



# Mapping out regional disparities of reproductive health care services (RHCS) across Pakistan: an exploratory spatial approach

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## Abstract

Although Pakistan has reduced maternal mortality ratio by 57% over the last 2 decades, Millennium Development Goals (MDGs) unmet maternal mortality targets are a matter of concern to achieve the Sustainable Development Goals (SDGs) by 2030. Provincial level maternal mortality data suggested large disparities and inequalities within the country. Therefore, the primary objective of this study was to identify the national- and provincial-level spatial inequalities regarding access to reproductive health care services. Exploratory Spatial Data Analysis (ESDA) was used to leverage the information of spatial clusters and outliers based on the Reproductive Healthcare Services (RHCS) index of 2004 and 2014. Growing high–high clusters were only found in the North-east Punjab Province and neighboring Khyber Pakhtun Khawa Province. Conversely, low–low clusters increased in North Baluchistan and neighboring districts south of Khyber Pakhtun Khawa and southwest of Punjab. The present study is one of the first attempt to investigate the national- and provincial-level variations for access to reproductive healthcare services across Pakistan. The findings provide valuable insights for the government and policymakers regarding the dimensions of clusters to address reproductive healthcare issues in vulnerable districts. These results also revealed many questions that need further investigation to uncover the determinants of these geographical clusters and outliers in reproductive healthcare services.

**Keywords** Maternal mortality · Reproductive healthcare services · Provincial spatial inequality · Spatial analysis

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## 1 Introduction

Pakistan has reduced maternal mortality by 57% over the last 2 decades. However, large disparities and inequalities still exist within the country. For instance, the Maternal Mortality Ratio (MMR) in Punjab is 227 out of 100,000 live births, whereas it is 758 in Baluchistan (PDHS 2006–07). The primary causes of maternal mortality or morbidity are excessive bleeding, hypertensive disorder, and sepsis. All of these complications are preventable if women have access to Antenatal Care (ANC) and presence of Skilled Birth Attendants (SBAs) at the time of delivery (WHO 2019). However, according to a national estimation, access to SBAs and ANC is 52.1% and 36.6% respectively. Apart from that, huge disparities can also be found in access the SBAs (the highest is in Sindh at 60% with the lowest in Baluchistan at 17.8%) and ANC (44.4% in Sindh as the highest compared to 12% in Baluchistan at the lowest) (PDHS 2012–13).

In addition, Pakistan has already missed maternal and neonatal targets of MDGs, and the outcomes are a matter of concern to achieve the Sustainable Development Goals (SDGs) by 2030. Bhutta and Reddy (2012) suggest that progress is best measured at the aggregate level to see the overall performance in a particular sector; however, progress may act to widen inequalities. In a developing country like Pakistan, where there are scarce resources, achieving maternal health-related SDGs requires an analysis to identify the most marginalized communities where access to healthcare services has not changed over time or worsened.

The poor health outcomes would ultimately affect the human development of the country (Onarheim et al. 2016). The economic performance and development are tied with the health of women, because healthy women provide healthy and educated generations to the society. Another research investigated that maternal mortality or morbidity does not only affect an adult, but it limits the productivity, increases the medical cost, and reduces the savings and investment patterns of a household (Reed et al. 2000).

In this context, this research uses exploratory spatial data analysis methods to investigate the subnational situation and spatial inequalities regarding access to reproductive health care services in Pakistan. First, this paper proposes a reproductive health care services index to check the inequalities and maps out the marginalized districts at the national level using geospatial data. Second, for more in-depth analysis, the national map is categorized into four provincial maps to identify the clusters within provinces to reach out the most left behind regions and compare inequality with high access districts. Finally, a comparison between national- and provincial-level clusters is used to explain more comprehensive location-based information for the purpose of providing policy recommendations.

In the past, numerous studies have addressed the inequalities of women's access to maternal health services in Pakistan. For example, a study that discussed the disparities in access the maternal health care services in the context of Pakistan revealed that gender and class are possible factors of inequality (Mumtaz et al. 2012). Another study that profiled the poorest women in the country concluded

that the pattern of access to healthcare service among poor women is much lower than the women in the fifth quintile (Agha 2014). However, the role of space (i.e., physical location) is missing in the context of women's access to maternal health care services in Pakistan. Therefore, the paper of Anselin et al. (2007) can be considered a seminal study in this field. As such, the current paper is consistent with some of its core methodological aspects. Nevertheless, the current paper is different on at least two fronts.

To the best of the author's knowledge, this is the first attempt of spatial analysis to evaluate the role of space at the national and provincial levels in the context of reproductive health services in Pakistan. Second, comparison between national- and provincial-level clusters is used to explain more comprehensive location-based information for the purpose of providing policy recommendations. The study aims to fill this void in the literature by answering these questions: Is there an overall clustering pattern in the spatial distribution of maternal health services? What districts can be identified as high–high and low–low clusters in terms of access to maternal health services? What is the relationship between the spatial distribution of macro- and micro-level LISA analysis?

Based on these questions, the study first provides the overall picture of access to reproductive health care services all over the country in 2004 and 2014. The results indicate that the overall situation has improved in 1 decade. Next, global and local spatial autocorrelation has been used to understand spatial dependence across districts. The results show the persistence of spatial clusters over time and an increase in the country's spatial dependence. Finally, I divided the country into four provinces to identify the clusters within provinces. The majority of the prior research has applied Local Indicator of Spatial Autocorrelation (LISA) at the macro-level to identify the geographical representation of clusters or outliers. In contrast, the formulation of national and regional policies should carefully consider the risks of information loss due to data aggregation. Aggregating regional differences from the municipal to the state level can hide the local clusters (Santos-Marquez and Mendez 2020). Therefore, this study attempts to do LISA analysis at the national and provincial level in the same paper to compare the macro- and micro-results of local indicators of spatial autocorrelation. The results indicate that low–low clusters or low access to reproductive health care service districts persist in similar geospatial locations at the macro- and micro-level analysis.

The rest of the paper is organized as follows. The second section will provide a snapshot of related literature. The third section will explain the paper's methodology, namely, principal component analysis, global spatial autocorrelation, and spatial indicator of autocorrelation. The fourth section will describe the results of each method that is used in this research. The fifth section will present a discussion and policy implications. Finally, the sixth section will conclude and explain the importance of the findings.

## 2 Related literature

### 2.1 Measuring regional disparities using spatial data

Anselin et al. (2007) stated that spatial data analysis is essential for the policy implication, because the aggregate approach of state-level policy might not address the risks existing across different regions, varying in different jurisdictions. In their paper, they have leveraged the information of child risk through exploratory spatial data analysis for the counties in Virginia. This paper also used a Principal Component Analysis (PCA) model to generate a child risk scale to provide summary information on the multiple child-related indicators.

Mohanty and Bhanumurthy (2018) mentioned that exploratory spatial data analysis helps identify the use of different policies for different regions' spatial clusters. Jin et al. (2015) similarly used geospatial data to measure the spatial accessibility to healthcare facilities in China's Deqing province. They concluded that spatial data analysis is a successful tool to give an affective policy direction.

