DEPARTMENT OF ENVIRONMENTAL SCIENCE, COMPUTER SCIENCE AND STATISTICS

MAJOR IN GLOBAL ENVIRONMENTAL CHANGE

Master Thesis

POPULATION DISTRIBUTION AND WATER RESOURCES IN PAKISTAN

Submitted to:

Prof. Carlo Giupponi

Co-supervisor:

Fabio Cian

Submitted by:

Usman Yaqoob

Abstract

Growing population, lack of water resources, the massive amount of water withdrawal, and migration of people from rural to urban areas are creating a water scarcity issues in Pakistan. However, the suitable quantity of water resources is decreasing due to the unsustainable extraction. Whereas, the land availability for the construction of domestic areas is reducing gradually because of an urbanization as a result urban area are becoming overcrowded.

Therefore, the aim of present work is to analyse the population distribution in the different province of Pakistan as well as the amount of total blue water, people access to drinking water and water withdrawal activities. To determine the outcomes/results the datasets have been downloaded from various sources i.e. SEDAC (NASA), World pop, Joint Research Centre (JRC-GHS), Gridded Population of the World version 4 (GPWv4) and World Resource Institute (WRI). Population distribution and water resources maps have been investigated by the implementation of mapping algebraic approach in the context of Quantum Geographic Information system (QGIS). Classification, overlapping, clipping, masking and other GIS techniques are applied with the help of raster and vector datasets. Although, by means of zonal statistics tool, we examined the number of people living in each province of Pakistan. However, during the overlapping of population density and water resources maps, we derived the outcomes that in which part of the country people are extracting the massive amount of water resources and where people are facing the water scarcity related issues.

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1: INTRODUCTION:

1.1. General background

Today most of the worldwide population settled in urban areas. The ratio of urban residents increased from 43% in 1990 to 52% in 2011, and it is predicted to grow to 67% by 2050. All population growth from 2011 to 2050 is probably to be absorbed by urban areas, and most of this growth will occur in cities of less developed regions (Juan C. Duquea, 2015). World's population is growing swiftly because of changes including the industrial revolution. Urbanization is likely to accelerate through population growth and social development in the novel century (Heilig G K, 2012). This growth leads to intense pressure on natural resources creating an urgent need for sustainable development. Appropriate and correct information about the world's population distribution at a variety of scales like global, national, regional, and local is a key to responding to population-related social, economic, also environmental issues. For example, information on small-area population distribution is significant for the private sectors such as to determine the optimal site location of the business. In addition, population distribution information is also important for urban planning in determining when and where to build public services such as religious buildings, libraries, hospitals/health centres, and schools/universities. Population information is also important in determining urban transport such as bus transit routes. Such decisions are made within the framework of urban and regional planning, national resource management, and analysis of urban-sprawl (Mohammed Alahmadi, 2016). Researchers agree that an understanding of population distribution is essential for urban planning and sustainable development studies and for exploring the interrelationship between humans and their environment on diverse spatial scales. Urban planning adopted tasks including new town planning (NTP), urban infrastructure planning (UIP), and urban traffic planning (UTP) must forecast the population size and its development trend based on long-term statistics and then make a foresighted blueprint. New town planning must consider not only the land size, enterprise number, and output economic value but also, the share between population and industries. Therefore, the task demands a deep understanding of present population distribution patterns, historical movement processes, and future change tendencies for the population in the inner space of cities to produce an effective plan with reasonable land size, industrial structure, and supporting facilities. (Yin, 2015). Today Urbanization developments in developing countries

mainly differ from previous urban transitions in terms of scale, speed, and morphology, and they should receive suitable attention. On the other hand, urbanization generates extraordinary impacts on environmental systems such as urban heat island effect, water run-off change, biodiversity decrease, and anthropogenic carbon emission (Xuehong, 2016). Urbanization is an essential result of economic and urban development, which is associated to functional and spatial transformations and its form will have long-lasting results on the lives of urban residents (Dung,2016).

The aim of this study is the analysis of population distribution, people access to drinking water, amount of water withdrawal and available blue water in Pakistan. To reach the aim of the study we required several types of datasets such as population data, remotely sensed data, census data. To obtain the population data I approached to distinct sources like World pop, JRC-Global Human Settlement, SEDAC (NASA-Columbia), Food and Agricultural Organisation (FAO) and for water-related datasets we have WRI (WRI) Aqueduct global map 2.0. Most of the researchers have used the same sources for data collection and have done the work on the assessment of population distribution by using remotely sensed data, census data and with the help of other ancillary data. In 2014 researchers used the 2010 census data and 2010 parcel data of USA to highlight the population density on high resolution gridded population surface they also used the dasymetric and heuristic sampling method with 30*30 m spatial resolution and accuracy has been assessed by National land cover database to produce land cover-based population product and then linked it by high resolution gridded population surface (HGPS). In the outcome, they produced parcel based dasymetric map and choropleth map (composed of a series of vector polygons representing administrative units and summed values depicting the aggregated attributes over those units) of State of Florida is in the southeaster United States and Alachua County is in the north-central part of Florida and compared to highlight the population distribution as shown in Fig. 1 (Gaughan, 2014). In 2017 the researchers disaggregated the census data for gridded prediction of population density by using Semi-automated dasymetric modelling and random forest estimation method with 100 m resolution. For the accuracy assessment of Population mapping approach compared with other map production algorithms Asia pop/Africa pop, GRUMP, GPW. Therefore, while determining different feature roads, schools, health facilities and updated Random forest weighting algorithm population map had created which is more accurate than GPW (Gridded population of world), GRUMP (Global

rural-urban mapping project), Asia pop/Africa pop and represent variability in population density (Stevens, 2015).

Fig.1 The High-Resolution Gridded Population Surface (HGPS) within the buffer zone with a half-mile radius centred (Source: Gaughan, Andrea E. 2014).

Researchers used the Landsat 2000 and 2010 data in 2016 by using operation mapping method with V-Map, 1:1 million GIS data. Pixel-based, object-based classification and knowledge-based editing technique are used to obtain the artificial surface with 30 m resolution. In pixel-based classification each image scene was classified by 3 operators independently if the result is > 90% then the voting method will accept the image. Hand editing checked by National Geomatics Centre China (NGCC) if there is no omission/commission error then artificial surface map produced by these two techniques are more suitable for accuracy assessment. Global artificial surface maps for the base-year of 2000 and 2010 were produced with artificial surface density at 0.1° resolution as you can see in Fig. 2 (Xuehong, Global mapping of artificial surfaces at 30-m resolution, 2016).

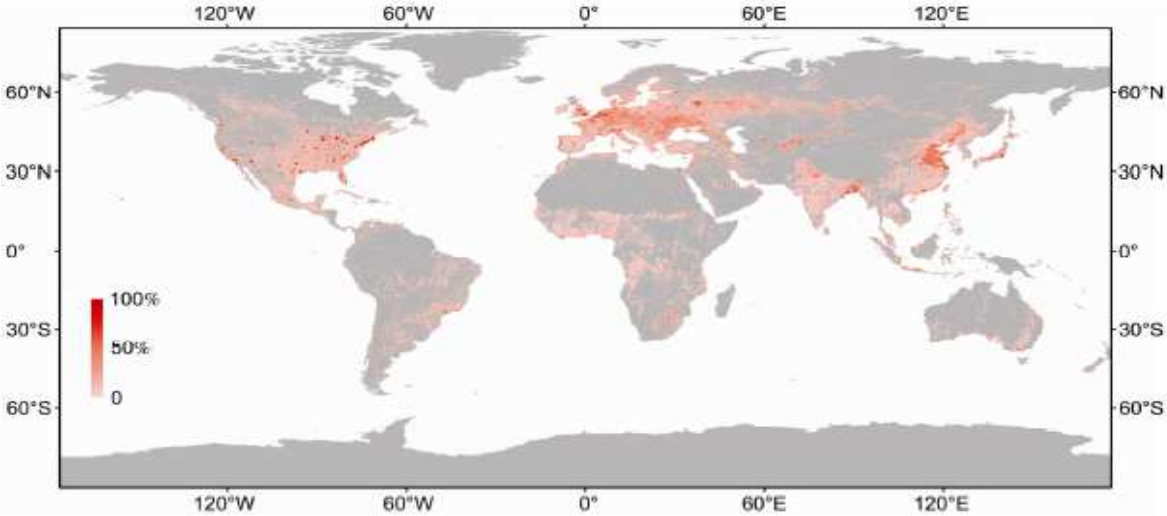


Fig. 2 Global map of artificial surface in 2010 (Source: Xuehong, Global mapping of artificial surfaces at 30-m resolution, 2016).

An automated monitoring of human settlement has been done in 2015, the methodology used to automatically extract human settlement information from high-resolution satellite images by textural, morphological and radiometric features detection with spatial resolution panchromatic 2.5m and multispectral 10m respectively. The results validation depends on confusion matrix and accuracy is measured by classification accuracy. The completeness relates to the ability to classify urban pixels, specificity relates to the ability to classify negative results and correctness relates to the ability to classify the non-urban areas from urban extent. In the end, the researcher produces two output produces building density and land use map of the international airport of Cape Town with the Boquinar Airport Industrial Area in the north-east and the Gugulethu and Nyanga townships in the south and south-west. layer both are produced with 10 m resolution as shown in Fig. 3 (Kemper, 2015).

Fig.3 Comparison of SPOT Building Count points (red dots and polygons) with built-up mask and the reference image (Source: Kemper, 2015).

The researchers adopted the Statistical modelling and areal interpolation method with (LULC) Land use land cover data at 30m spatial resolution, LULC data 1 m resolution and parcel data. However, accuracy assessment performed at the block level and validated at parcel level, (ORE) overall relative error, (MAE) mean absolute error, (RMSE) was used to check the accuracy of prediction. Therefore, Population distribution assessed based on the average population on each dwelling units 8 models were developed and tested and model 7 (Dasymetric model) produced accurate results than others and produced a map of Um-Alhamam Riyadh, Saudi Arabia. Um-Alhamam ward has an overall area of 4 km2 and contains 488 blocks and 2839 parcels as shown in Fig. 4 (Mohammed Alahmadi, 2016).

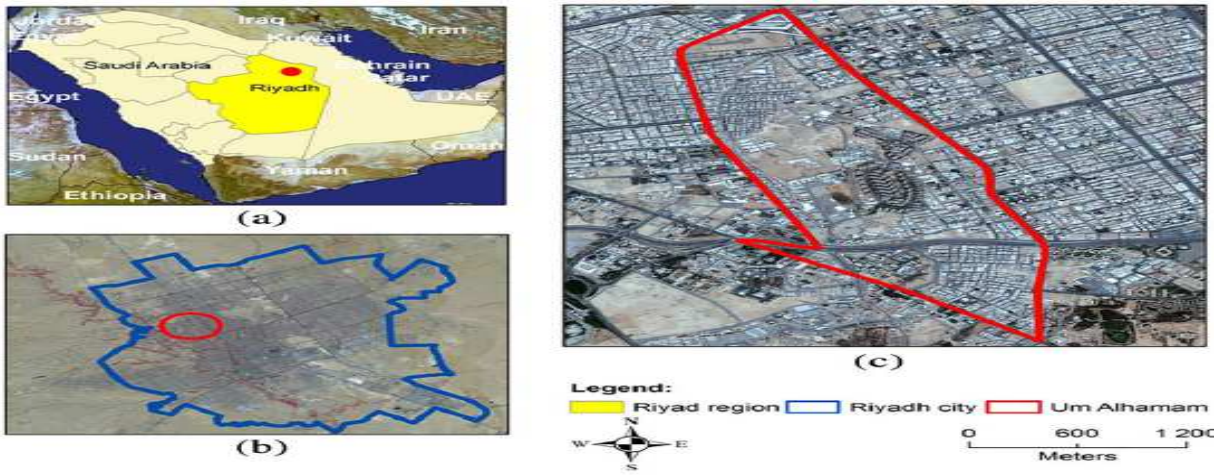


Fig. 4 Site location. (a) Saudi Arabia. (b) Riyadh. (c) Um Alhamam (Source: Mohammed Alahmadi, 2016).

In 2015 researcher used the Modified inverse distance weighted (MIDW) interpolation method for population distribution in a built-up area along with GIS and high resolution remotely sensed images (0.61*0.61 m) to get results. Whereas four other methods have been applied for accuracy assessment these are census unit population specialization (CUPS), Traditional inverse distance weighted (TIDW), Inverse national population aggregation (INPA) and compared with MIDW. INPA and MIDW interpolation methods generate a refined result MIDW outperform INPA and at the end Modified inverse distance weighted (MIDW) map has been produced (Yin, 2015)

2: Materials:

2.1. Description of the study area:

2.1.1. Location and Demography

The Islamic Republic of Pakistan is in the continent of Asia, the coordinates between 30.3753° N, 69.3451° E and it is situated eastern and northern hemisphere with a height of 8,125 m (26,660 ft.) above sea level. Islamabad is the capital of the Islamic Republic of Pakistan which is located on a latitude of 33.7294° N and longitude of 73.0931° E. Pakistan shares its borders with four neighbouring countries Iran, China, India, Afghanistan. In the east of Pakistan is India, which has a 2,912-km border with Pakistan. Iran is in the west of Pakistan, which has a 909-km border with Pakistan. Afghanistan located at the northwest of Pakistan, with a shared border of 2,430 km. China is towards the northeast and has a 523-km border with Pakistan Fig. 5 (Wikipedia, Geography of Pakistan, 2017).

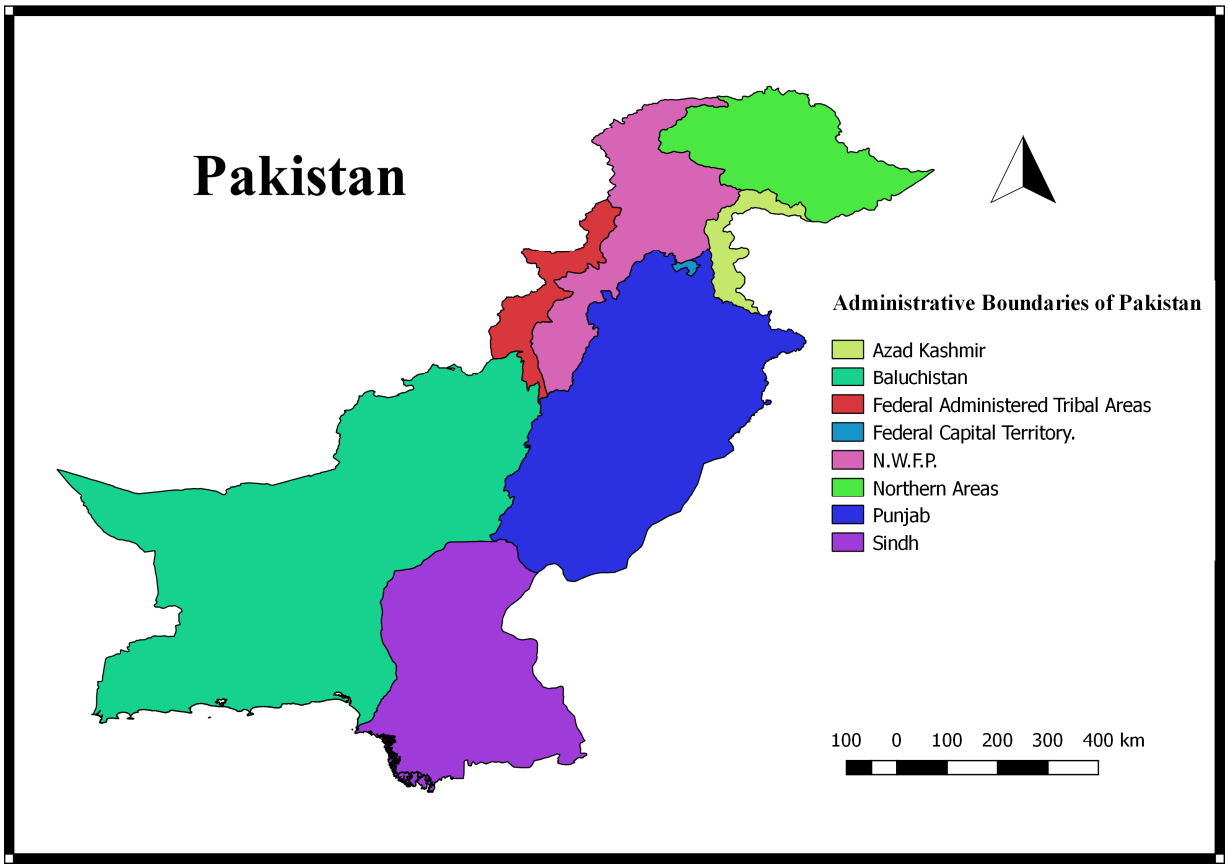


Fig.5 Location map of study area.

