agricultural intensification in rural areas of the district, imrpoved transportation facilities and infrastructure and many more. Furthermore, many demographic factors are also involved in shaping the spatial pattern of popualtion growth in the district especially in rrual parts of the district. Spatial analysis of population growth rate shows that some rural UCs of the district also experienced high growth rate of 5 to 7% from 1981 to 1998 and again from 1998 to 2017. According to (Khan 2013) rural- urban fertility differentials can be one of the factors for high growth rate in rural villages because fertility of rural women in every age group is more than fertility of urban women in Bahawalpur District. Factors that lie behind high fertility rate in rural areas of the district are lower literacy rate, early age marriages and willingness for more children. Moreover, agrarian structure of the district is also triggering lower literacy rate and involvement of child labor in agricultural activities. Therefore, many rural UCs of the district are experiencing annual population growth rate from 2.5% to 6% in 2017.

Other than demographic factors, intensification of agricultural activities is also a reason of high popualtion growth rate in rural UCs of tehsil Yazman. Development of new farmlands near Derawar Fort since 2009 engaged the population of tehsil in agricultural activities which demotivated people for out migration. Additionally, development of transportaion infrastrure in the form of road network expansion also increased the accessibility towards rural UCs of tehsil Yazman. Therefore, population residing nearby their agricultural fields and keeping their livestock does not leave their home place at any cost. Though seasonal migration towards irrigated areas for temporary employement oppertunities, water avaialbility, and livestock grazing is a prominent feature of rural UCs of cholistan desert (Soharwardi, Khan and Khalid 2014). Runoff farming and rainwater harvesting are also playing an important role to provide water for local community and their livestock and also for minor irrigation and agricultural activities and overall supporting this semi permanent population(Ahmad 2013). Role of rural women in agricultural activities is also worth mentioning because they are involved in the whole process of crop production such as thinning, sowing, transplanting, harvesting and post harvesting operations like threshing, husking and storage.

All the above discussion shows that a distinct social and economic structure prevails in the far most rural parts of the district and keeps its own and unique population distribution pattern. Rural UCs in the surroundings of tehsil head quarters like Bahawalpur city, yazman city, hasilpur city have comparatively lower growth rate or negative growth rate**.**UC Jhangiwali and Khanuwali (23 and 27) in the north of

Bahawalpur city, UC Hasilpur Old (40) of tehsil Hasilpur and Chak 67/DB (99) of tehsil Yazman experienced negative growth rate of -2% to -3% in 1998 reflecting rural urban migration towrds cities. Similalry negative growth rate of -2.5% is observed in UCs Khud Bax mehar and Sukhal of tehsil Ahmadpur East. Alongwith negative growth rates in suburbs of the cities high positive growth rates are observed within the city like Bahwalpur, Ahmadpur and Hasilpur cities. It is resulted from above analyais that's cities are growing at maximum growth rate of 10% to 15% from 1981 to 1998 and 7.5 to 10% from 1998 to 2017 showing some stability or decrease as compared in the previous time span.

Increased annual rate of popualtion growth in the urban settlements are reflecting urban agglomeration specially in Bahawalpur city. Improved living and health facilities (Water nd Sanitation), upgraded medical facilities in urban centers of the district have lower down the mortality rate and increased the life expectancy. Moreover improved maternal health facilities have also decreased the chances of infant mortality rate. All such reasons became a major cause of high population growth rate in urban UCs of Bahawalpur City prompting it at initial stage of urbanization with comparatively high growth rate due to high proportion of young adult migrated population. (Khan 2013).

7. CONCLUSION

The study reveals that population growth rate is the most influential variable of determining the distribution of population in the Bahawalpur district. Study uses the GIS based spatial techniques for analyzing the distribution pattern of population growth rate in the district. The exploratory spatial data analysis (ESDA) of population growth rate shows that there is spatial heterogeneity found in the district which reveals that population of the district is not randomly distributed but exhibits a clustered pattern. Modern geospatial techniques of autocorrelation using Moran's index proves that urban union councils of Bahawalpur city is the most urbanized part of the district located on the extreme north and is surrounded by union councils with low population growth rate. The analysis depicts that Bahawalpur City is facing a high population pressure in terms of rural-urban migration.

The study can provide a new methodology for population geographers to analyze the population and resource distribution in the region. The research can be beneficial for urban planners to identify the major clusters of high and low population centers. The study recommends that application of modern geo-spatial techniques can be beneficial for analyzing the spatial trends of population distribution and resource allocation.

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