Panda et al. (2020) are one of the most comprehensive studies that used geospatial data; at first, they composite the Coverage Gap Index (CGI) and Socio-economic Development Index (SDI) to assess the links between SDI inequalities in CGI at the national level. The research used CGI geospatial data to identify the hotspot and cold spot districts regarding reproductive, maternal, neonatal, and child health coverage in India. The results suggested that many districts are at a high risk of failing to achieve universal health coverage and the underprivileged population needs closer attention to reduce the CGI.

### 2.2 Importance of access to the maternal healthcare services

The Regional Committee for Africa (WHO 2000) reported that maternal mortality remains a challenge for the twenty-first century for many developing countries that can be addressed by providing essential healthcare services during pregnancy or at the time of childbirth. Another study, Koblinsky et al. (2006) describe that increasing the supply of skilled health professionals and strengthening the health care system will reduce maternal deaths. A number of authors concluded that the presence of SBAs is a positive factor in reducing the number of maternal deaths (Bernis et al. 2003; Ljungblad et al. 2019; Prata et al. 2011). A report published by UNFPA (2012) also suggested that SBAs could prevent two-thirds of all maternal deaths. According to Blumenthal et al. (2010), skilled birth professionals are not only essential to save lives of the mother and newborn but also provide family planning education, because unintended pregnancy remains a global health issue that results in adverse birth outcomes.

Similarly, a vast literature also emphasizes the use of Antenatal Care (ANC) during pregnancy to prevent maternal mortality and morbidity, such as Pandit (1992) who describes the role of ANC as a useful tool to reduce maternal mortality. Kuhnt and Vollmer (2017) also found that the effectiveness of ANC offered

to pregnant women is directly associated with improved birth outcomes. Pervin et al. (2012) researched Bangladesh to determine the role of ANC on maternal mortality; they reported that ANC visits increase the prenatal survival chances.

### 2.3 Maternal healthcare services and its utilization in Pakistan

The MDGs report published by UNICEF (2015) reported that in Pakistan, access to SBAs and ANC is 52.1% and 36.6% respectively, which resulted in the failure of meeting MDG goals five by 2015. According to the World Bank database (2019), lifetime risk of death due to pregnancy-related issues is 1 in 180 in Pakistan, the highest among south-Asian regions compared to 1 in 290 in India, 1 in 250 in Bangladesh, 1 in 230 in Nepal, and 1 in 1300 in Sri Lanka. Nisar et al. (2017) assessed the maternal health situation in Pakistan over 20 years and stated that 84.78% of maternal mortality in Pakistan occurred due to direct causes of death. WHO (2019) suggested that all the direct causes of maternal deaths can be preventable through timely management and treatment by skilled health professionals.

### 2.4 Drivers causing inequality to utilize the maternal healthcare services in Pakistan

#### 2.4.1 Demand side factors

Inequality in access to maternal healthcare services is well documented in the previous literature. Mumtaz et al. (2012) discussed the power dynamic of gender and class-based exclusion that prevent the marginalized women to access the maternal healthcare services. Similarly, Rizvi and Nishtar (2008) also revealed that despite strengthening the health system, the main obstacles to utilize the healthcare services still need to be addressed, namely, the non-availability of female healthcare providers, women's illiteracy, and the lack of women's empowerment to make health-related decisions. It is necessary but not sufficient, for the health system that good maternal health services are widely available; use of these services involves individual's behavior and decision-making of families. Another study reported that although government has strengthened the district health care system through improving the technical and managerial capacities, maternal health seeking behavior is subject to a range of societal constraints including poverty, the low status of women, and illiteracy (Mahmud et al. 2011).

Research conducted in the Jhangara region of Sindh Pakistan concluded that women at a young age are less likely to receive antenatal care than the elder one (Fatmi and Avan 2002). Another study analyzed the inequity in the use of facility-based delivery in three South-Asian countries, including Pakistan. The results revealed that education status, income status, and number of antenatal care visits influenced the place of delivery (Rahman 2021).

### 2.4.2 Supply side factors

The federal government of Pakistan has the primary role in formulating the national health policies, while the provincial and district governments are responsible for implementing those policies. A study that analyzed three maternal and child health policies of Pakistan concluded that the ministry of health needs cost-effective strategies to protect cuts in resource allocation (Siddiqi et al. 2004). Moreover, the government needs shreds of evidence to identify the most marginalized areas in need of improvements. The research also emphasized that due to political instability, healthcare policies have not been implemented between 1990 and 2001. Similarly, a study conducted by Bhutta and Hafeez (2015) presented a range of actions to improve Pakistan's maternal and child health situation. It stated that the government needs to strengthen the district-level information about maternal mortality or morbidity to enhance the quality of district healthcare facilities.

A country cooperation strategy report published by WHO (2011–2017) reported that facilities provided by emergency obstetric care (EmOC) in Pakistan do not meet the minimum requirements set by WHO. It resulted in the low utilization of public healthcare facilities. Similarly, research conducted in Sindh Pakistan analyzed the provision of maternal healthcare services in the private sector. The results revealed that huge cost disparities could be found among public and private facilities (Khowaja et al. 2018). The private sectors are an expensive choice, because, primarily, it serves as the fee-for-service system without any regulatory framework (Siddiqi et al. 2004).

## 3 Data and measures

Data of RHCS was taken from Pakistan Social and Living Standard Measurement (PSLM) data produced by the Pakistan Statistics of Bureau (PBS) in alternate years at the provincial and districts level up to June 2015. The PSLM survey was conducted with the particular aim of development and planning at the district level in MDGs. PSLM has monitored different sectors such as education, health, water and sanitation, household economic situation, and satisfaction level by the facilities; however, this research has used only maternal health care indicators to estimate the results. The PSLM survey covered about 80,000 households at the district level and 26,000 at the provincial level, whereas restricted military areas were excluded from the survey. Ten surveys were conducted from 2004 to 2015, and micro-level reports are published on the PBS homepage.

This research has used data from 118 districts (see Appendix Table 4) of all four provinces and removed military restricted areas due to data unavailability. The shapefile has taken from the Humanitarian Data Exchange (HDE) website, and analyzed on GeoDa.

### 3.1 Research variables

Based on the literature review, the present study has chosen two variables that helps to reduce the preventable causes of maternal mortality.

ANC is the maternal care pregnant women receive during pregnancy. Having access to ANC mitigates all life-threatening diseases and ensures on-time professional advice or medication to allow for a safe motherhood journey. ANC rate reflects the percentage of women aged 15–49 having at least four visits to a health-care professional during pregnancy in the last 3 years.

SBA is the number of women who have assisted birth at a healthcare facility. Assisted birth is essential due to sudden complications at the time of childbirth that cannot be handled by the traditional birth attendants. SBA reflects the percentage of women aged 15–49 who gave birth at a healthcare facility in the last 3 years.

The study analyzes two different periods, 2004 as the initial year and 2014 as the final year, to see whether inequality has reduced over 1 decade. Appendix Fig. 9 demonstrates that the LISA analysis of ANC and SBAs indicates a similar clustering pattern; therefore, creating a single scale would be appropriate to visualize the information and avoid unnecessary explanation. Based on the approach used by Anselin et al. (2007), this research has also adopted Principal Component Analysis (PCA) technique. It helps to obtain a linear combination of the original variable for each of 2 years and provide a summary of information on both indicators. The principal component index will simplify the analysis and look for the data's spatial patterns. Moreover, the scale for each period (2004 and 2014) allows comparing the spatial pattern of clustering in the data.