Pakistan estimated population till January 1st, 2017 was 194.9 million considering it sixth most populated country its population is less than Brazil but more than Nigeria. Pakistan covers an area of 796,095 km². An administrative unit of Pakistan consists of five provinces (KPK) Khyber Pakhtunkhwa Province, Punjab, Sindh, Gilgit-Baltistan, Balochistan and four territories (FATA) Federally Administrative Tribal Areas, Azad Kashmir and (ICT) Islamabad Capital Territory Table 1. Islamabad is the federal territory of Pakistan and covers an area of 1,165.5 km². Islamabad is situated in between two provinces (KPK) Khyber Pakhtunkhwa and Punjab but it is not a part of any province. Climate is healthy, comparatively pollution free, abundant in water resources and lush green. It is a modern and carefully planned residential city with wide roads and avenues, many public buildings and well-organized markets, and shopping malls. (KPK) Khyber Pakhtunkhwa is situated in the north-western part of the country along the shared border with Afghanistan. (KPK) Khyber Pakhtunkhwa covers an area of 74,521 km² and its provincial capital is Peshawar. Sindh is in the southeast of the country and is the third main province of Pakistan by an area (14.,914 km²) and after Punjab, it is the second major province by Population. Karachi is the provincial capital of Sindh and it is the financial hub of Pakistan. Balochistan is situated in the southwest part of Pakistan and Quetta is the provincial capital of Balochistan. It has shared borders with Punjab and (FATA) Federally Administered Tribal Areas and the total area is 347,190 km². Punjab is the second largest province of Pakistan with an area of 101,391,000 km² and its provincial capital is Lahore. It shares the borders through Indian states of Punjab, Rajasthan, and Jammu and Kashmir. Gilgit-Baltistan is the northernmost administrative territory in Pakistan. It shares borders with Azad Kashmir to the south, (KPK) Khyber Pakhtunkhwa to the west, Afghanistan to the north, the Xinjiang region of China to the east and northeast, and the Indian-administered state of Jammu and Kashmir to the southeast and its total area is 72,971 km². (AJK) Azad Jammu and Kashmir territory lie west of Indian administrative state and the total area is 13,297 km² (Wikipedia, Geography of Pakistan, 2017).

Administrative Division	Capital	Population
Islamabad Capital Territory	Islamabad	1,151,868
Khyber Pakhtunkhwa	Peshawar	28,000,000
Sindh	Karachi	42,400,000
Balochistan	Quetta	7,914,000
Punjab	Lahore	101,000,000
Gilgit-Baltistan	Gilgit	1,800,000
Azad Kashmir	Muzzaffarabad	4,567,982

Table 1 Administrative division along with capital and their population (Source: Wikipedia, 2017).

2.1.2. Physiography

The physiography/topography of the Islamic Republic of Pakistan ranges from flat surfaces to mountainous and hilly areas. It is subdivided into six natural regions of the Northern mountains, the Indus plains, the Baluchistan plateau, the western bordering mountains, the Submontane plateau, and the desert areas. Submontane mountains regions are briefly explicated below (Wikipedia, mountain ranges of Pakistan, 2017).

The Northern Mountains

At the entire northern end of Pakistan, the Himalayan and Trans-Himalayan mountains exist. The mountains average height is more than 6,100 meters and it includes Nanga Parbat 8,126 meters and K-2 (Godwin Austen) 8,611 meters. According to rough estimates, approximately 82,000 km² of Himalayan range is in Pakistan. The Chinese province of Sinkiang occupies beyond the Karakoram range in the extreme northern part of Pakistan. Hindu Kush range is occupying to the north-west beyond which are the Pamirs “the roof of the World”.

The Submontane plateau

The Submontane plateau has four diverse divisions the Potohar Plateau, Trans-Indus Plains, Salt range, and Sialkot District.

The Potohar Plateau

The Potohar Plateau lies covers an area of about 12,800 km² to the east of the Indus river at the height of 400 to 600 meters in the province of Punjab. Potohar Plateau is open undulating country, developed from Siwalik Range which is largely of sandstone covered by the thickness of soil (Loam) which erodes easily.

The Trans-Indus Plains

Trans-Indus Plains is in the west of Indus River consist of high grit plateau of the valley of Kohat, Peshawar, and Banu which have many watering spots.

The Salt Range

In the southern edge of Potohar Plateau salt range lies with an average height of 670 meters. It's tremendously arid territory that sharply marks the border between Submontane area and Indus plains in the south.

The Sialkot District

Sialkot District is a narrow sub montane region in the north-east it is rich agricultural region and soil is heavy and fertile.

The Baluchistan Plateau

Baluchistan Plateau spreads westward with many ridges running crossways it from the north-west to the south-east. It's divided from Indus plains by Sulaiman, Kirthar ranges and it is separated into five zones.

1. The Coastal Zone spreading over a 50km wide coastal belt.
2. Flat Plain Zone stretching from Sibi and Dhadar to Usta Mohammad.
3. Low Upland Zone is an area of Loralai, Khuzdar, Chagi, and Turbet district at an elevation of 700 to 1300 meters.
4. Medium Upland Zone consists of an area of Quetta, Kalat, and Zohb at an elevation of 1300 to 2000 meters.
5. High Upland Zone extending from 2000 to 2700 meters with very cold long winter and mild short summer.

Mountains Bordering West of Pakistan

These mountains run south from the Hindu Kush in various corresponding ranges outside the path of monsoons. Other three ranges run south from Hindu Kush to the Kabul River, to the south which lies the famous Khyber Pass bordering of Afghanistan (Wikipedia, mountain ranges of Pakistan, 2017).

2.1.3. Water Resources in Pakistan

Water is important for sustaining the quality of life on earth. This finite commodity has a direct

behaviour on almost all sectors of the economy. In Pakistan, its reputation is more than regular due to the agrarian nature of the economy.

Surface Water Resources

Pakistan surface water resources largely comprise of flows of the Indus River and its streams, which carry in about 138.7 million-acre feet of water per annum. The Indus River delivers 65% of the total river flows, whereas the portion of Jhelum and Chenab is 17 and 19%. Hydro-power is a renewable resource which assistances Pakistan. Afterward, the Indus Water Treaty of 1960 World Bank definite that River Sutlej, Ravi, and Beas water will be used via India and River Indus, Jhelum also Chenab water will be used by Pakistan. Pakistan was stated to construct 2 Dams one Tarbela and second Mangla, 5 Barrages, 8 linking Canals. For this India was said to contribute 60% whereas Pakistan will contribute 40%. Pakistan is sighted developing wind turbines to achieve the demand for energy. Solar power is now gradually successful, but it is still mounted on a minor scale. Pakistan major River is known as River Indus which flows from Tibet China and arrives over Pakistan by (KPK). River Indus System is identified as Indus System it is separated into two plains. Upper Indus Plain starts from Northern Pakistan and split ends up at Mithankot. River Indus has branches on equally western and eastern side. Indus River has a overall distance of 2900 kilometres (Km) and the drainage area is about 966,000 km². Five main tributaries linking its eastern side are Jhelum, Chenab, Ravi, Beas, and Sutlej in addition, three minor streams are the Soan, Harow, and Siran, which drain in mountainous areas. Several small streams also join the Indus towards its western side. The biggest of such tributaries is River Kabul. These four rivers flow in Punjab and meet at Panjnad where they are identified as River Panjnad. River Indus western streams are River Swat, Kabul, Kurrram, Tochi, Gomal, Zhob and join River Indus at (KPK) Khyber Pakhtunkhwa and at Mithankot these rivers lastly meet with River Indus while River Indus flows alone through Lower Indus Plain. Lower Indus Plain Starts after Mithankot up to Thatta where River Indus meets with the Arabian Sea. This place is also recognised as Indus Delta. Besides main rivers, there are several small rivers and streams, which are only seasonal with flow depending on rainfall and bring almost no water during the winter months. The seventy-seven-year record of the Indus River 1922-23 to 1999-2000 shows that the watersheds of the Indus River yield per annum is about 138.7 million-acre feet (MAF). Mountain

fast-moving water in the mountainous areas of the country provide alternative source of surface water, which has not been established to its full potential. There are fourteen distinct Mountain fast-moving water areas in entirely the four provinces of Pakistan, with a total potential of about 19 million-acre feet (MAF) at around 1,200 spots. Out of this, almost 60 percent can be developed for crop production. This water provides excellent opportunity to irrigate almost six million acres of culturable wasteland in the hill torrent areas Table 2 (Majeed, 2010).

Province	Water Development Potential (MAF)
Punjab	2.7
Khyber Pakhtunkhwa	7.3
Balochistan	7.86
Sindh	0.78

Table 2 Surface water flows of four provinces in MAF.

Ground Water Resources

To know the groundwater resources of Pakistan is important for that research. Groundwater resources of Pakistan occur in the Indus Plain, spreading from Himalayan foothills to the Arabian Sea, and are deposited in alluvial deposits. The Plain is approximately 1,600 Km extended and covers an area of 21 Million hectares and is blessed with the widespread unconfined aquifer, which is fast becoming the additional source of water for irrigation. The aquifer has been constructed due to direct recharge by natural precipitation, river flow, and the continuous seepage from the conveyance-system of waterways, distributaries, water channels and application-losses in the irrigated lands throughout the last 90 years. This aquifer, with a potential of around 50 MAF, is being exploited to a range of about 38 MAF by over 562,000 private tube wells and about 10,000 public tube wells. In Balochistan, groundwater, pull out through dug wells, tube wells, and springs is the main dependable source of water for irrigation of orchards and further cash crops. This is because nearly all the rivers and natural streams are ephemeral in nature, through seasonal flows. It is projected that, out of a total accessible potential of about 0.9 MAF, 0.5 MAF is already exploited, thereby leaving a balance of 0.4 MAF that can still be used. This generates misconception, as the aquifers are not continuous but are restricted to basins due to geologic circumstances. It is noted that in two of the basins (Pishin-Lora and Nari) groundwater is being ruined, beyond its development potential, creating mining

situations and causing a vast overdraft of groundwater that is threatening to dry up the aquifers in the long term (Majeed, 2010).

2.1.4. Rainfall trends in Pakistan

The inconsistency of rainfall has augmented geographically, across seasons, and yearly in Asia over the past few decades. Declining trends in rainfall patterns along Pakistan's coastal areas and arid plains have also been detected (IPCC, 2007). According to Pakistan Meteorological Department, most important parts of Pakistan experience dry climate. Humid environments prevail but over a small area in the north. The whole of Sindh, most of Balochistan, most parts of Punjab and central parts of Northern Areas obtain less than 250 mm of rainfall per year. There is no clear altitudinal trend of rainfall which is covering to the whole country. The researcher selected 30 stations from extreme north to south and east to west and dataset spreads over a period of 30 years (1976-2005). The selected stations have been divided into five dissimilar microclimatic zones. These zones were named A, B, C, D and E as shown in Fig. 6 (Salma, 2012) with their latitudinal range.

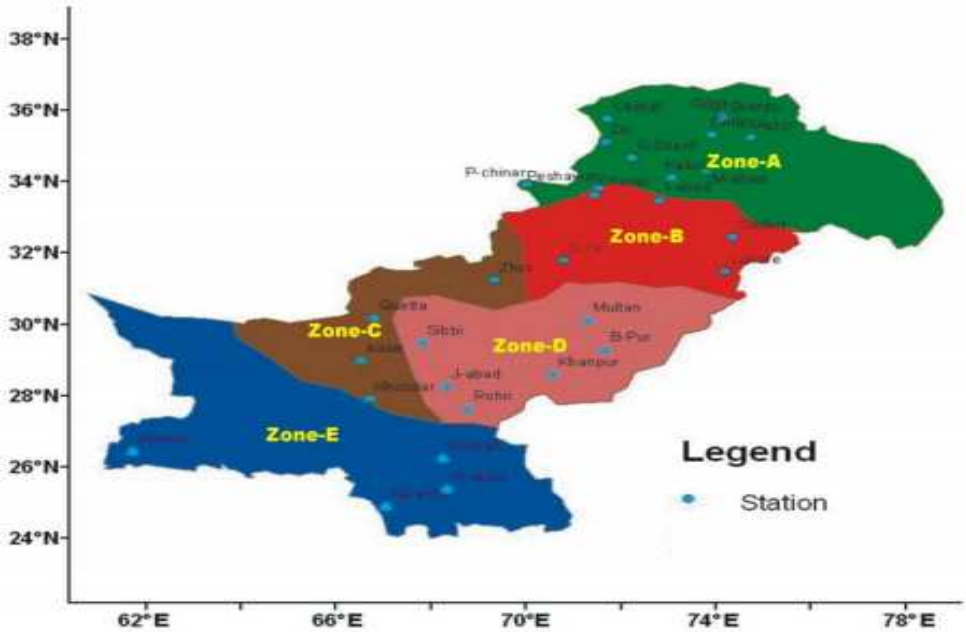


Fig.6 Map showing the rainfall trends in Pakistan (Source: Salma 2012).

Zone A: Having cold climate and high mountains, situated in the north of Pakistan. These stations include are Chitral, Gilgit, Muzaffarabad, Said-u-Sharif, Skardu, Astor, Dir, Chilas

Parachinar, and Kakul. These are mostly hill stations located between 34 N to 38 N in the Himalaya, Hindukash, and Koh-e- Sufaid mountain ranges.

Zone B: Has mild cold climate and Sub Mountains, situated between 31N to 34 N. The stations are Sialkot, D.I. Khan, Islamabad, Peshawar, Cherat, and Lahore.

Zone C: Climate is cold in winters and hot in summers most of them are mountainous stations and cover an area between 27 N to 32N and 64 E to 70 E. Stations contained within this zone are Quetta, Zhob, Kalat, and Khuzdar.

Zone D: Is the hottest and dry zone of the country where peak maximum temperatures are documented in stations of Sibbi and Jacobabad. Stations included are Sibbi, Jacobabad, Bahawalpure, Khanpur, Multan, and Rohri.

Zone E: Is a big zone having several stations and coastal cities, near to the Arabian Sea. The coastal part covers only a small portion of this zone and climate above coastal parts in Balochistan as well as in Sindh province is typically arid to hyper-arid and the selected stations from this zone are Hyderabad, Karachi, Nawabshah, and Jewani (Salma, 2012).