## 4 Methodology

This section explains the methodologies used in this study. All spatial analysis is carried out using the GeoDa software package.

### 4.1 Principal component analysis (PCA)

Principal component analysis (PCA) is a multivariate technique used to reduce the extensive data set of a variable and summarize it into one scale. The new variable obtained from PCA is uncorrelated and captures most of the large dataset's original information. It extracts the essential information, gives more visualization, and simplifies it.

### 4.2 Spatial connectivity structure and spatial weights matrix

Assigning weights helps to measure the intensity of the relationship among pairs of the spatial unit. There are numerous ways to compute the spatial weights to see the variation in the results. Anselin et al. (2007) used five different spatial weight

matrices. Ahmed (2011) used two approaches, distance and contiguity matrices, to assess the regions' spatial effects. This study employed only one weight ( $W$ ) matrix for Pakistan, queen contiguity, to compute the spatial weight. The concept of queen contiguity is that if a district  $I$  is a border with another district  $j$ , they would be considered neighbors. Queen-contiguity weights define neighbors as those with common borders on north, east, west, south, and corners and verticals. The  $W_{ij} = 0$  for the diagonal element, because one region cannot be a neighbor to itself.

### 4.3 Exploratory spatial data analysis (ESDA)

ESDA helps us to identify the pattern of data and summarize the main characteristics of the data. The conventional method of Exploratory data analysis (EDA) helps deal with the relationship between the variables. However, ESDA helps us to correlate the values of the same variable among neighbors. The tool to do this analysis is called spatial autocorrelation. Spatial autocorrelation is used to identify the existence or non-existence of spatial variance. It has a positive or negative value. For example, neighbors having the same values, high–high or low–low, would have positive spatial autocorrelation. In contrast, Anselin et al. (2007) mentioned that neighbors with different values, such as high value next to a low value, would negatively impact spatial autocorrelation. There are two main methods of ESDA; global and local spatial autocorrelation.

#### 4.3.1 Global spatial autocorrelation

Global spatial autocorrelation is used to assess the similarity across districts with respect to access to RHCS. It helps us to identify the overall clustering of a variable in the space and aims to test the null hypothesis of spatial randomness. Moran's  $I$  test is the most commonly used measure to detect spatial patterns and provide graphical representation. The global Moran's  $I$  statistic is defined as

$$I_i = \frac{N}{\sum_{i=1}^n \sum_{j=1}^n w_{ij}} \left[ \frac{\sum_{i=1}^n \sum_{j=1}^n w_{ij} (X_i - \bar{X}) (X_j - \bar{X})}{\sum_{i=1}^n (X_i - \bar{X})^2} \right]. \quad (1)$$

In this equation,  $N$  explains the number of regions that will be analyzed, is an element of the spatial  $W$  matrix, and explains the neighborhood's structure, the values of access to RHCS of regions  $i$  and  $j$  are the average value of access to RHCS.

Anselin et al. (2007) mentioned that high value of Moran's  $I$  (greater than 1.96) and a positive  $z$ -value indicate statistically significant clustering across the districts. A low value of Moran's  $I$  (less than  $-1.96$ ) and negative  $z$ -value indicates being clustered in a competitive way. Similarly, the slope of Moran's scatter plot corresponds to the spatial correlation, and the four quadrants explain four different types of association among regions.



### 4.3.2 Local spatial autocorrelation (LISA)

Anselin et al. (2007) describe that global spatial autocorrelation is used to identify the overall clustering and spatial correlation; however, it does not give us the graphical representation of clusters or outliers. Therefore, local Moran's  $I$  correspond to examine the location of spatial clusters as well as spatial outliers breaking up the spatial dependence of global statistics. It provides a detailed overview of local spatial pattern with four types of association: (1) low–low (LL) low-value regions surrounded by the neighboring regions with low value, (2) low–high (LH) low-value regions surrounded by the neighboring regions with high value, (3) high–low (HL) regions with high value surrounded by neighboring with low value, and (4) high–high (HH) regions with high value surrounded by neighboring regions with high value. The Local Moran's statistic for any time period  $t$  and each region  $i$  is defined as

$$I_{it} = \left( \frac{X_i - \bar{X}}{m_o} \right) \sum_{j=1}^n w_{ij} (X_j - \bar{X}) \text{ with } m_o = \sum_{i=1}^n \frac{(X_i - \bar{X})^2}{n}. \quad (2)$$

Notation follows the above-mentioned equation of global Moran's  $I$ .

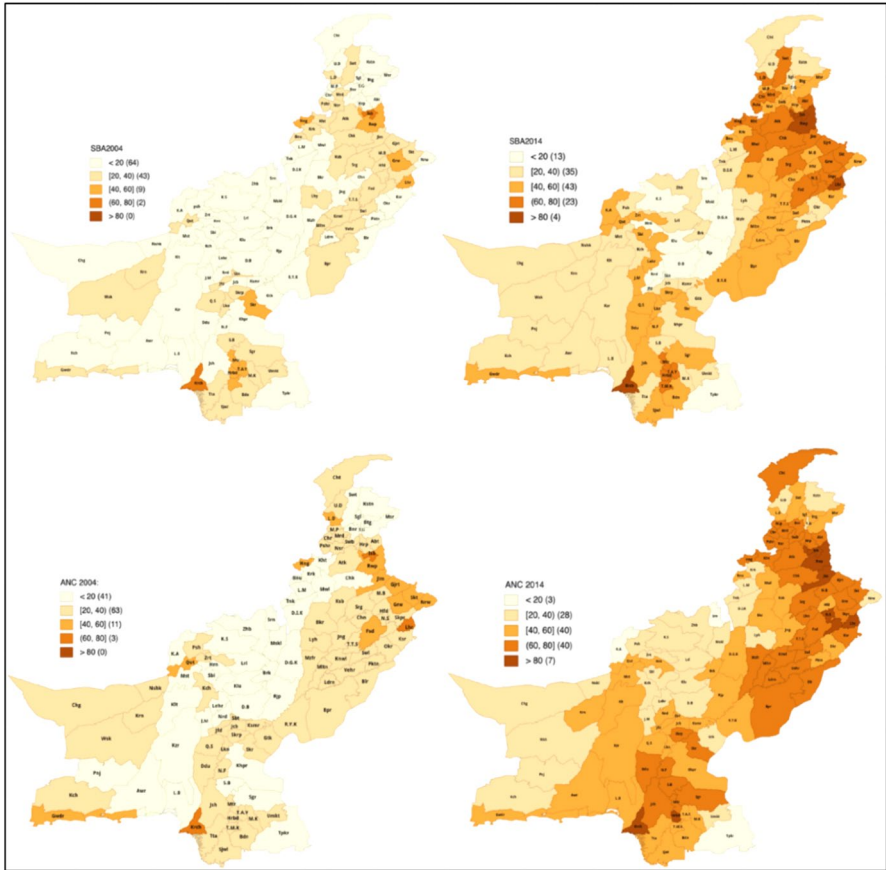
## 5 Results

### 5.1 Spatial distribution map

The spatial distribution maps help us to understand the spatial pattern of access to skill birth attendant and antenatal care in 2004 and 2014. They give a general overview of spatial inequality regarding access to maternal health care facilities in 1 decade at the sub-regional level. This study uses five class quintile maps (shown in Fig. 1) of ANC and SBA to cover the same number of observations. The lighter color shows the low value and darker color represents the high value of access to RHCS in two different time periods. Additionally, the darkest colors in all four maps are located in central Punjab or a few districts of Sindh, whereas the lighter colors mostly represent the Northern Baluchistan and Southern Punjab districts. For further clarification, all the districts are also labeled with name codes that are listed in Appendix Table 4.

### 5.2 Empirical results

The empirical results are divided into two sections. The first section explains the spatial analysis of 118 districts as national-level analysis, while the second section describes the provincial-level LISA analysis to locate the high–high and low–low clusters within provinces.



**Fig. 1** Quintile maps of ANC & SBAs 2004 & 2014. Notes: The map is first categorized into quintile values of data set, first quintile represents the lowest value of the data 1–20%, second quintile is 20–40%, third quintile is 40–60%, fourth quintile is 60–80% and highest data value is fifth quintile over 80%. The lighter color represents lowest access to RHCS, darker color represents higher access to RHCS. Source: Author

**Table 1** Variable loading RHCS index

Variables	2004	2014
ANC	0.70	0.70
SBA	0.70	0.70

Source: Author

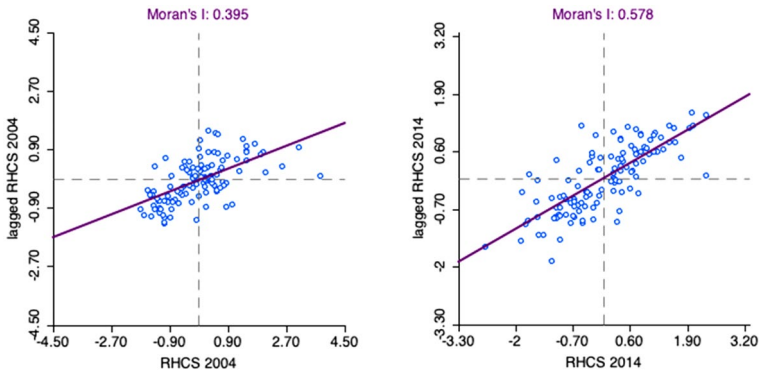
### 5.2.1 Principal component analysis (PCA)

A single underlying dimension is extracted from the two variables using principal component analysis. The variable loadings are listed in Table 1. The PCA results show 87% variance in 2004 and 88% variance in 2014, which provides support

**Table 2** Moran's I values for RHCS in 2004 & 2014

Spatial weight (queen contiguity)	Moran's value	P value	Slope & Moran's value
RHCS 2004	0.39	0.001	Positive & significant
RHCS 2014	0.57	0.001	Positive & significant

Source: Author

**Fig. 2** Moran scatter plot of RHCS in 2004 & 2014. Source: Author

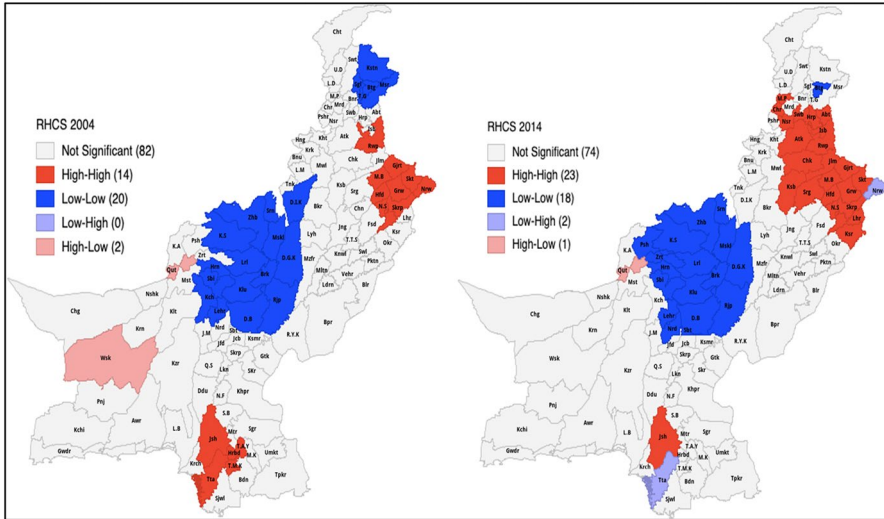
to reduce the two variables into one Reproductive Health Care Services (RHCS) index.

### 5.3 Exploratory spatial data analysis (ESDA)

To examine the spatial character of regional access to reproductive health care services, this study used ESDA for two points of time: 2004 as base year and 2014 as final year. ESDA enables us to see the spatial patterns of access to reproductive health care facilities in whole country. The tools of ESDA are as follows.

Global spatial autocorrelation (Moran's I): Table 2 shows the results of global Moran's I test for spatial autocorrelation. The global Moran's I value for RHCS in 2004 is 0.39 ( $p < 0.01$ , 999 permutations) and RHCS in 2014 is 0.57 ( $p < 0.01$ , 999 permutations). It signifies that there is high spatial autocorrelation, and the positive value signifies spatial clustering and association of RHCS among districts of Pakistan. This means that the access to RHCS in one province cannot be isolated from the access of RHCS in the neighboring provinces and this is not random.

Figure 2 shows the Moran's scatter plots for the initial (2004) and final year (2014); the horizontal axis represents the value of the RHCS index and vertical axis measures the spatially lagged value of the RHCS index. The scatter plot divides the results into four groups. The first quadrant (HH) in the top right includes high-valued districts with high-value neighbors where RHCS is high. The second quadrant (LH) in the top left has low-valued districts surrounded by high-value neighbors.

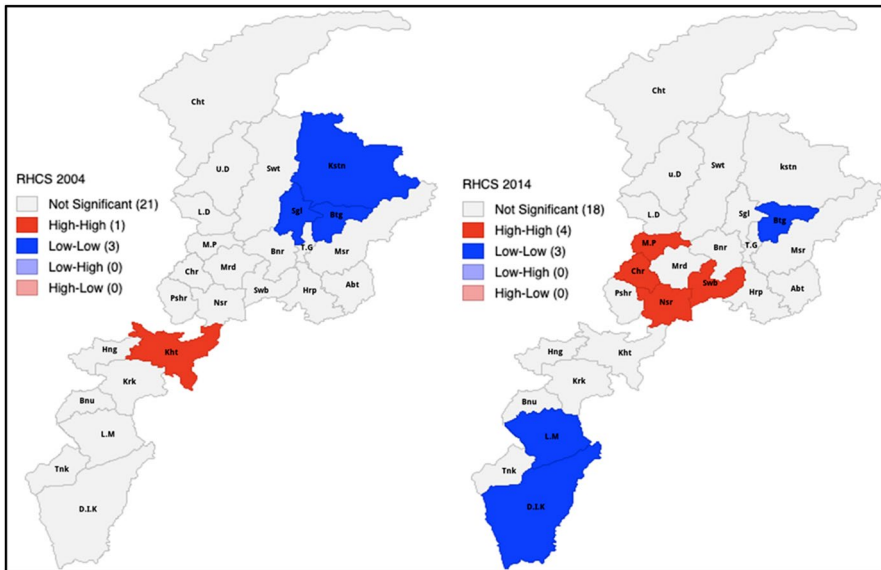


**Fig. 3** LISA map for RHCS, 2004 & 2014. Notes: Code and district names are listed in Appendix Table 4. Source: Author

The third quadrant (LL) in the bottom left contains low-valued districts surrounded by their low-value neighbors. Finally, the fourth quadrant (HL) contains high-valued districts surrounded by low-value neighbors.