Trends Determination

The researcher presented the descriptive statistical analysis results in Table 3 (Salma, 2012) with ANOVA result of the rainfall for different microclimates zones of Pakistan. In the given table, the number of valid/missing values show the length of data from 1976- 2005. Researcher produced the results which are obvious from these statistical gauges that maximum zonal means and medians were observed for zone A (66.64 mm, 57.22 mm) and zone B (66.99 mm, 57.05 mm) for 30 years average rainfall while zone D shows the lowest value of mean (22.65 mm) and median (19.29 mm) respectively. Statistics such as standard error and 95% confidence interval all are also higher for zone A and B as compared to other zones. The skewness expressions positive values for all five zones with zone C and E being higher. Results from the ANOVA test are most important ($F=71.64$, $p=0.00$) not only within each zone but also for inter-zonal analysis on decadal and inter-decadal scales. Each individual zone, analysis of variance shows different results, like probability for zone A ($F=1.93$ $p=0.15$) is not found substantial. The outcomes show the higher value than the critical tabulated value ($p > 0.05$). While, for zone B, and zone D, ANOVA test display non-significant results for all the involved stations ($p > 0.05$ or 0.1). Whereas in contrast, the ANOVA results for the zone C ($F=3.81$, $p=0.03$) and zone E ($F=5.92$,

p=0.00) are found most important to the change and it is also understandable from inter decadal significance of the zones Table 3 (Salma, 2012).

		ZoneA	ZoneB	ZoneC	ZoneD	ZoneE
Stations		10	6	4	6	4
30 Years	Valid/Missing values	297/3	175/5	116/4	172/8	118/2
Mean	All value used	66.64	66.99	32.92	22.65	32.10
	5%trimmed Mean	64.72	64.42	31.74	21.76	29.62
Median		57.22	57.05	30.47	19.29	25.04
Std. Error		2.70	2.77	1.39	1.05	2.35
95%CI	Lower Bound	61.31	61.52	30.16	20.58	27.45
	Upper Bound	71.96	72.46	35.68	24.72	36.75
Skewness		0.46	1.12	1.56	1.15	1.45
F- Value		1.93	0.91	3.81	1.53	5.92
Sig.		0.15	0.41	0.03	0.22	0.00

Table 3 Statistics and (ANOVA) analysed through Analysis of Variations results for rainfall (Source: Salma, 2014)

2.2. Data Collection

The main significance of current work is the collection of spatial data sets and the generation of a complete database. Once the data sets have been collected this spatial data sets are described in the (ANNEX-I) of the dissertation in the form of metadata. For this present study, this metadata of spatial data sets of Pakistan is stored and make them accessible for future studies. Meanwhile, the main concept is that the information is stored and made available to all potential users, this approach should be followed in other countries worldwide.

The objective is to assess the various population density datasets while comparing it with water resources map. To fulfil the objective of the study it is essential to download dataset for population mapping and to determine the water resources. The datasets downloaded from several sources in which we have SEDAC (NASA-Columbia), WorldPop, JRC-Global Human Settlement Layer, and FAO. SEDAC (NASA-Columbia) is providing estimates of population density for the years 2000, 2005, 2015, and 2020, created on counts consistent by national censuses and population catalogues, as raster data to enable data integration. The fourth version of Gridded Population of the World (GPWv4) is gridded with an output resolution of 30 arc-seconds, or ~1 km at the equator (NASA, 1958). World pop is providing an estimate of the

number of people residing in each 100*100m grid cell for every low and middle-income country with Geographic projection WGS84. Through integrating census, satellite survey, and GIS datasets in a supple machine learning framework, high-resolution maps of population count and concentrations for 2000-2020 are produced, along with additional metadata (WorldPop, 2013). JRC- Global Human Settlement Layer is providing the global spatial raster dataset which shows the distribution and density of population, expressed as the number of people per cell with a spatial resolution 250m, 1km with Spherical Mercator (EPSG:3857), World Mollweide (EPSG:54009) (JRC Human Settlement Layer, 2010-2011). FAO is providing the information about the population density was derived from Land Scan 2000-Global Population Database with a spatial resolution of a 5*5 arc and Geographic projection WGS 1984 (FAO, 1945). Aqueduct Global Maps 2.1 data contain indicators of water quantity, water variability, water quality, public awareness of water issues, access to water, and ecosystem susceptibility. Aqueduct country and river basin rankings dataset shows countries and river basins average exposure to five of Aqueduct's water risk indicators baseline water stress, interannually variability, seasonal variability, flood occurrence, and drought severity (World Resources Institute, 1982).

3.1. Methodology

Starting from the given background the aim of this research is to examine the utility of mapping algebraic approach based on QGIS, in the case of water resources and people of Pakistan. The datasets have been collected from diverse sources and analysed through the adoption of QGIS. First, different vector and raster layers have been imported with the help of QGIS. Secondly, all the raster layers were clipped for the study area (Pakistan) the Pakistan map has been clipped from global raster dataset by using the processing toolbar. Whereas the Global aqueduct map has been clipped for the study area (Pakistan) and the new vector layer has been created (Layer> create layer> new shapefile layer), as well as features have been extracted by using the feature extraction tool with attribute toolbar. Raster layer has been clipped by using the processing toolbar (Processing toolbar > GDAL extraction > clip raster by mask layer). The vector layers of Pakistan consist of three different maps depicting the total water withdrawal in cubic kilometre per year, Total blue water in cubic kilometre per year, Access to water in percentage and raster layer showing the population densities in different provinces/regions of Pakistan with the unit of persons per sq. Kilometre. The Total withdrawal is the total amount of water extracted from freshwater sources for human use. The Total blue water for each catchment is the collected runoff upstream of the catchment plus the runoff in the catchment. Access to water measures the percentage of population without access to improved drinking-water sources. Higher values indicate areas where people have less access to safe drinking water and consequently higher reputational risks to those not using water in an equitable way. However, the zonal statistics tool has been used to check the population density of each raster layer which gives us the outcome/results. Finally, each population distributed raster layer has been overlapped and compared with water withdrawal vector layers of Pakistan to assume about the amount of water withdrawal, people access to water and total blue water in different provinces of Pakistan.

4. Results and discussions

The results/outcomes derived from the application of census and other ancillary data are presented now. Results/outcomes in the form of raster and vector maps are elaborated and discussed. The population density maps have been analysed by overlapping with the aqueduct layer. The data sets of SEDAC Gridded Population of the World version 4 (GPWv4) downloaded from different years 2020, 2015, 2005, 2000. Whereas, Joint Research Centre Global Human Settlement layer dataset has been adopted from the subsequent years 2015, 2000, 1990, 1975. To assess the population density these layers have been overlapped with each other. While the population datasets taken from Food and Agriculture Organization (FAO) and World Pop has been overlapped as well and highlighted for the analyses of population density. Finally, the data sets of GPWv4, JRC-GHS, FAO, World Pop datasets were used to overlap with aqueduct layer to analyse the amount of water withdrawal, and to realise which region, district or part of the country is more vulnerable to water stress while aqueduct layer consists of water withdrawal, total blue water and access to water. Here in given figure as you can see the population density map of 2010 Fig.7 (UNOCHA, 2010).

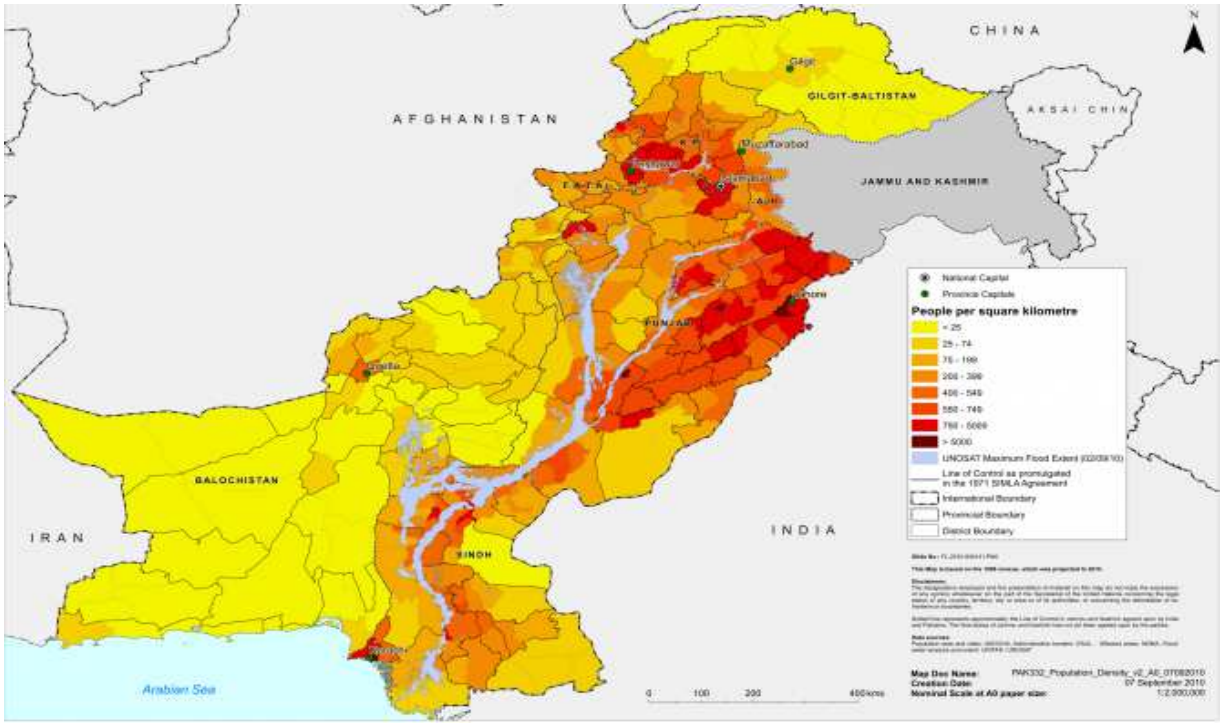


Fig.7 Population density map of Pakistan 2010 (Source: UN Office for the Coordination of Humanitarian Affairs, Sep 2010).

4.1. Aqueduct Global map 2.0

Aqueduct Global Maps 2.0 contains indicators of water quantity, water variability, water quality, community alertness of water issues, access to water, and ecosystem vulnerability. Awareness nearby the physical, regulatory, and reputational water risks to companies and their investors is on the rise and strong, similar, and complete data is required to help evaluate these water-related risks. In reply to this demand, WRI established the Aqueduct Water Risk Atlas, including 12 universal indicators and maps of water-related risk. Companies can use this information to arrange actions, investors to leverage economic interest to improve water management, and governments to involve with the private sector to seek solutions for more equitable and sustainable water governance. WRI produces maps, charts, data sets, infographics, and further visual resources as part of our commitment to turn "information into action." These products are created on our data and research, which are held to traditional academic standards of excellence, including objectivity and rigor. (Gassert, WRI, 2013).

According to the Fig.8 as you can see most of the blue water resources approximately > 100 km³ exist in the northern part of the country and in the north-east of Pakistan the amount of total blue water is about 50-70 km³ while in the north-west of the country the blue water resources are 30-50 km³. When we assessed the blue water resources towards southern part of the country the given map Fig.8 showing the scarcity of blue water resources which is about 10-30 km³, but some southern part reserved blue water resources > 100 km³ though in the south-western portion of Pakistan the total blue water is about 10-30 km³ whereas, in the south-eastern part of Pakistan the country is also facing the lack of water resources and the water resources existing over there are 30-50 km³. However, the reason is that in the south-eastern part of the country there is a Thar desert. Thar desert is the largely arid region in the south-eastern part of the Pakistan that forms a natural boundary between Pakistan and India. It is the seventeenth world's largest desert and the world's ninth largest subtropical desert. About 25% of Thar desert is in Pakistan and remaining part is in India. Thar desert located in the Sindh province of Pakistan.

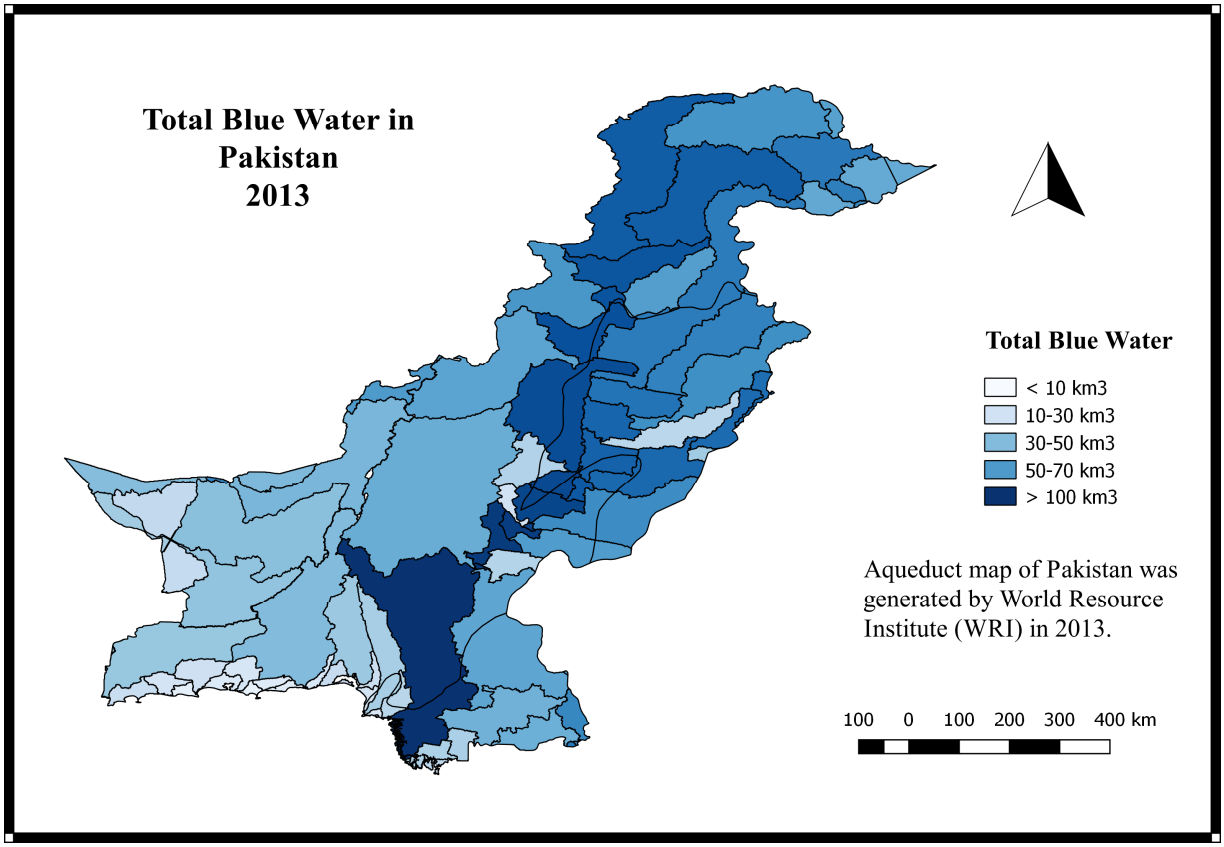


Fig.8 The map of Pakistan showing the average amount of blue water resources in Pakistan. (Source: WRI).