Local Indicator of Spatial Autocorrelation (LISA): Global spatial autocorrelation suggests non-randomness in the spatial pattern, and LISA analysis helps us to identify the location of this non-randomness. The highlighted areas are significant clusters and outliers that are detected through LISA analysis, as shown in Fig. 3. The LISA cluster maps are for the RHCS in 2004 and 2014.

The result indicates the high–high and low–low clusters for the years 2004 and 2014 (see Appendix Table 5 for the details of LL and HH districts). The highlighted regions are significant ( $p < 0.005$ ) clusters or outliers based on the local Moran's I statistics. The LISA map results are categorized into four groups: two are clusters of high-valued districts surrounded by high-value neighbors and low-valued districts surrounded by low-value neighbors. The other two are outliers: high-value regions surrounded by low-value neighbors, or low-value regions surrounded by high-valued neighbors. The overall spatial patterns of clusters in both maps (initial year and final year) are similar, which means that there is spatial persistence. Overall low access to RHCS clusters is located in mostly Baluchistan and its neighboring districts of other provinces. The size of low access to RHCS clusters decreased over time; 20 regions belong to low access to RHCS clusters in 2004 and 18 in 2014; however, some provinces are different in both years. Some districts were exceptions, such as Dera Ismail Khan, Kacchi, Kohistan, Mansehra, Shangla, and Tor Ghar, that are no longer low–low clusters in 2014, whereas four new districts have entered in low–low regions, namely, Nasirabad, Pishin, Sohatpur, and Ziarat. Additionally, all of the newly formed low–low regions are part of Baluchistan. High access to RHCS



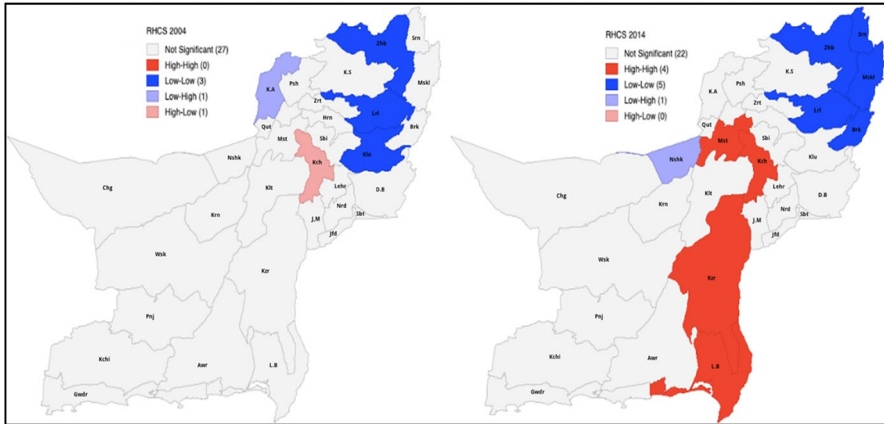
**Fig. 4** LISA map for RHCS in KPK. Note: Code and district names are listed in Appendix Table 4. Source: Author

clusters has also increased over time from 14 to 23; however, most high–high clusters increased only in Punjab. Similar to the low access to RHCS clusters, some districts joined, and some exited over time. None of the low–high outliers were found in 2004, whereas, over time, two (Thatta and Narowal) outliers of low–high districts have formed in Punjab and Sindh. There were two (Quetta and Washuk) high–low outliers in the same province in 2004, and one (Quetta) persistent as high–low in 2014, while the Washuk become non-significant.

### 5.3.1 LISA analysis at the provincial level

This section will explain the clusters within provinces, because Pakistan is a state with scarce financial resources. Previous literature also suggested that government needs to strengthen the district-level information about maternal mortality or morbidity to enhance the quality of district healthcare facilities (Bhutta and Hafeez 2015). Therefore, it is essential to identify the micro-level information of marginalized districts where basic health services are not available or people are unaware of utilizing those existing facilities. In particular, the country map has divided into four provinces according to its official geographical classification to run the analysis in each province.

LISA analysis of Khyber Pakhtun Khawa (KPK): The LISA map (Fig. 4) shows the presence of high–high and low–low clusters over time. Result shows that the location of high–high and low–low clusters has changed in 1 decade; however, the Batagram district remains a part of a low–low cluster in its initial and final year. In



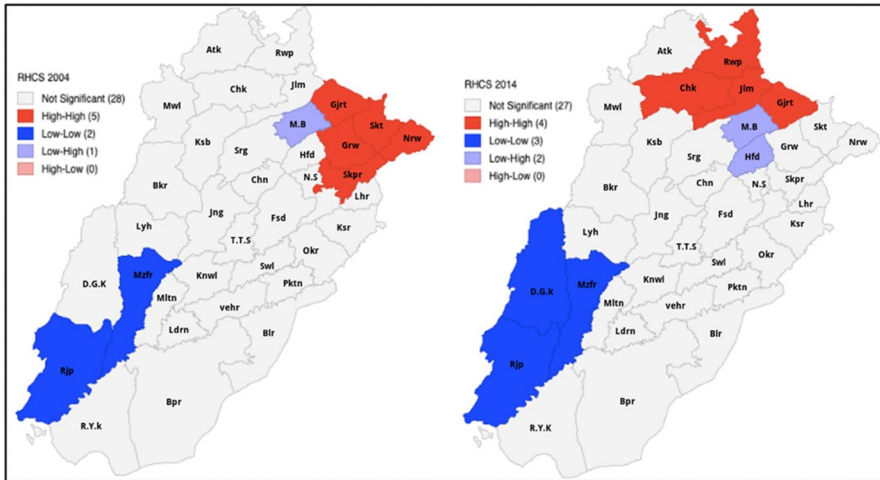
**Fig. 5** LISA map for RHCS in Baluchistan. Note: Code and district names are listed in Appendix Table 4. Source: Author

contrast, the high–high clusters have increased from 1 to 4, which symbolizes that these districts have higher access to RHCS with their neighboring districts. The new high–high districts were clustered in Nowshera, Charsada, Malakand, and Swabi. In addition, none of the spatial outliers were found in both years.

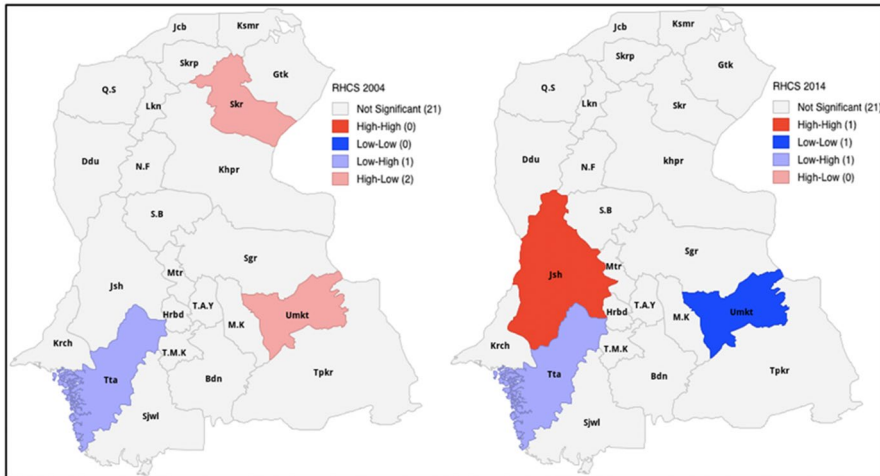
**LISA analysis of Baluchistan:** The result of LISA map indicates an increase of low–low and high–high clusters over time. In 2004, there were 3 low–low clusters, as shown in Fig. 5, but it has increased to 4 after a decade, whereas, in 2004, none of the high–high clusters can be found. However, in 2014, there are three high–high clusters which means that some progress to access the RHCS have been made over time. Furthermore, in 2004, Kachhi was a high–low outlier; conversely, in 2014, it becomes a high–high cluster. Killa Abdullah was a low–high outlier in 2004, but becomes non-significant in 2014. Whereas, Nushki became a low–high outlier in 2014. Further investigation is still needed to validate these outliers.

**LISA analysis of Punjab:** Fig. 6 represents the clusters and outliers using space–time local Moran statistics; there were 5 high–high and 2 low–low clusters in 2004; however, in 2014, high–high clusters reduced to 4 and also moved their location (except Gujrat) from Gujranwala, Narowal, Sheikhpura, Sialkot to Chakwal, Jehlum, and Rawalpindi. Additionally, all of these districts are highly populated and developed in terms of infrastructure and economic resources with relatively good means of transportation. The low–low clusters in Punjab are relatively stable, formed by Rajanpur and Muzaffargarh in both years. Dera Ghazi Khan also entered in the low–low cluster in 2014. Regarding spatial outliers, only one high–low outlier existed in 2004; however, Hafizabad also became an outlier in 2014.

**LISA analysis of Sindh:** Interestingly, Fig. 7 represents only spatial outliers of RHCS in 2004, none of the high–high and low–low clusters were seen in the initial year. By contrast, in 2014, one high–high and one low–low RHCS cluster were composed by Jamshoro and Umerkot. The high–low outlier in 2004 turned to a low–low cluster in 2014, because Umarkot was surrounded by low access to RHCS



**Fig. 6** LISA map for RHCS in Punjab. Note: Code and district names are listed in Appendix Table 4. Source: Author



**Fig. 7** LISA map for RHCS in Punjab. Note: Code and district names are listed in Appendix Table 4. Source: Author

neighbors. Conversely, the low–high spatial outlier persisted its location in Thatta, although a high–high neighbor surrounds it.

**Table 3** Summary of common low–low clusters

Clusters of LL districts	Districts
LL clusters, 2004	Kohlu, Loralia, Zhob, Rajanpur, Batagram, Kohistan, Shangla
LL clusters, 2014	Barkhan, Loralia, Musakhel, Sheerani, Zhob, Rajanpur, Dera Ghazi Khan, Batagram
Common LL clusters 2004/2014	Batagram, Loralai, Zhob, Rajanpur

Source: Author

### 5.3.2 Similarities at macro- and micro-level analysis

After summarizing the LISA results of national- and provincial-level analysis, the following similarities of low–low clusters are found (see Table 3).

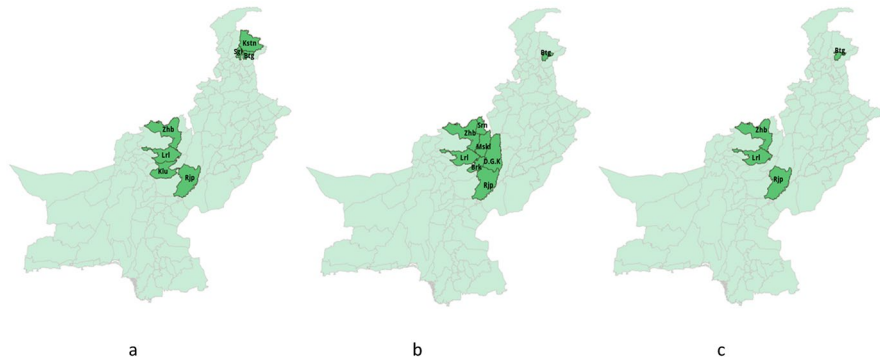
## 6 Discussion and policy implication

Using spatial analysis techniques, this research has shown how substantial geographical variation exists in access to reproductive health care services across Pakistan. It demonstrates the presence of significant high–high clusters, low–low clusters, and spatial outliers.

Results of global Moran's I spatial autocorrelation confirmed that RHCS exhibits spatial dependence. Districts with high access to RHCS tend to be located closer to each other, and low access to RHCS also tends to cluster together. It also exhibits an increase in access to RHCS from 2004 to 2014 whereas, inequality exist across different geographical regions within the country. The majority of that increase occurred in the northeast of the country, particularly in the north of Punjab and northeast of KPK. They are centered regions in terms of urbanization and infrastructure. In other words, upper decile districts have more access to the RHCS than lower decile districts. Unfortunately, the number of high–high clusters in the south of Pakistan reduced in 2014; additionally, one high–high cluster of 2004 formed a low–high outlier in 2014. LISA results reveal that clusters persisted over time, which suggested a growing polarization of low access to the RHCS in the west and center of the country and high access in the northeast region. Punjab has the highest population among all other provinces and Baluchistan has the lowest population despite having the largest portion of land. The inequality can be clearly seen across the country (Fig. 1). The persistence of low–low clusters in one decade and increasing trends of low–low clusters in Baluchistan is an alarming situation that should be consider in further research.

Moreover, within the provincial spatial analysis, the LISA results are relatively similar with national-level local Moran's I analysis. Some districts that have formed low–low clusters in 2004 and 2014 at the national-level analysis repeatedly formed low–low clusters within provincial-level LISA analysis. It is obvious from the map that northern and eastern districts located in Punjab and KPK are developed and healthier. Similarly, the low access to the RHCS districts are located in





**Fig. 8** Common low–low clusters at national and provincial level. Note: Author’s calculation a and b are common districts at the national and provincial level in two different time periods, whereas c represents the geographical location of these districts in both (2004 and 2014) years (the darker color represents the geographical location of target regions). Source: Author

western and southern areas of Pakistan. The results in geographical visualization in Fig. 8 show that in 2004, Kohlu, Loralai, Zhub, Rajanpur, Batagram, Kohistan, and Shangla are common districts that formed low–low clusters at national- and provincial-level LISA test. Conversely, in 2014 Barkhan, Loralai, Musakhel, Sheeran, Zhub, Rajanpur, Dera Ghazi Khan, and Batagram are the common low–low clusters at the national and provincial level according to the local Moran’s I test. Interestingly, some of the low–low districts have become insignificant in 2014, but some districts persisted as low–low regions over time, such as Zhub, Batagram, Loralai, and Rajanpur.

Zhub is a district of Baluchistan and connects with Punjab and Khyber Pakhtunkhwa. It has the lowest in female literacy rate; a lack of a cottage industrial sector leads to the limited employment opportunities and high poverty. People do not have access to clean drinking water, because girls need to fetch water from distant places. In terms of healthcare, people in the Zhub district are in a miserable situation; healthcare equipment is not sufficient to cater to the people’s needs (Mandokhail 2020).