If we look at the water withdrawal map of Pakistan as in Fig.9 we can say that in the northern part of the country the total water withdrawal is about 10-30 km^3 per year and in the north-east of the country the water withdrawal is approximate > 100 km^3 per year while in the north-west the water withdrawal is in between 30-50 km^3 per year. Whereas, in the southern part of the country the water withdrawal is 10-30 km^3 per year while in the south-west the water withdrawal is < 10 km^3 per year and in the south-east of the country the water withdrawal is > 100 km^3 per year.

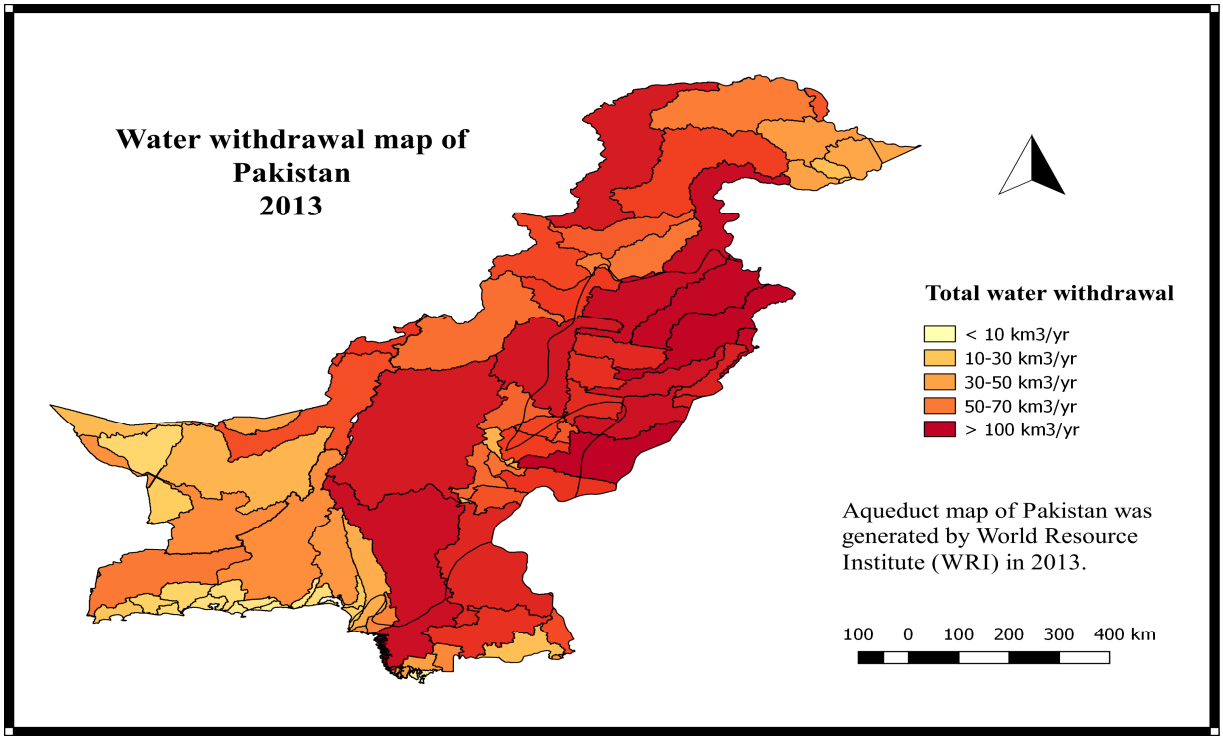


Fig.9 The map of Pakistan showing the total water withdrawal in Pakistan. (Source: WRI).

According to the given map Fig.10, each inhabitant in the entire country has High (100%) access to safe drinking water.

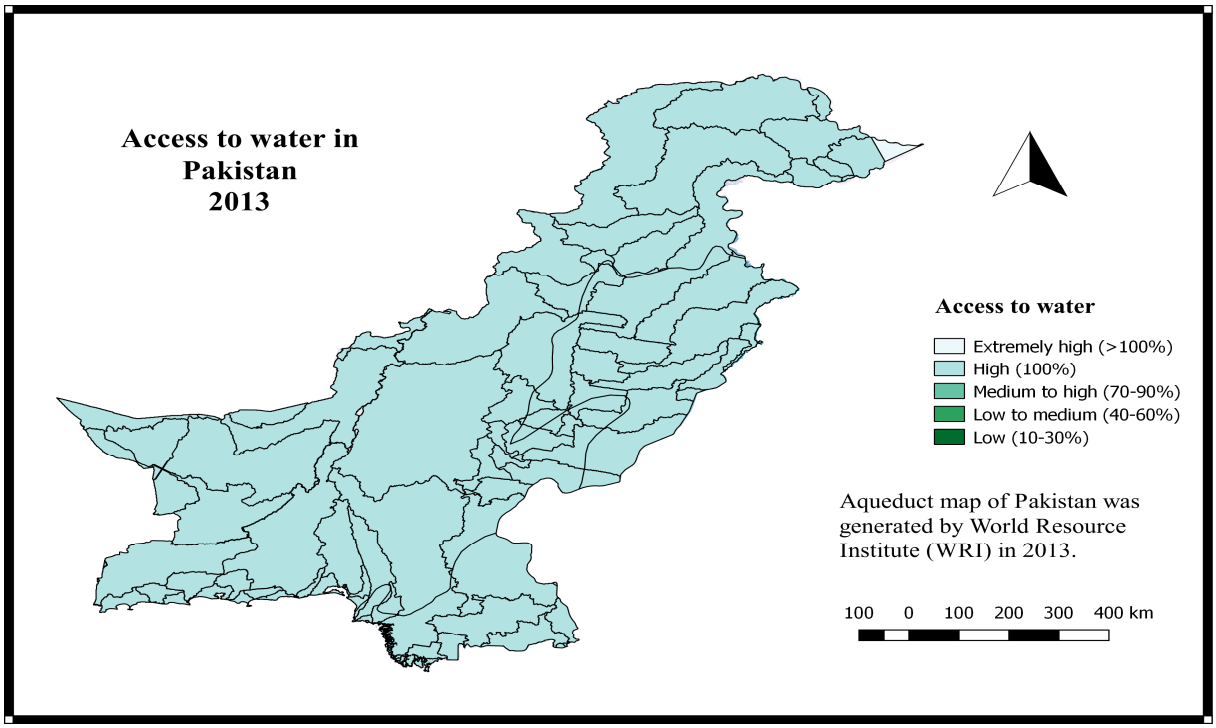


Fig.10 The map of Pakistan showing the people access to water in Pakistan. (Source: WRI).

4.2. SEDAC Gridded Population of the World (GPWv4)

Gridded Population of the World, Version 4 (GPWv4) Population Count contains estimates of human population, dependable with national censuses and population registers, for the years 2000, 2005, 2010, and 2020. A proportional allocation gridding algorithm, using about 12.5 million national and sub-national administrative units, is used to allocate population values to 30 arc-second (~1 km) grid cells. The population count grids contain estimates of the number of persons per grid cell. The Gridded Population of the World version four (GPWv4) replicas the dispersal of the human population on a continuous raster surface. Meanwhile the announcement of the first version of this worldwide population grid in 1995, the indispensable inputs to GPW have been population census tables and administrative boundaries. The determination of GPW is to deliver a spatially disaggregated population layer that is well-matched with datasets from social, economic, and earth science disciplines, in addition, remote sensing data. It provides worldwide consistent and spatially clear data for use in research, policy-making, and communications the fourth version of GPW (GPWv4) is a gridded data product of globally-integrated nation-wide population data from the 2010 round of population and housing surveys. The gridded data sets are created from national or subnational participated administrative units. GPWv4 is gridded by an output resolution of 30 arc-seconds or ~1 km at the equator. Isolated grids are accessible for population counts and population density, UN-adjusted population counts and population density, data quality indicators, and land and water areas. Moreover, a vector dataset of the centre point places (centroids) for each of the input administrative units and a grid of national level numeric identifiers are involved in the collection to share information regarding the input data layers. (SEDAC, 2016).

The outcomes derived from the SEDAC (GPWv4) data sets are explained below. As given Fig.11 showing the population density per person per grid cell (~1km) in different regions/districts of Pakistan. As in Fig.11 assumption made for the year 2020 during this assumption we realize that most of the population will get settled in the Punjab province which is 31° north and 72° towards the eastern part of the country and it is the second largest province by area after Baluchistan. In Punjab, the population will be highly dense > 1000 Persons per km². In the northern areas of Pakistan which is located at 35.35°N and 75.9°E, the total population in 2020 will be 1-5 Persons per km². NWFP (North West Frontier Province) which is 34.00°N and 71.32°E it was established in 1901 and was known by this name until 2010. The area

became Khyber Pakhtunkhwa (KPK) Province on April 19, 2010, when the Eighteenth Amendment was signed. In KPK province the total expected population for the year 2020 will be 25-250 Persons per km². Baluchistan is the largest province of Pakistan with respect to the area forming the south-western region of Pakistan. Their predictable population for 2020 is 1-5 Persons per km² and the total area is 347,190 km² it lies 27.7 °N and 65.7°E. The Federally Administered Tribal Areas (FATA) is a semi-autonomous tribal region in 33° north and 70° east of Pakistan, comprising of seven tribal agencies/districts and six frontier areas, and are directly governed by Pakistan's federal government through a special set of laws called the Frontier Crimes Regulations (FCR). The expected population of 2020 for this region is 5-25 Persons per km² and the total area is 27,220 km². Azad Kashmir province is situated in the 32.22°N and 73.28° towards east. The total predictable population of Azad Kashmir province is 25-250 Persons per km² for the year 2020 while the total area is 13,229 km². Sindh is one of the fourth provinces of Pakistan in the southeast of the country. Sindh is the third largest province of Pakistan by area which is 140,914 km² and it lies 25.89°N, 68.52°E. The population density of Sindh is 250-1000 Persons per km². Federal capital territory (FCT) Islamabad is the capital city of Pakistan and it is the 10th largest city of Pakistan which is located in the Pothohar Plateau in the north-eastern part of the country with 33°′N 73°E their expected population for the year 2020 will be > 1000 Persons per km². In the northern areas of Pakistan which are 35.35°N and 75.9°E, the total population in 2020 will be 1-5 Persons per km² and the total area is 72,971 km².

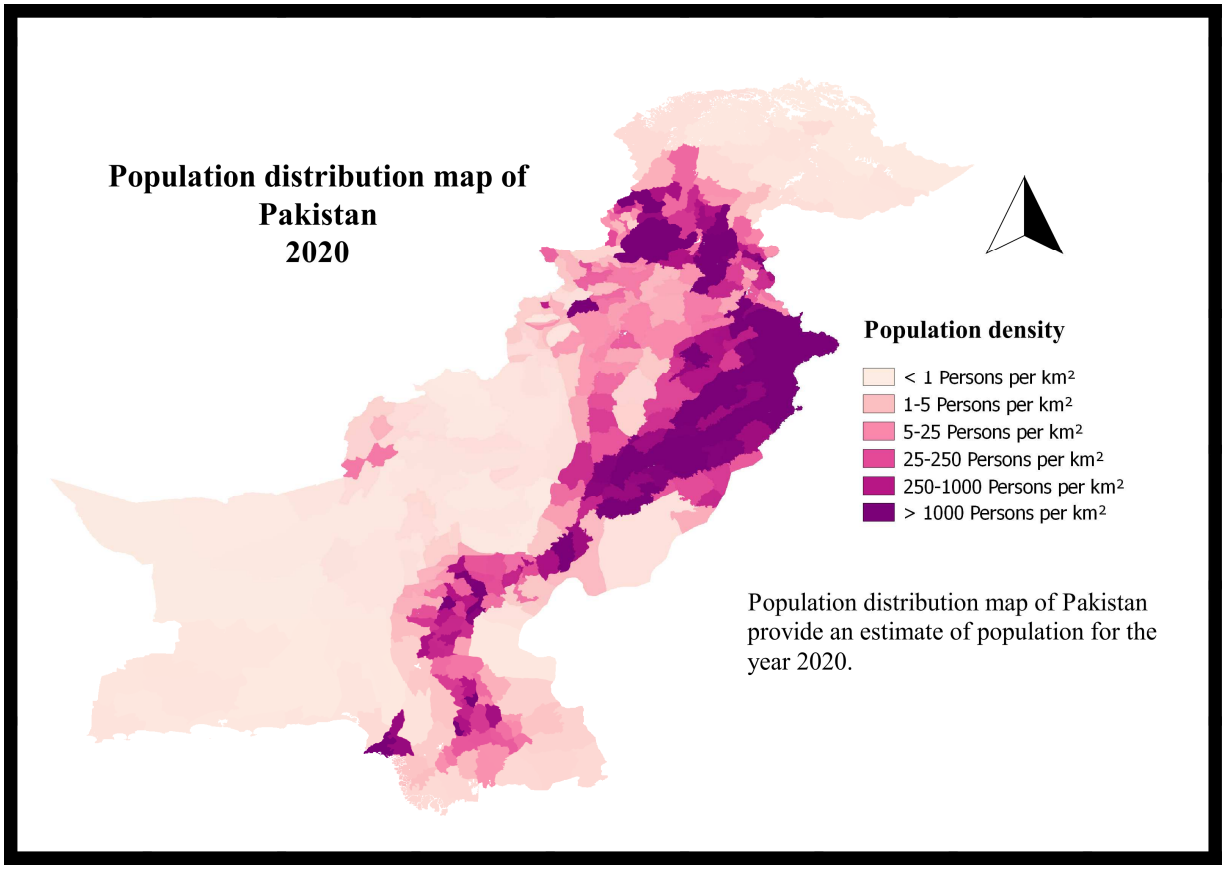


Fig.11 Population density in different regions of Pakistan for the year 2020 (Source: SEDAC).

The outcomes derived from the Fig.12 about dissimilar provinces of Pakistan is that most of the population is living in Punjab province which is extremely high > 1000 Persons per km². If we assess the population density of northern areas for the year 2015 it's about 1-5 Persons per km². In 2015 Khyber Pakhtunkhwa (KPK) province population density is >1000 Persons per km² but towards the north-west of the (KPK), the population is about < 1 Persons per km². In 2015 Azad Kashmir (AK) province population density is about 25-250 Persons per km². According to the 2015 analysis, the Federally Administered Tribal Areas (FATA) population density is 5-25 Persons per km². The population density of Sindh province in 2015 is 25-250 Persons per km². In 2015 the Baluchistan population density is < 1 Persons per km² and the estimated population density of Islamabad is > 1000 Persons per km² for the year 2015.