Similarly, over 85% of the population Rajanpur in the southwestern part of Punjab Pakistan lives in rural areas (PBS 2020). A newspaper reported that at least 85% of deaths occur in the hospitals due to lack of health care facilities, including doctors and other medical staff. These deaths can be preventable if appropriate medical care services would be provided on time. Like the district Zhub, it has inadequate means of transportation and road infrastructure that could cause less access to health care facilities (DAWN 2020). A study conducted in Punjab to improve the public health care delivery services reported that Rajanpur has the lowest number of Basic Health Units<sup>1</sup> (BHU) among all the districts in the province (Callen et al. 2013). According

<sup>1</sup> BHUs are the basic health units with small number of medical personnel who provide basic healthcare services. Each BHU must have one medical doctor who serves as the main head of the BHU and is supported by lady health workers who move around the communities to provide essential nutrition information and vaccines to newborns and pregnant women.

to the WHO standard, there should be one BHU per 10,000 people; however, Rajanpur has 30,000 rural inhabitants per BHU. In the case of Battagram, it comprises a rural district of KPK where people earn their living through farming, small shops, small hotels, and overseas jobs. Unfortunately, during the earthquake of 2005, over 80% of the healthcare facilities were heavily damaged. Moreover, the public hospital's health care facilities have increased over time, but the BHU and rural health centers have decreased between 1998 and 2006 (Battagram district profile 2007).

The results are supported by some previous literature in the context of Pakistan. For instance, a study that performed exploratory data analysis of social and economic disparities in 98 districts of Pakistan, revealed similar results regarding access to socio-economic facilities, particularly patterns of income, education, and district growth (Ahmed 2011). Moreover, it has reported significant disparities at the human development level and concluded that the high-high clusters are only concentrated in northern Punjab.

Additionally, the findings are consistent with the report published with Baluchistan's government's joint effort, the World Bank and the Asian Development Bank (ADB) (2008) that reported that Baluchistan has the weakest growth rate throughout history, 0.7% lower than other three provinces. It has the worst infrastructure, including road and transportation and access clean drinking water, and the lowest social and economic indicators in all aspects such as literacy, health, employment, and the weakest government institutions—leading to low living standards. Results of the LISA analysis shows that these lagging regions need attention to work on at state-level policy formation to provide necessary health care facilities to the most marginalized communities.

Finally, results also revealed that people in Punjab enjoy more maternal healthcare facilities, whereas most Baluch people are suffering from lower access to these facilities. There could be some possible demand-side factors that are causing inequalities to access the RHCS. For instance, inequality in access to maternal healthcare services are caused by the power dynamic of gender (Mumtaz et al. 2012), women's illiteracy, availability of female healthcare workers (Rizvi and Nishtar 2008), age of women (Fatmi and Avan 2002), and income status of women (Rahman et al. 2021). In contrast, supply-side factors can also be the reason for these disparities, including quality of emergency obstetric care (EmOC), the burden of out-of-pocket expenditures, political instability (Siddiqi et al. 2004), and lack of information about district-level healthcare facilities (Bhutta and Hafeez 2010).

## 7 Conclusion

This study set out to perform exploratory spatial data analysis to investigate the sub-national spatial inequalities regarding access to reproductive health care services. The motivation of this study came from the unmet targets of MDG 5 in the context of Pakistan. Although the country claimed to reduce the maternal mortality ratio by 57%, disparities and inequalities in access the maternal health care facilities can be found across provinces. Several studies have begun to address the disparities of women's access to healthcare services in Pakistan, primarily constrained by

the small sample size or unaddressed inequalities. Conversely, the role of time and space has been ignored in the context of access to RHCS in Pakistan. Therefore, the present study was designed to perform the spatial analysis to evaluate space at the national and provincial levels. It developed an RHCS index through PCA to estimate 118 districts' inequalities for 2004–2014. The global Moran's I test was used to understand the spatial autocorrelation among regional distributions; a positive value indicates the spatial clustering, and a negative value signifies random spatial clustering. Moreover, LISA analysis was been used to measure the location of spatial clusters or outliers at the national and provincial levels.

The results conclude significant and positive spatial autocorrelation and that some districts demonstrate persistent low access to RHCS clusters. In other words, across Pakistan, districts with similar access to RHCS tend to locate closer to one another from 2004 to 2014. Although the country started the lady health workers program in 1994 to reach out to the rural and urban slum areas, the spatial structure has stably maintained low access to RHCS districts. Specifically, the following findings emerge from this research. First, there is an increasing degree of spatial dependence over time, and some persistent spatial clusters are identified across the country. The increasing trend of high–high clusters can only be found in the northeast of Punjab province and its neighboring KPK province districts. However, over time, high–high clusters have decreased in Sindh province, and none of the high–high spatial clusters were formed in Baluchistan in 1 decade. Conversely, low access to RHCS clusters has increased in the north of Baluchistan and its neighboring districts in the south of KPK and southwest of Punjab. Furthermore, notable changes were found in some high–high districts of the initial year, manifesting as spatial (low–high) outliers in the final year, which can be investigated in future research to understand the contributing factors.

Despite a significant increase in healthcare services at the national level, there are many districts across the country where access to health services remains low. In sum, there is a substantial geographical variation in access to RHCS across the country. The present study is the first attempt to investigate the country-level and provincial-level variation in access to RHCS over the entire area of Pakistan. The results provide a foundation for measuring the drivers of inequalities within districts and communities. The findings give valuable insight to understand the dimension of clusters to the government and policymakers to address the RHCS issues in vulnerable districts. The results also raise many questions in need of further investigation to uncover the determinants driving these geographical clusters and outliers of RHCS. Additionally, spatial analysis is needed at the Tehsil (i.e., local administrative or township) level to find out the most marginalized communities in depth. Finally, it is essential to identify whether these disparities are being caused by demand-side or supply-side determinants.

## Appendix

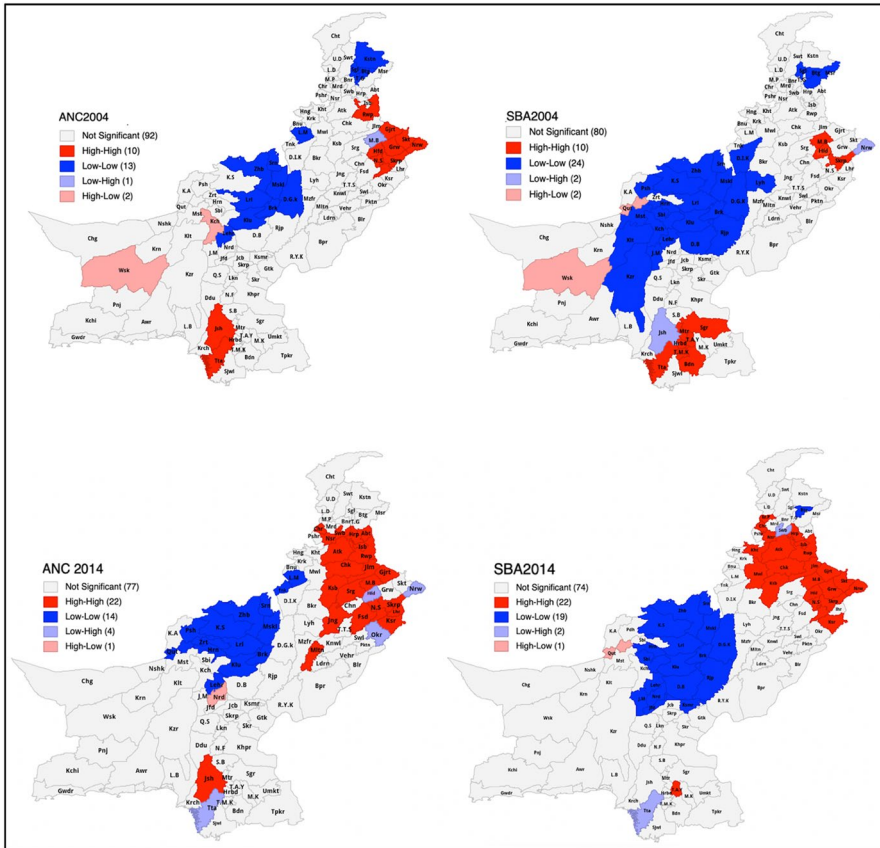
See Tables 4, 5 and Fig. 9.