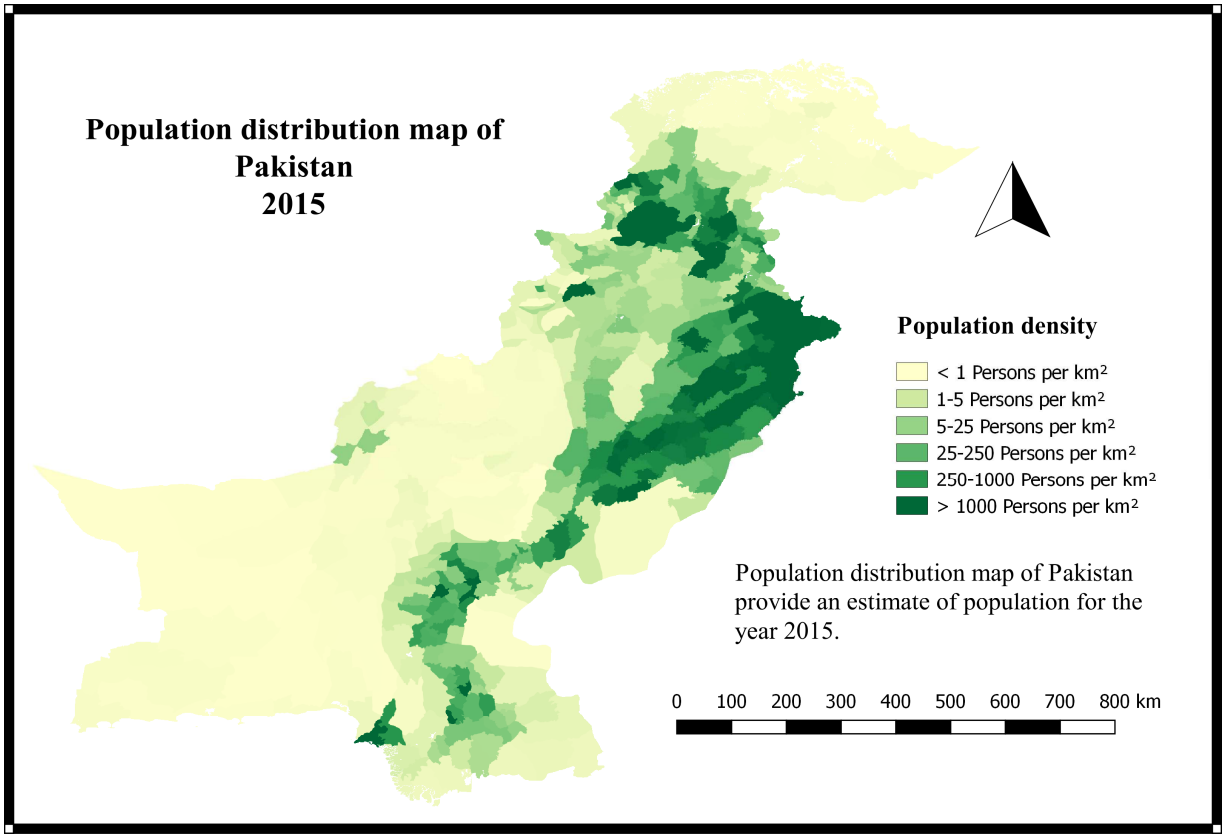


Fig.12 Population density in different regions of Pakistan for 2015 (Source: SEDAC)

The given Fig.13 explaining the outcomes derived for the year 2005 as the population density of Punjab province is > 1000 Persons per km² and in northern areas, the population density is < 1 Persons per km². Whereas the population density of Khyber Pakhtunkhwa (KPK) province has been determined about > 250-1000 Persons per km² and towards the north-west, their population is < 1 Persons per km² while the population density of Azad Kashmir (AK) is 25-250 Persons per km². If we look at the population density of Federally Administered Tribal Areas (FATA) it's about 5-25 Persons per km² though the population density of Sindh province is 25-250 Persons per km² and the population density of Baluchistan is < 1 Persons per km². The capital of Pakistan (Islamabad) population density is > 1000 Persons per km².

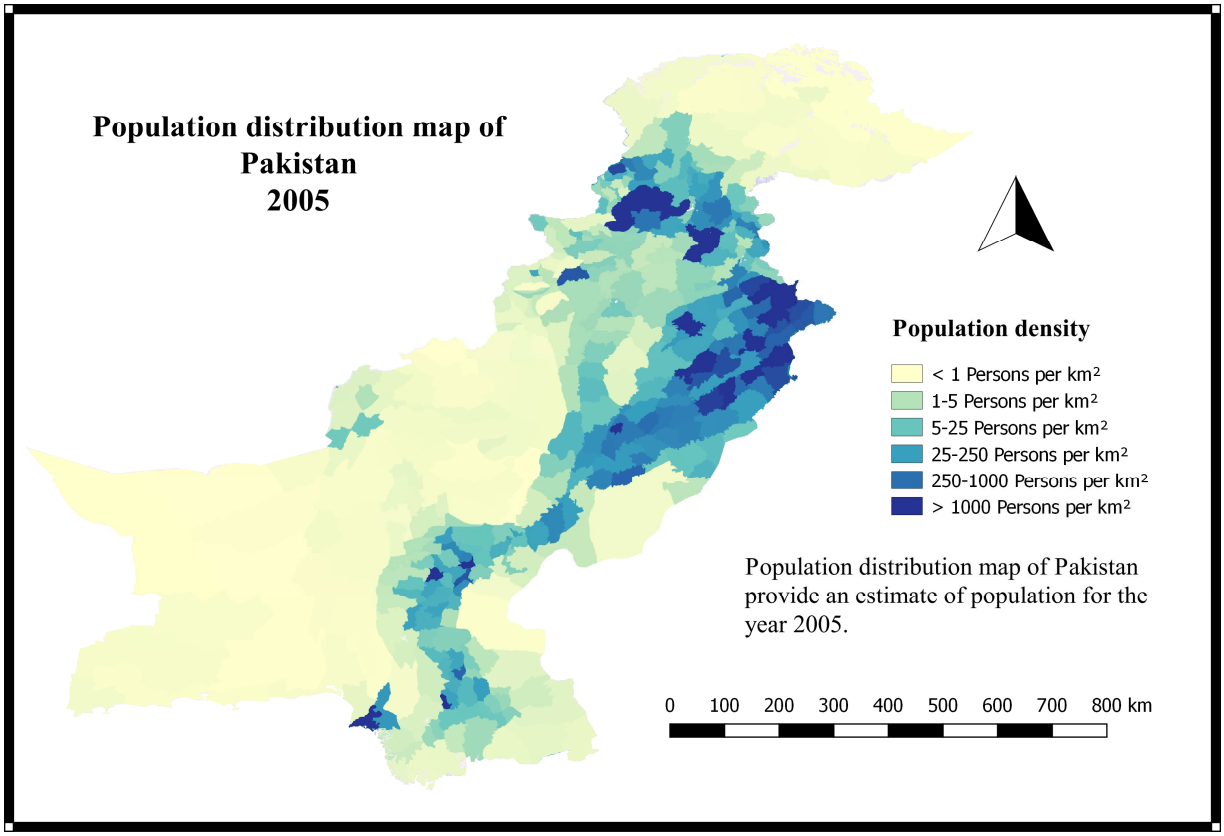


Fig.13 Population density in different regions of Pakistan for 2005 (Source: SEDAC)

The given Fig.14 illustrating us the population density for the year 2000. As you can see the population density of Punjab province is about > 1000 Persons per km² and if we analyse the population density for northern areas their population density is < 1 Persons per km². Although, the population density of Khyber Pakhtunkhwa (KPK) province is about > 25-250 Persons per km² and towards the north-west, their population is < 1 Persons per km² while the population density of Azad Kashmir (AK) is 1-5 Persons per km². Whereas, the population density of Federally Administered Tribal Areas (FATA) it's about 5-25 Persons per km², however, the population density of Sindh province is 25-250 Persons per km² and the population density of Baluchistan is < 1 Persons per km² and the population density of Islamabad is > 1000 Persons per km².

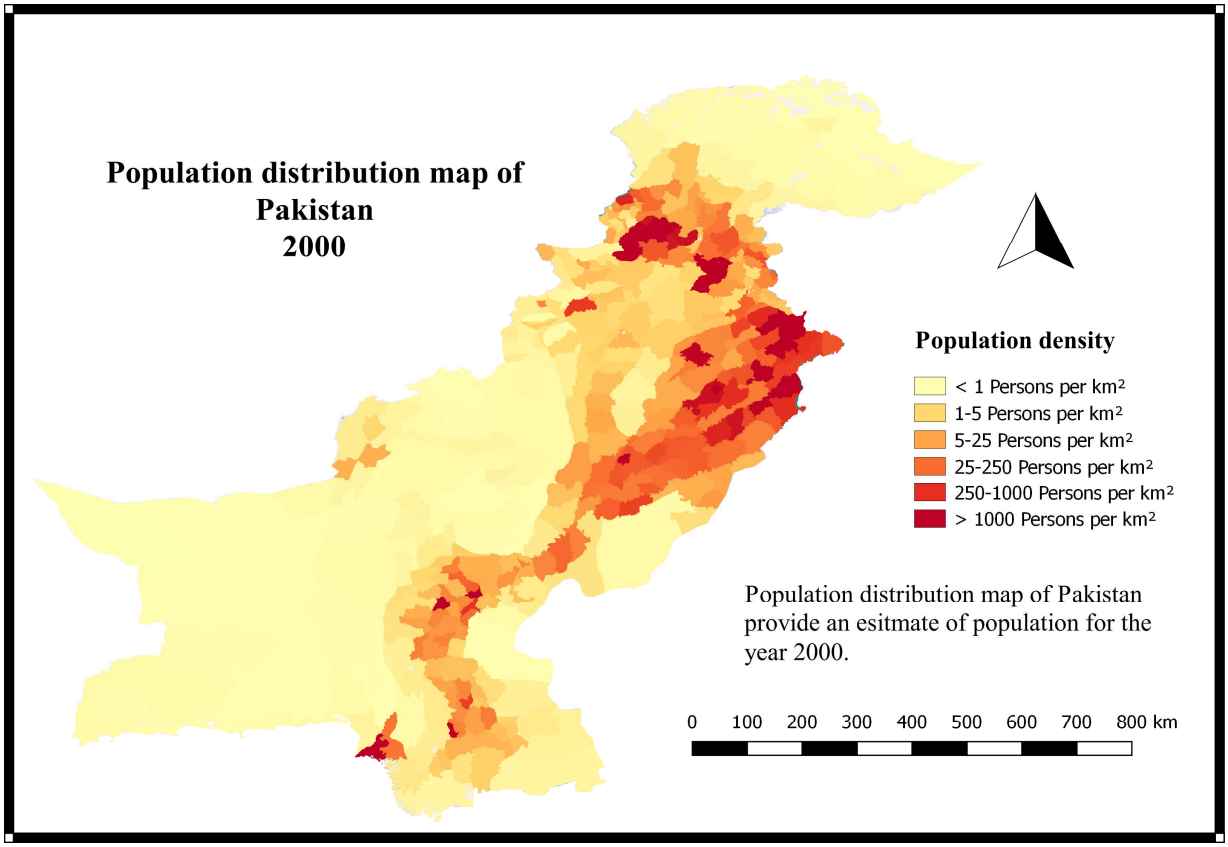


Fig.14 Population density in different regions of Pakistan for 2000 (Source: SEDAC)

4.3. Joint Research Centre (JRC) Global Human Settlement Layer (GHSL)

The Global Human Settlement (GHS) framework produces global spatial information regarding the human existence on the planet over time. This is the form of built up maps, population density maps and settlement maps. This information is produced with evidence-based analytics and information by means of new spatial data mining skills. The framework uses heterogeneous data with worldwide archives of fine-scale satellite imagery, census data, and volunteered geographic information. The data is managed fully automatically and produces analytics and knowledge reporting objectively and systematically about the occurrence of the population and built-up infrastructures. Spatial data reporting objectively and systematically about the

occurrence of the population and built-up infrastructures are indispensable for any evidence-based modeling or evaluating of

(i): Human and physical contact to threats as environmental pollution and deprivation, natural disasters and conflicts.

(ii) Effect of human activities on ecosystems.

(iii) Contact to resources.

This spatial raster dataset illustrates the density of population, expressed as the sum of people per cell. Residential population estimates for target years 1975, 1990, 2000 and 2015 provided via CIESIN GPWv4 were disaggregated from census or administrative units to grid cells, informed by the distribution and density of built-up as mapped in the Global Human Settlement Layer (GHSL) global layer per corresponding epoch, but according to all GHS maps some census/spatial data is missing that's why we can't assess population density (JRC(GHSL), 2010-2011).

The given Fig.15 has been clipped from a Global dataset of (JRC-GHS) and representing the population density for the year 2015 but in this figure, data is missing for some part of the country. As you can see in northern areas which are 35.35°N and 75.9°E their population density < 1 Persons per km², but data is missing to some extent. While in Punjab province the population density is 250-1000 Persons per km² which is 31° north and 72° towards the eastern part of the country. If we determine the population density of Federally Administered Tribal Areas (FATA) which is 33° north and 70° east with population density < 1 Persons per km², Azad Kashmir 32.22°N and 73.28° towards east their population density is < 1 Persons per km², and Baluchistan 27.7 °N and 65.7°E with a population density < 1 Persons per km² because there is lack of census data available which will represent population density of respective province. Whereas the population density of Sindh is 25-250 Persons per km² it lies 25.89°N, 68.52°E. In (KPK) the population density is 250-1000 Persons per km² while some data is missing, and it lies 34.00°N and 71.32°E of Pakistan. In Islamabad, the population density is > 1000 Persons per km² and it is located at 33°43′N 73°04′E.

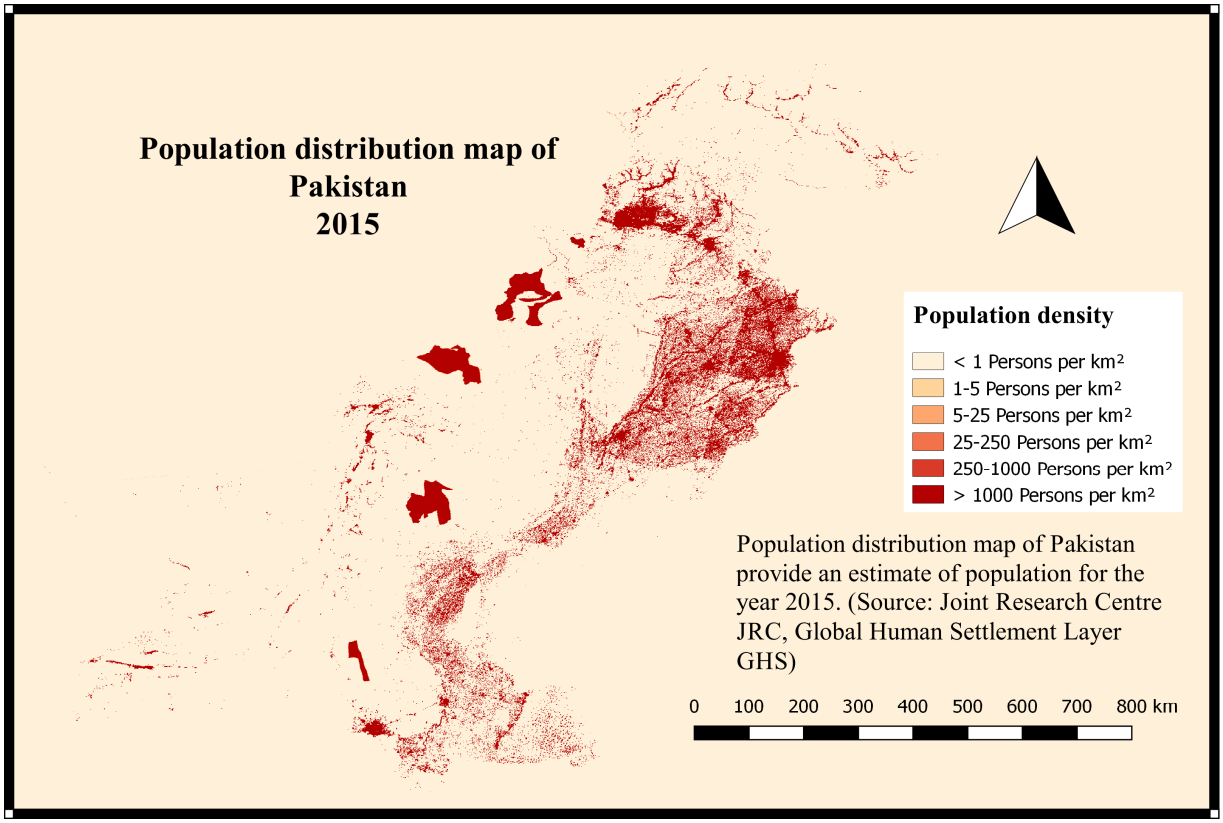


Fig.15 Population density in different regions of Pakistan for 2015 (Source: JRC-GHS)

According to Fig.16, we can see that some parts of the country don't have sufficient data for analysis. In that case, if we analyse the population density of different provinces we have this kind of results. As northern areas, Azad Kashmir (AK), Federally Administered Tribal Areas (FATA), Baluchistan have population density < 1 Persons per km² because of lack of census data. Whereas, the population density of Sindh is 25-250 Persons per km². In (KPK) the population density is 250-1000 Persons per km² while some data is missing. In Islamabad, the population density is > 1000 Persons per km².