**Table 4** List of districts (118) used for spatial analysis

Code	District	Code	District	Code	District
Abt	Abbottabad	Krk	Karak	Nshk	Nushki
Atk	Attock	Ksmr	Kashmore	Okr	Okara
Awr	Awaran	Ksr	Kasur	Pktn	Pakpattan
Bdn	Badin	Kch	Kech	Pnj	Panjgur
Blr	Bahawalnagar	Khpr	Khairpur	Pshr	Peshawar
Bpr	Bahawalpur	Knwl	Khanewal	Psh	Pishin
Bnu	Bannu	Krn	Kharan	Q.S	Qambar Shahdaddock
Brk	Barkhan	Ksb	Khushab	Qut	Quetta
Btg	Batagram	Kzr	Khuzdar	R.Y.K	Rahim Yar Khan
Bkr	Bhakkar	K.A	Killa Abdullah	Rjp	Rajanpur
Bnr	Buner	K.S	Killa Saifullah	Rwp	Rawalpindi
Chg	Chagai	Kht	Kohat	Swl	Sahiwal
Chk	Chakwal	Kstn	Kohistan	Sgr	Sanghar
Chr	Charsadda	Klu	Kohlu	Srg	Sargodha
Chn	Chiniot	Lhr	Lahore	S.B	Shaheed Benazirabad
Cht	Chitral	L.M	Lakki Marwat	Sgl	Shangla
Ddu	Dadu	Lkn	Larkana	Srn	Sheerani
D.B	Dera Bugti	L.B	Las Bela	Skpr	Sheikhupura
D.G.k	Dera Ghazi Khan	Lyh	Layyah	Skpr	Shikarpur
D.I.K	Dera Ismail Khan	Lehr	Lehri	Skt	Sialkot
Fsd	Faisalabad	Ldrn	Lodhran	Sbi	Sibi
Gtk	Ghotki	Lrl	Loralai	Sbt	Sohbatpur
Gjrt	Gujranwala	L.D	Lower Dir	Sjwl	Sujawal
Gwdr	Gujrat	M.P	Malakand PA	Skr	Sukkur
Hfd	Gwadar	M.B	Mandi Bahauddin	Swb	Swabi
Hng	Hafizabad	Msr	Mansehra	Swt	Swat
Hrp	Hangu	Mrd	Mardan	T.A.Y	Tando Allah Yar
Hrn	Haripur	Mst	Mastung	T.M.K	Tando Muhammad Khan
Hrn	Harnai	Mtr	Matiari	Tnk	Tank
Hrbd	Hyderabad	Mwl	Mianwali	Tpkr	Tharparkar
Isb	Islamabad	M.K	Mirpur Khas	Tta	Thatta
Jcb	Jacobabad	Mltm	Multan	T.T.S	Toba Tek Singh
Jfd	Jaffarabad	Mskl	Musakhel	T.G	Tor Ghar
Jsh	Jamshoro	Mzfr	Muzaffargarh	Umkt	Umerkot
J.M	Jhal Magsi	N.S	Nankana Sahib	U.D	Upper Dir
Jng	Jhang	Nrw	Narowal	Vehr	Vehari
Jlm	Jhelum	Nrd	Nasirabad	Wsk	Washuk
Kch	Kachhi	N.F	Naushahro Feroze	Zhb	Zhob
Klt	Kalat	Nsr	Nowshera	Zrt	Ziarat
Krch	Karachi city				

**Table 5** High–high and low–low districts of initial (2004) & final (2014) year (macro-level LISA analysis)

HH 2014	LL 2014	HH 2004	LL 2004
Abbottabad (Abt)	Barkhan (Brk)	Gujranwala (Grw)	Barkhan (Brk)
Attock (Atk)	Batagram (Btg)	Gujrat (Gjrt)	Batagram (Btg)
Chkwal (Chk)	Dera Ghazi Khan (D.G.K)	Hafizabad (Hfd)	Dera Bhugti (D.B)
Charsada (Chr)	Dera Bhugti (D.B)	Hydrabad (Hrbd)	Dera Ghazi Khan (D.G.K)
Gujranwala (Grw)	Harnai (Hrn)	Jamshoro (Jsh)	Dera Ismail Khan (D.I.K)
Gujrat (Gjrt)	Killa Saifullah (K.S)	Mandi Bahauddin (M.B)	Harnai (Hrn)
Hafizabad (Hfd)	Kohlu (Klu)	Nankana Sahib (N.S)	Kachhi (Kch)
Haripur (Hrp)	Lehri (Lehr)	Narowal (Nrw)	Killa Saifullah (K.S)
Islamabad (Isb)	Lorralai (Lrl)	Rawalpindi (Rwp)	Kohistan (Kstn)
Jamshoro (Jsh)	Musakhel (Mskl)	Sheikhupura (Skpr)	Kohlu (Klu)
Jhehlum (Jlm)	Nasirabad (Nrd)	Sialkot (Skt)	Lehri (Lehr)
Kasur (Ksr)	Pishin (Psh)	Tando Allah Yar (T.A.Y)	Lorralai (Lrl)
Khushab (Ksb)	Rajanpur (Rjp)	Tando M. Khan (T.M.K)	Mansehra (Msr)
Lahore (Lhr)	Sheerani (Srn)	Thatha (Tta)	Musakhel (Mskl)
Malakanad PA (M.P)	Sibi (Sbi)		Rajanpur (Rjp)
Mandi Bahauddin (M.B)	Sohbatpur (Sbt)		Shangla (Sgl)
Nankana sahib (N.S)	Zhob (Zhb)		Sheerani (Srn)
Nowshera (Nsr)	Ziarat (Zrt)		Sibi (Sbi)
Rawalpindi (Rwp)			Tor Ghar (T.G)
Sargodha (Srg)			Zhob (Zhb)
Sheikhupura (Skpr)			
Sailkot (Skt)			
Swabi (Swb)			



**Fig. 9** Local indicator of spatial autocorrelation maps for ANC and SBAs 2004 & 2014. Notes: Code and district names are listed in Appendix Table 4. Source: Author

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**Availability of data and materials** The datasets for the present study are taken from the Pakistan social and living standards measurement surveys as well as the Multiple Indicators Custer Surveys (MICS) that are available online on the website of Pakistan Bureau of Statistics (PBS) as well as Data for Pakistan website.

**Declarations**

**Competing interests** The author declares no competing interests.

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