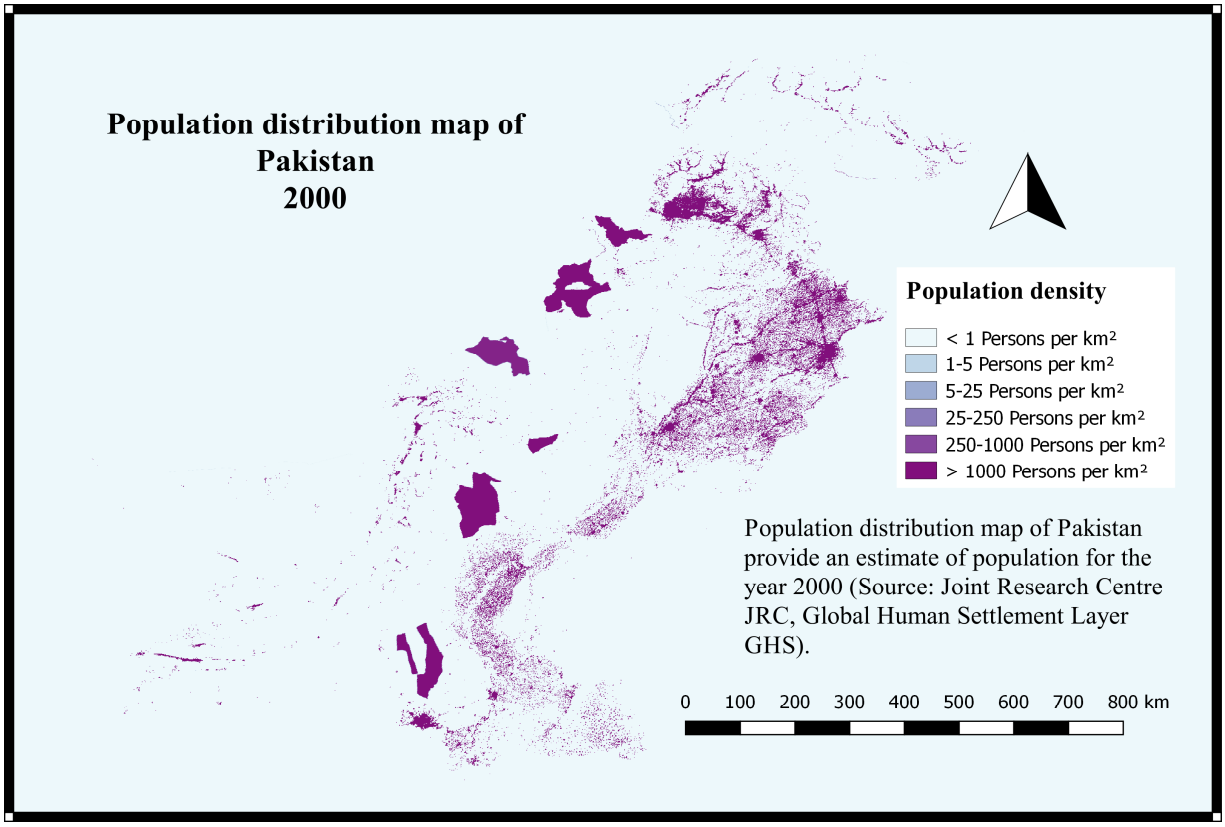


Fig.16 Population density in different regions of Pakistan for 2000 (Source: JRC-GHS)

In given Fig.17 there is little bit change has been noticed in population density for the year 1990 but also data is missing for some parts of the country. Due to lack of data the northern areas, Azad Kashmir (AK), Baluchistan telling us the population density < 1 Persons per km² but in the north east of Baluchistan the population density is >1000 Persons per km² and Federally Administered Tribal Areas (FATA) population density is 250-1000 Persons per km². Whereas, the population density of Sindh is 25-250 Persons per km². In (KPK) the population density is 250-1000 Persons per km² while in Islamabad, the population density is > 1000 Persons per km².

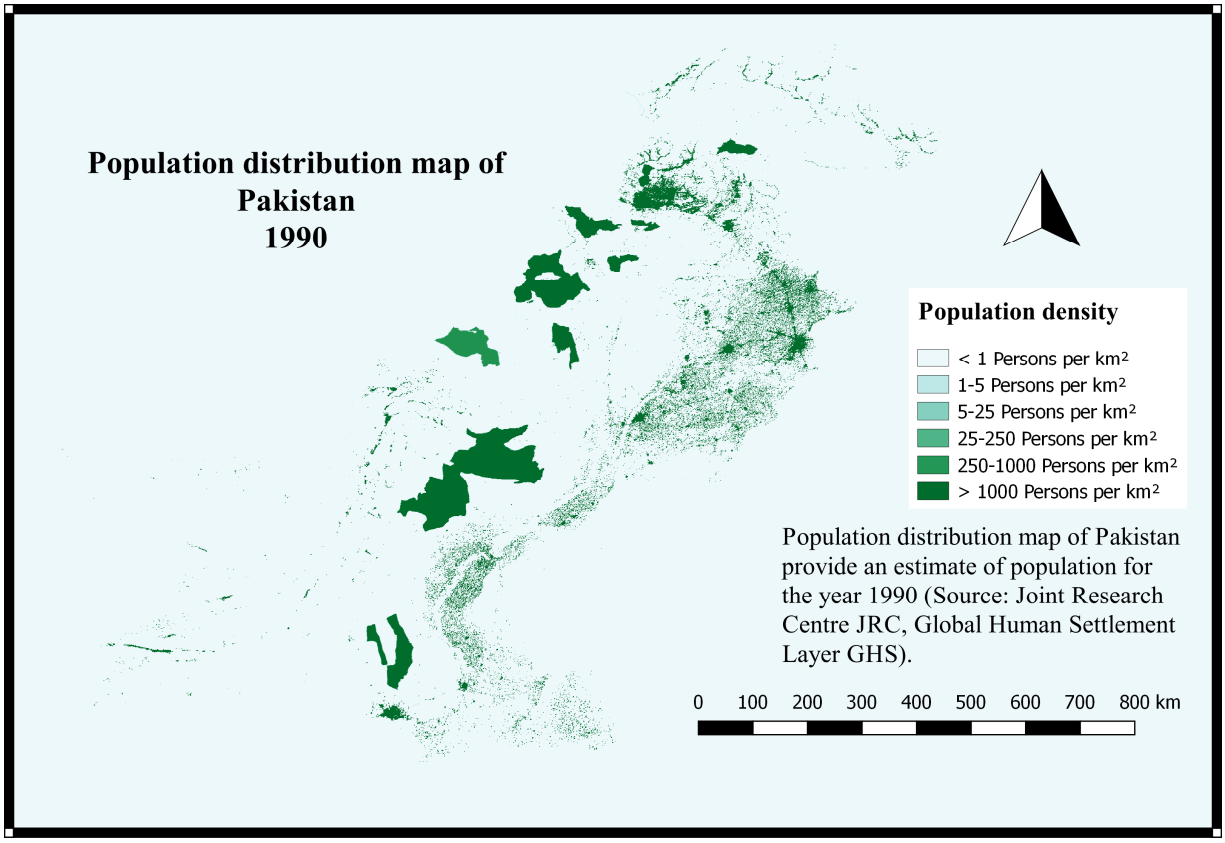


Fig.17 Population density in different regions of Pakistan for 1990 (Source: JRC-GHS)

Given Fig.18 explains the population density of Pakistan but data is missing for some parts of the country. In northern areas, Azad Kashmir (AK) population density is < 1 Persons per km² though Baluchistan province is telling us the population density < 25-250 Persons per km² but in the north east of Baluchistan the population density is >1000 Persons per km² and Federally Administered Tribal Areas (FATA) population density is 250-1000 Persons per km². However, the population density of Sindh is > 1000 Persons per km². In (KPK) the population density is 250-1000 Persons per km² but towards the north-west of the country, the population density is < 1 Persons per km² though in Islamabad, the population density is > 1000 Persons per km².

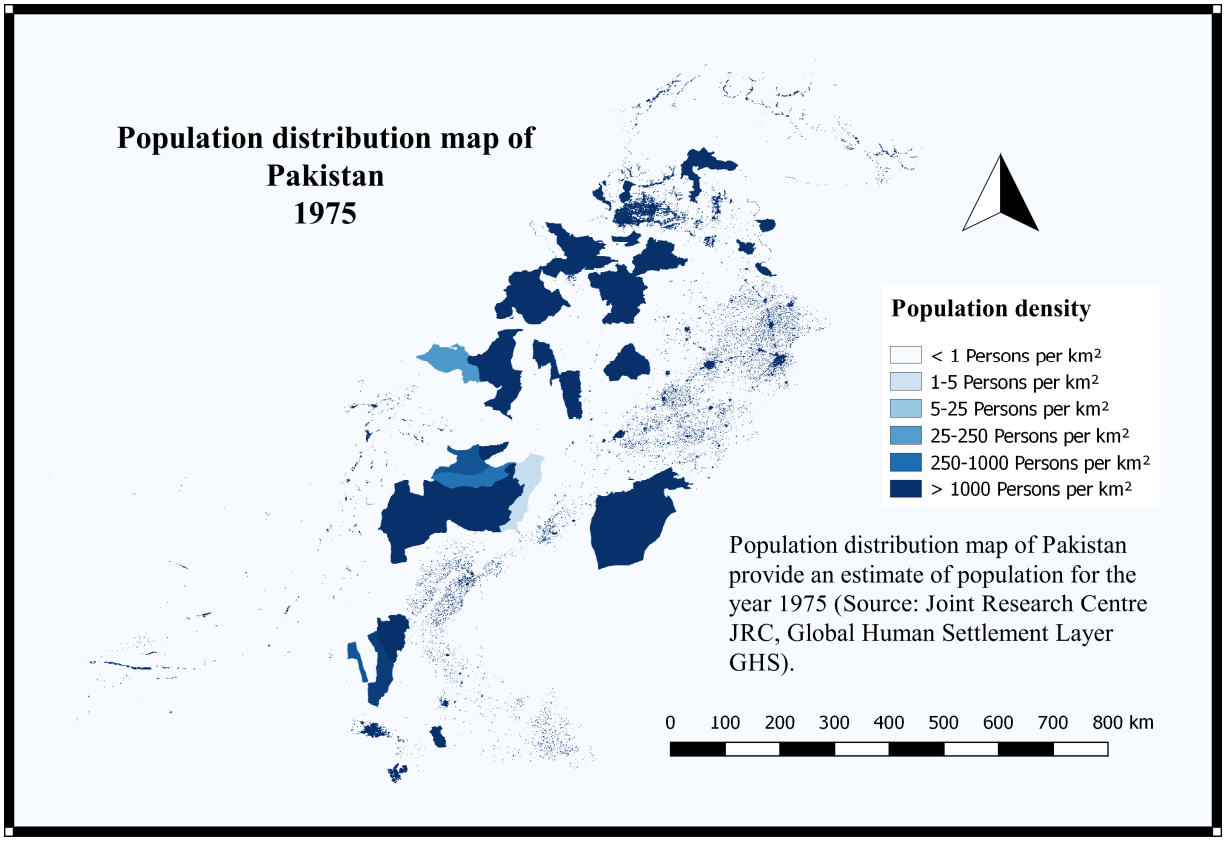


Fig.18 Population density in different regions of Pakistan for 1975 (Source: JRC-GHS)

4.4. Food and Agriculture Organization (FAO)

An intergovernmental organization, FAO has 194 Member Nations, two subordinate members and one-member organization, the European Union. Its employees come from several cultural backgrounds and are professionals in the several fields of activity FAO engages in. FAO's staff capacity permits it to support enhanced governance inter alia, create, develop and adapt current tools and guidelines and deliver targeted governance support as a resource to country and local level FAO offices. Headquartered in Rome, Italy, FAO is existing in over 130 countries. Attaining food security for all is at the heart of FAO's efforts to make sure people have steady contact to adequate high-quality food to lead active, healthy lives. Their three foremost goals are the eradication of hunger, food insecurity and malnutrition, the elimination of poverty, the driving forward of economic and social growth for all and the sustainable management and use

of natural resources, as well as land, water, air, climate and genetic resources for the benefit of existing and upcoming generations (FAO, 1945).

The raster dataset of population density has a spatial resolution of 5 * 5 arc minutes also is in geographic projection. Information regarding population density was derived from Land Scan 2000-Global Population Database. Oak Ridge, TN: Oak Ridge National Laboratory (30 x 30 arcs -seconds) and obtained from the Terrastat Global land resources CD-ROM (Healy, 2007).

The given Fig.19 has been clipped for Pakistan from the Global dataset of Food and Agricultural Organisation (FAO) and representing the population density for the year 2000. As northern areas which are located 35.35°N and 75.9°E their population density 1-5 Persons per km² while in Punjab province the population density is > 1000 Persons per km² which is 31° north and 72° towards the eastern part of the country. In Federally Administered Tribal Areas (FATA) which is 33° north and 70° east it has a population density < 1 Persons per km², Azad Kashmir 32.22°N and 73.28° towards east their population density is 25-250 Persons per km², and Baluchistan which lies 27.7 °N and 65.7°E with a population density 1-5 Persons per km². Whereas, the population density of Sindh is 250-1000 Persons per km² it lies 25.89°N, 68.52°E. In (KPK) the population density is >1000 Persons per km² but towards north-west, the population density in (KPK) is 1-5 Persons per km² and it lies 34.00°N and 71.32°E of Pakistan. In Islamabad, the population density is 250-1000 Persons per km² and it is situated at 33°43′N 73°04′E.

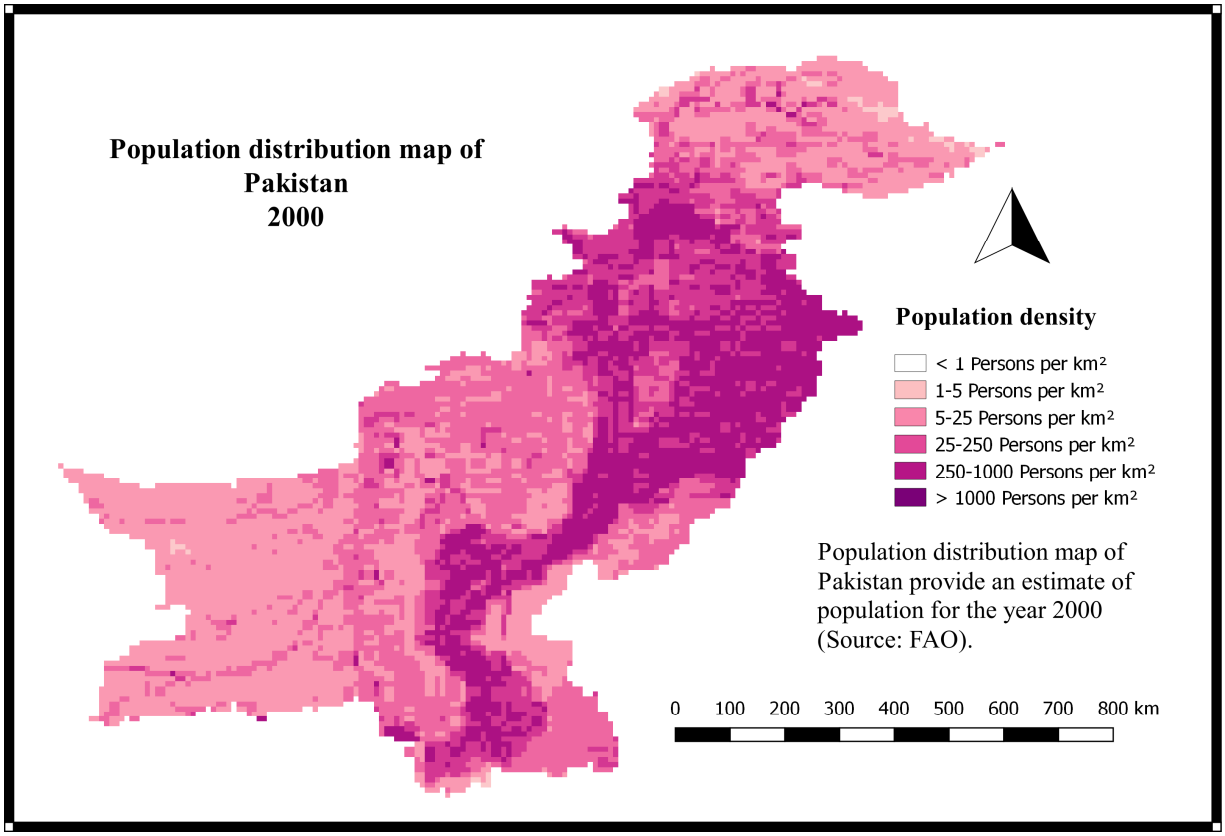


Fig.19 Population density in different regions of Pakistan provide the estimate of population for the year 2000 (Source: FAO)

4.5. World pop

The World Pop project was started in October 2013 to combine the Africa Pop, Asia Pop, and American Pop population mapping projects. It purposes to provide a direct access archive of spatial demographic datasets intended for Central and South America, Africa and Asia to support development, disaster response and health applications. The approaches used are designed with full direct admittance and effective application in mind, using transparent, entirely documented and peer-reviewed methods to produce easily updatable maps with supplementary metadata and measures of uncertainty. The World Pop project goals to meet these requirements through the provision of detailed and direct access to population distribution datasets built via transparent approaches with High spatial resolution, contemporary data on human population distributions are a prerequisite for the precise measurement of the impacts of population growth, for monitoring changes and for planning interventions (WorldPop, 2013).

The given Fig.20 has been directly downloaded from World pop website and it's representing the population density of Pakistan for the year 2000. According to this figure as you can see the northern areas of Pakistan which are located at 35.35°N and 75.9°E their population density < 1 Persons per km². The population density of Punjab province is > 1000 Persons per km² and it is situated 31° north and 72° towards the eastern part of the country while Federally Administered Tribal Areas (FATA) located 33° north and 70° east it has a population density 1-5 Persons per km². The Azad Kashmir is located 32.22°N and 73.28° towards east their population density is 25-250 Persons per km² and Baluchistan which lies 27.7 °N and 65.7°E with a population density 1-5 Persons per km². Whereas, the population density of Sindh is 250-1000 Persons per km² it lies 25.89°N, 68.52°E. In (KPK) the population density is >1000 Persons per km² but towards the north-west, the population density in (KPK) is < 1 Persons per km² and it lies 34.00°N and 71.32°E of Pakistan. In Islamabad, the population density is > 1000 Persons per km² and it is situated 33°43′N 73°04′E.

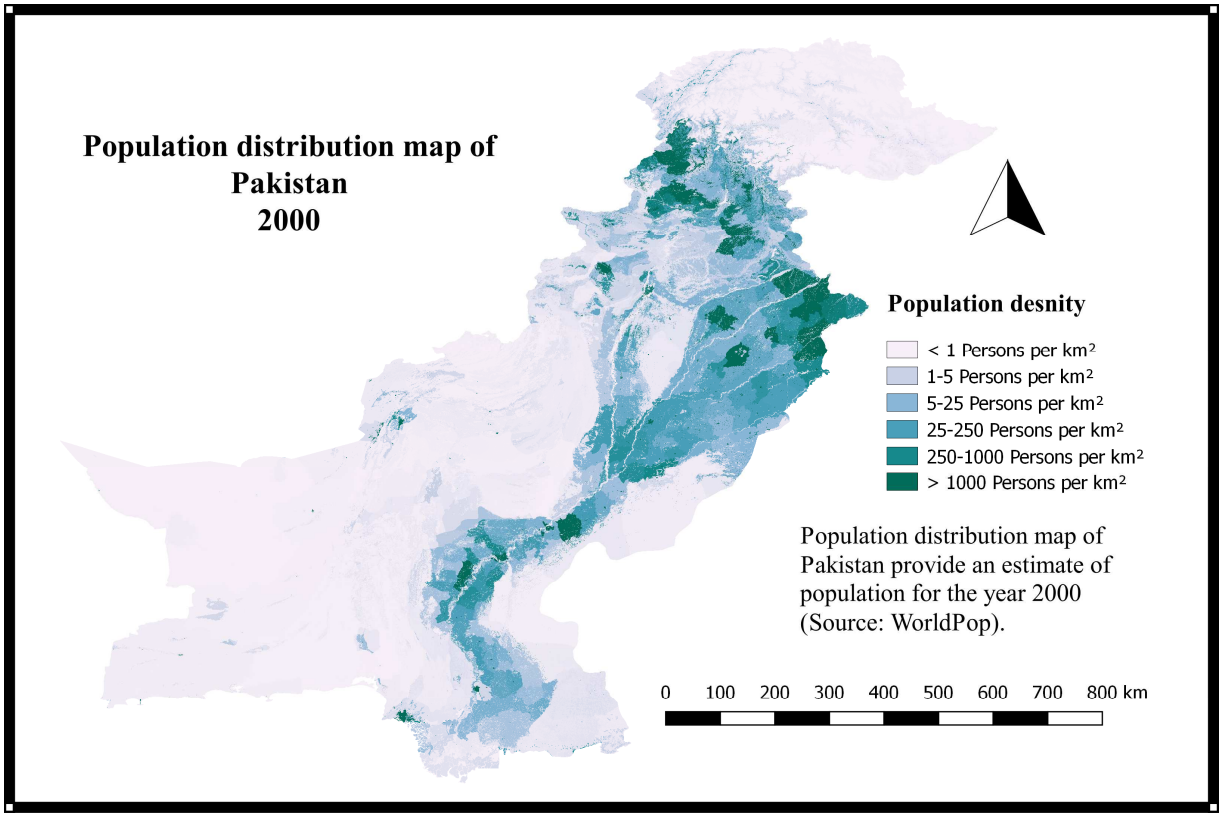
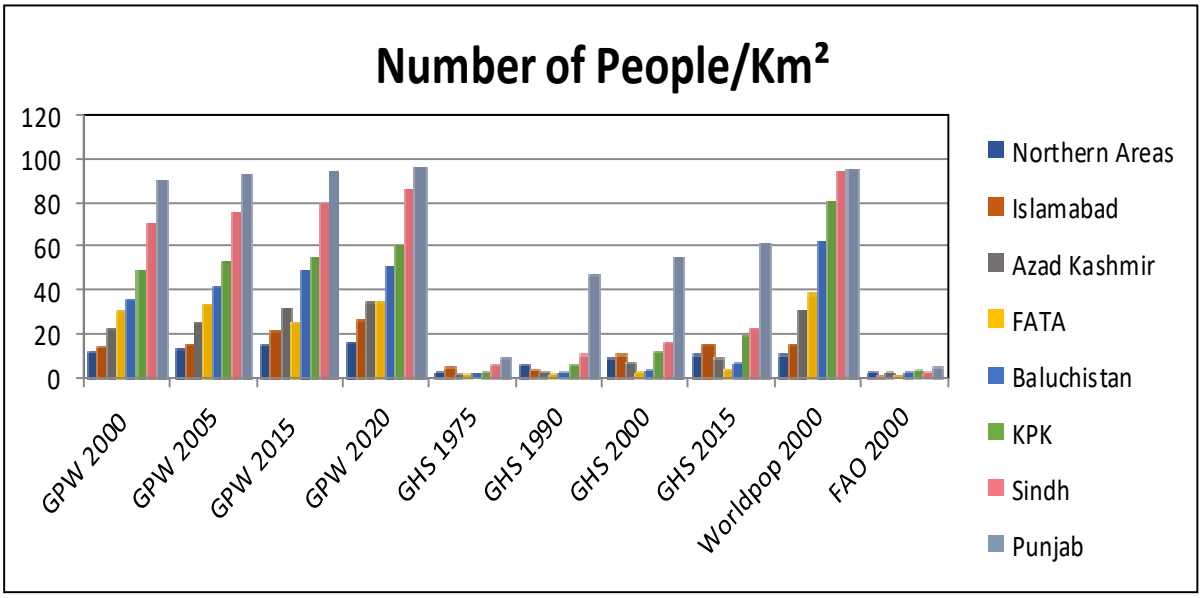


Fig.20 Population density map of Pakistan for the year 2000 (Source: Worldpop)

Through the implementation of zonal statistics (Raster toolbar > Zonal statistics) given Fig 21 illustrates the number of people living in each province of Pakistan with respect to different years and data sources.



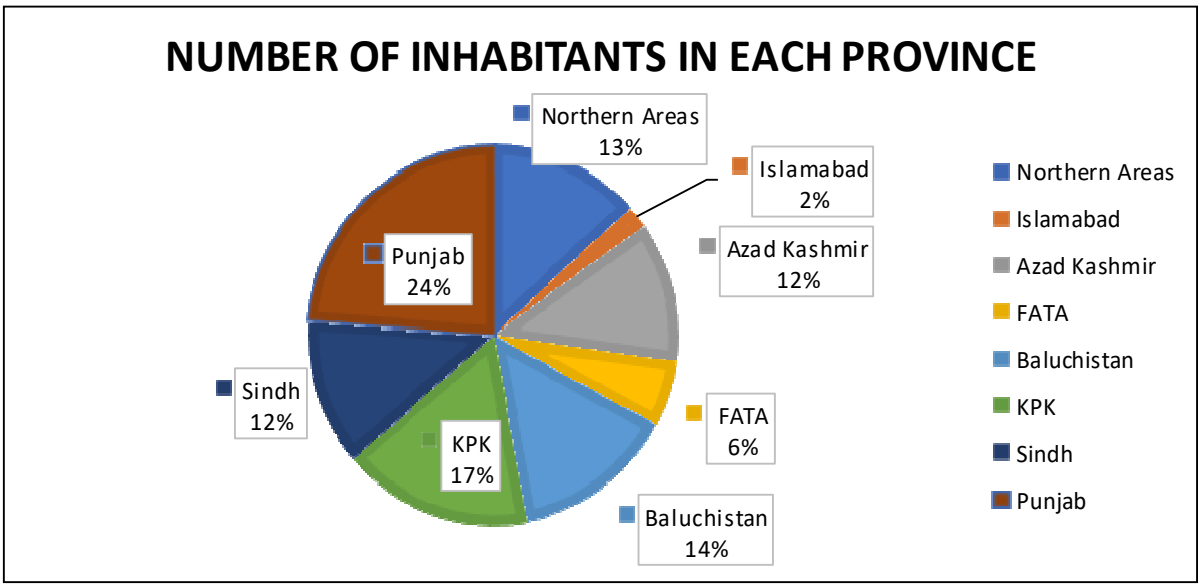


Fig 21 Depicting the population of Pakistan with respect to number of inhabitants in each province.

To make a comparison of population density map with water resources map we selected the water withdrawal map of Pakistan Fig.9 and population density map of Pakistan 2015 Fig.12.

While by means of the spatial analyst tools the raster layer has been reclassified and by conversion tools this raster layer has been converted into the polygon (Spatial analyst tools > Reclass > Reclassify), (Conversion tools > From Raster > Raster to polygon). To determine the results about the number of Persons per km² and amount of water withdrawal the overlapping technique has been done by using the analysis tools (Analysis tools > overlay > Union). However, the different geographic features have been identified randomly by (Feature Identifier) with the help of overlapped population density map and water withdrawal map of Pakistan and their respective values has been added as you can see the obtained values/outcomes in a given Fig 22.

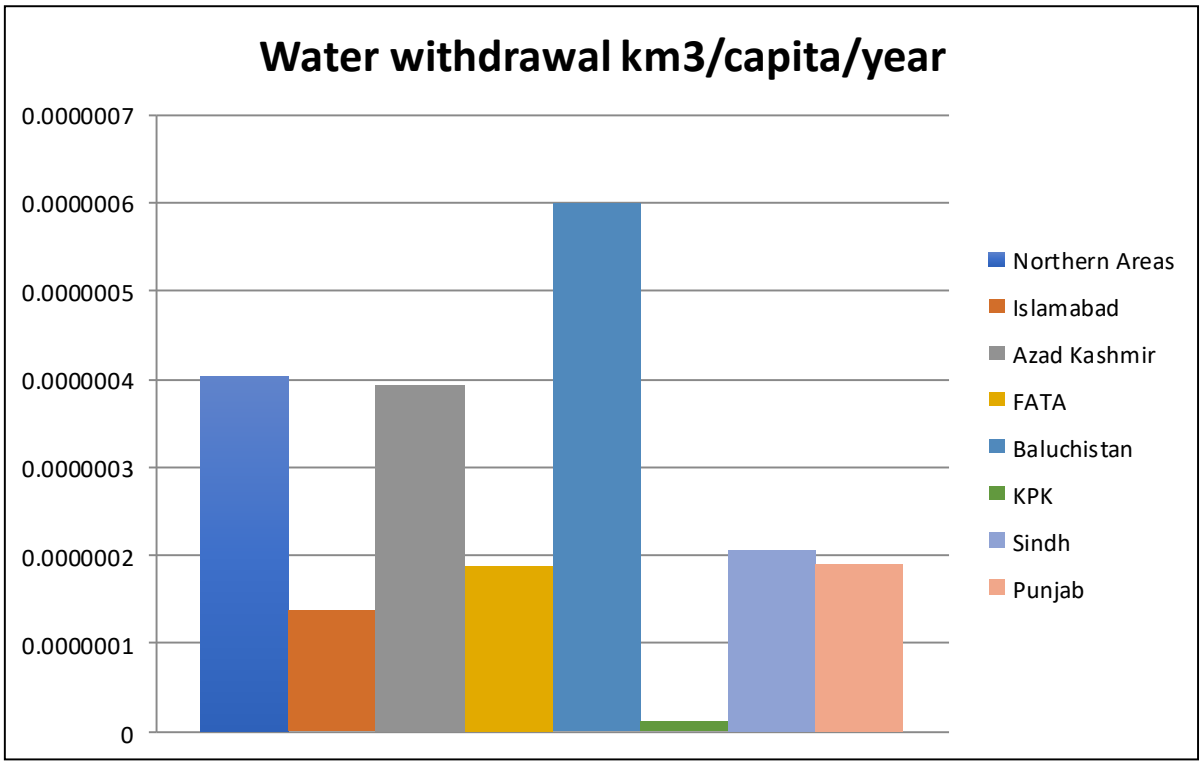


Fig 22 Representing the amount of water withdrawal km3/capita/year.

5. Conclusions

The purpose of the present work is to analyse the utility of mapping algebraic method based on QGIS the study area is Pakistan situated in South Asia. Through overlapping of population density map Fig.12 with water withdrawal layer Fig.9, we derived the outcomes that in which part of the country people are extracting the massive amount of water resources and where people are facing the water scarcity related issues. According to Fig.10 in Pakistan, people have High (100%) access to water. In Punjab province, the population density is about > 1000 Persons per km² though the water withdrawal amount is 1.9e-7 km^3/capita/year and it is located 31° north and 72° towards the eastern part of the country. Whereas, in northern areas which is located at 35.35°N and 75.9°E the population density is < 1 Persons per km² and the amount of water withdrawal is 4.012e-7 km^3/capita/year. Khyber Pakhtunkhwa (KPK) province lies 34.00°N and 71.32°E their population density is approximate >1000 Persons per km² but towards the north-west of the (KPK), the population is about < 1 Persons per km² and the amount of water withdrawal over there is 1.228e-8 km^3/capita/year. The Federally Administered Tribal Areas (FATA) is in 33° north and 70° east of Pakistan with a population density 5-25 Persons per km² and water withdrawal amount is 1.884e-7 km^3 per year. Azad Kashmir province is situated in the 32.22°N and 73.28° towards the east with a population density of 25-250 Persons per km² and water withdrawal amount is approximate 3.941e-7 km^3/capita/year. Sindh is the third largest province of Pakistan by area which lies in 25.89°N, 68.52°E while the population density of Sindh is 25-250 Persons per km² and the amount of withdrawal is 2.05e-7 km^3/capita/year. Baluchistan is the largest province of Pakistan with respect to the area it lies 27.7 °N and 65.7°E the population density < 1 Persons per km² and water withdrawal amount are 5.976e-7 km^3/capita/year. Federal capital territory (FCT) Islamabad is the capital city of Pakistan and it lies 33°′N 73°E with a population density > 1000 Persons per km² and the water withdrawal amount is 1.382e-7 km^3/capita/year. After assessing the population density Fig.21 and water withdrawal capacity Fig.22, we realized that most of the people are living in the Punjab province and extracting the massive amount of water as compared to the other provinces/territory of Pakistan.

Student and researchers who want to apply the same approach discussed here my recommendation is to access the cited literature for comprehensive descriptions of required procedure. Whereas, pre-planned dataset strategies can save time and additional struggle.

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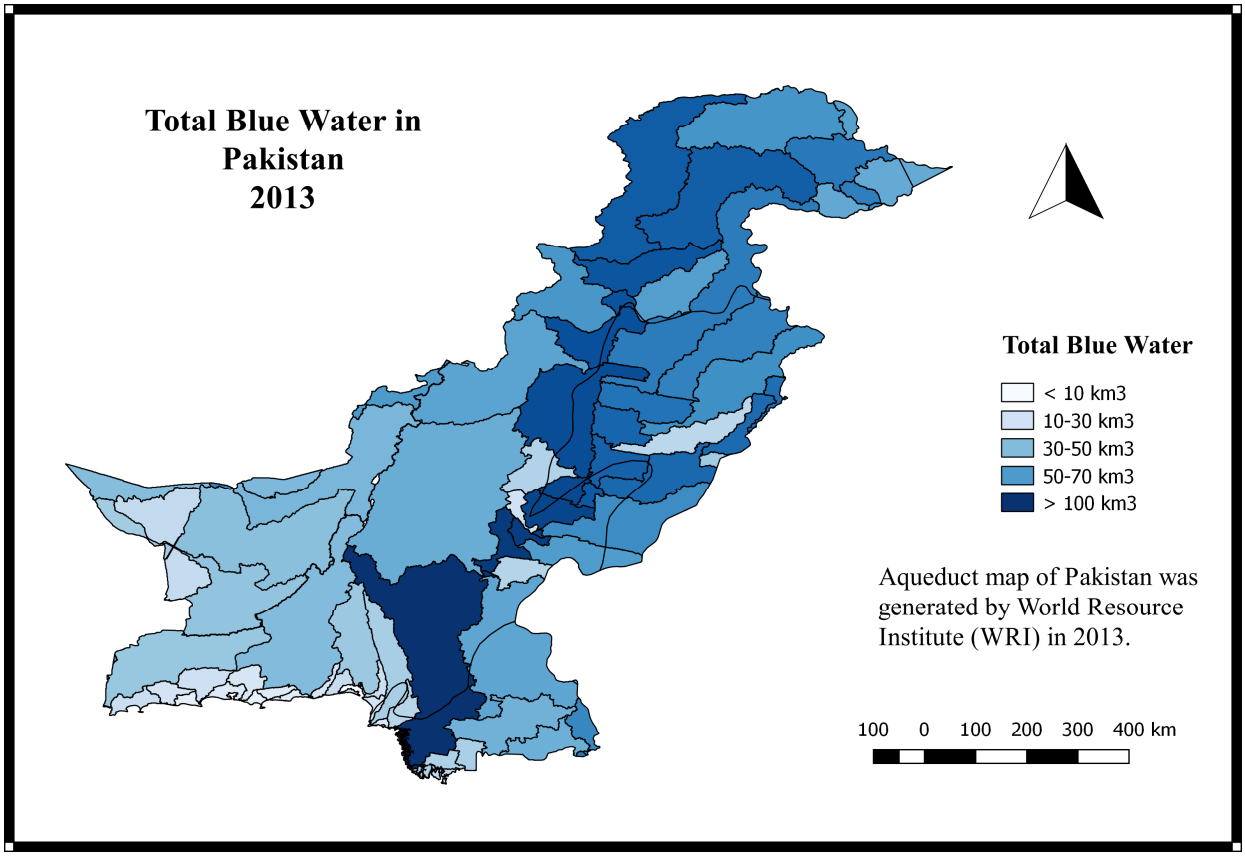
ANNEXES

ANNEXES I – METADATA

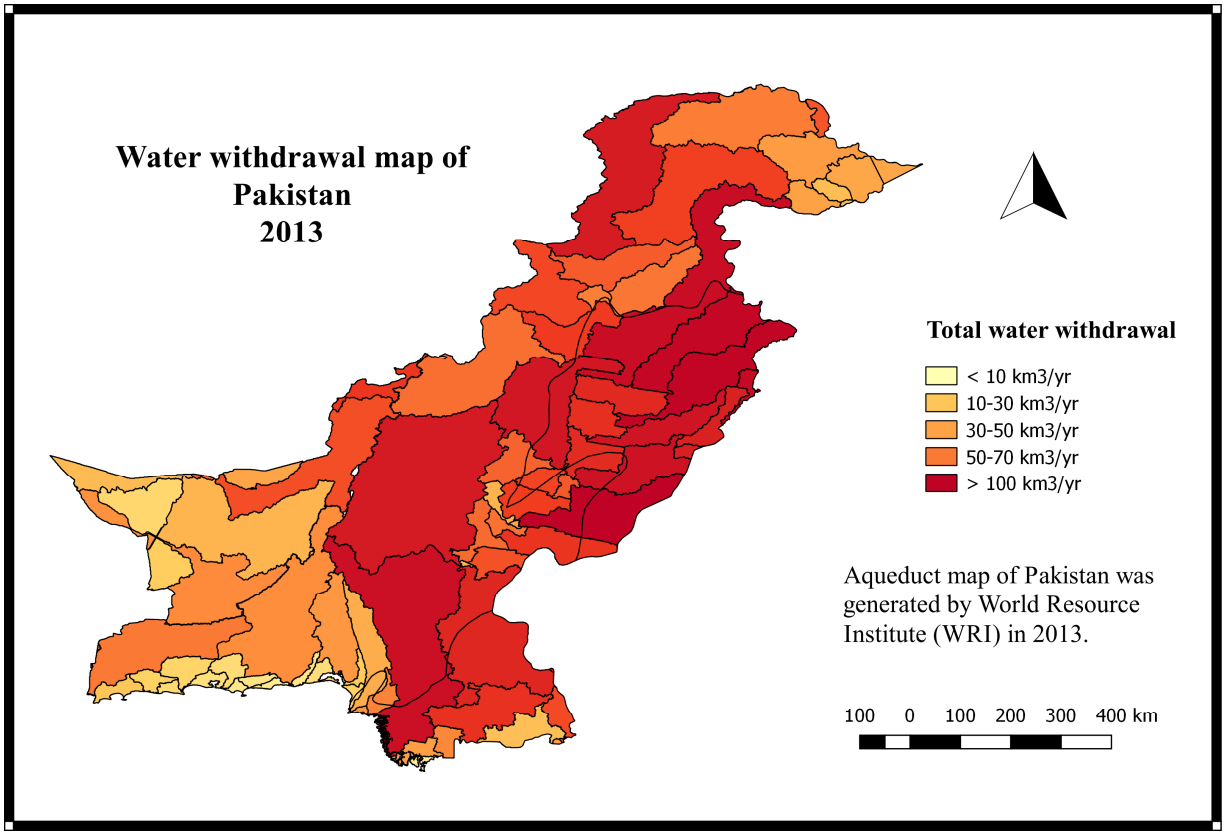
Aqueduct Global Map 2.0 (WRI)

Aqueduct Global Maps 2.1 data include indicators of water quantity, water variability, water quality, public awareness of water issues, access to water, and ecosystem vulnerability. The Aqueduct Water Risk Atlas makes use of a framework of 12 global indicators grouped into three categories of risk and one overall score. Aqueduct Global Maps 2.1 include indicators of water quantity, water variability, water quality, public awareness of water issues, access to water, and ecosystem vulnerability. This data updates the previous version with more recent data from the Global Land Data Assimilation System Version 2.

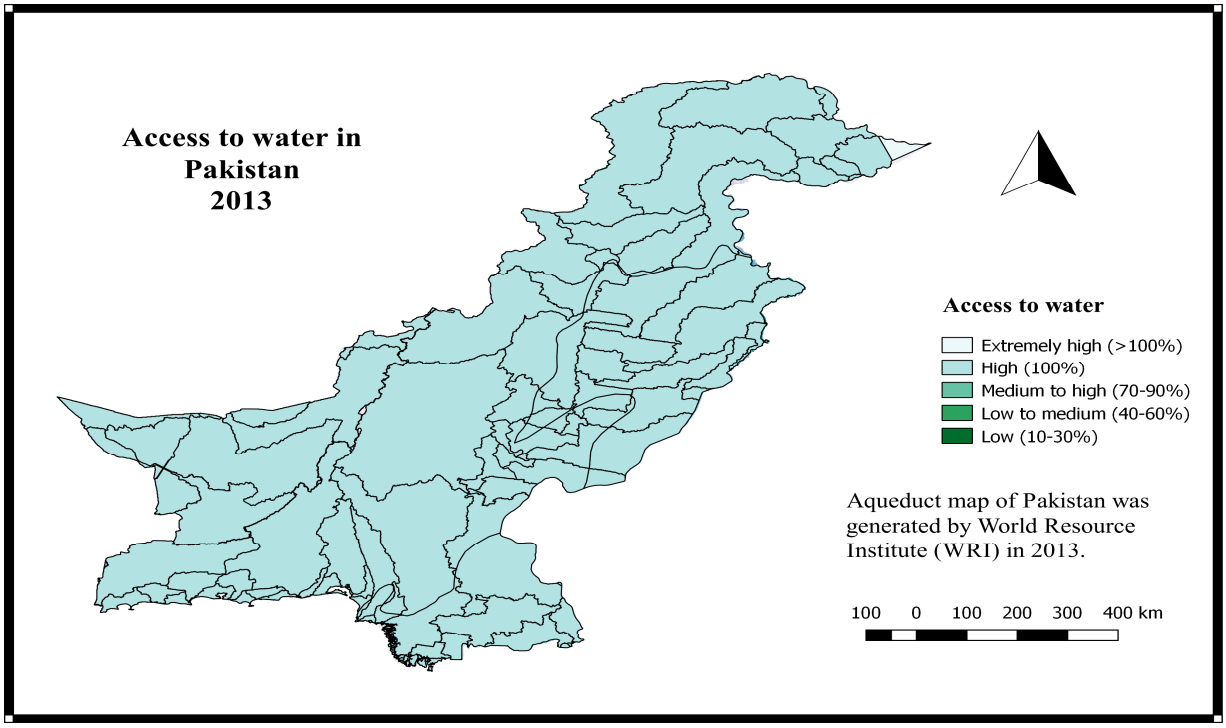
Variable	**Fresh water withdrawal**
Author	P.H Gleick
Title	the World's Water Volume 7: The Biennial Report on Freshwater Resources, Island Press
Year of publication	2011
URL	http://www.worldwater.org/data.html
Resolution	cubic kilometres per year (km^3 /year)
Country	Pakistan
Project	Aqueduct
Page last updated	June 28, 2016
License	Creative Commons Attribution 4.0 International License. Full license text available at Creative Commons Attribution 4.0
Citation	Gassert, F., M. Landis, M. Luck, P. Reig, and T. Shiao. 2014. "Aqueduct Global Maps 2.1." Washington, DC: World Resources institute. Available online at http://www. WRI.org/publication/aqueduct-metadata-global



The map of Pakistan showing the average amount of blue water resources in Pakistan (Source: WRI).



The map of Pakistan showing the total water withdrawal in Pakistan. (Source: WRI).



The map of Pakistan showing the people access to water in Pakistan. (Source: WRI).

SEDAC Gridded population of the World

Population Count are available as global grids in GeoTiff format. Each downloadable is a compressed zip file, which contains: 1) the global GeoTiff for the year of estimate, 2) PDF documentation, 3) a Microsoft Excel file (.xlsx) with country-level information and sources, and 4) a text file (.txt) with a log of changes to the dataset by version. Population Count contains estimates of human population, consistent with national censuses and population registers, for the years 2000, 2005, 2010, and 2020. A proportional allocation gridding algorithm, using approximately 12.5 million national and sub-national administrative units, is used to assign population values to 30 arc-second (~1 km) grid cells. The population count grids contain estimates of the number of persons per grid cell 2020,2015,2005,2000.

Citation information:

Originator: Centre for International Earth Science Information Network - CIESIN – Columbia University

Publication Date: 2016

Publication Time:

Title: Gridded Population of the World, Version 4 (GPWv4): Population Count

Edition: 4.00

Geospatial Data Presentation Form: raster, map

Publication Place: Palisades, NY

Publisher: NASA Socioeconomic Data and Applications Centre (SEDAC)

Other Citation Details:

Online Linkage: http://dx.doi.org/10.7927/H4X63JVC

Bounding Coordinates:

West Bounding Coordinate: -180.000000

East Bounding Coordinate: 180.000000

North Bounding Coordinate: 85.000000

South Bounding Coordinate: -60.000000

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Contact Organization: NASA Socioeconomic Data and Applications Centre (SEDAC)

Address: CIESIN, Columbia University, 61 Route 9W, P.O. Box 1000

City: Palisades

State or Province: NY

Postal Code: 10964

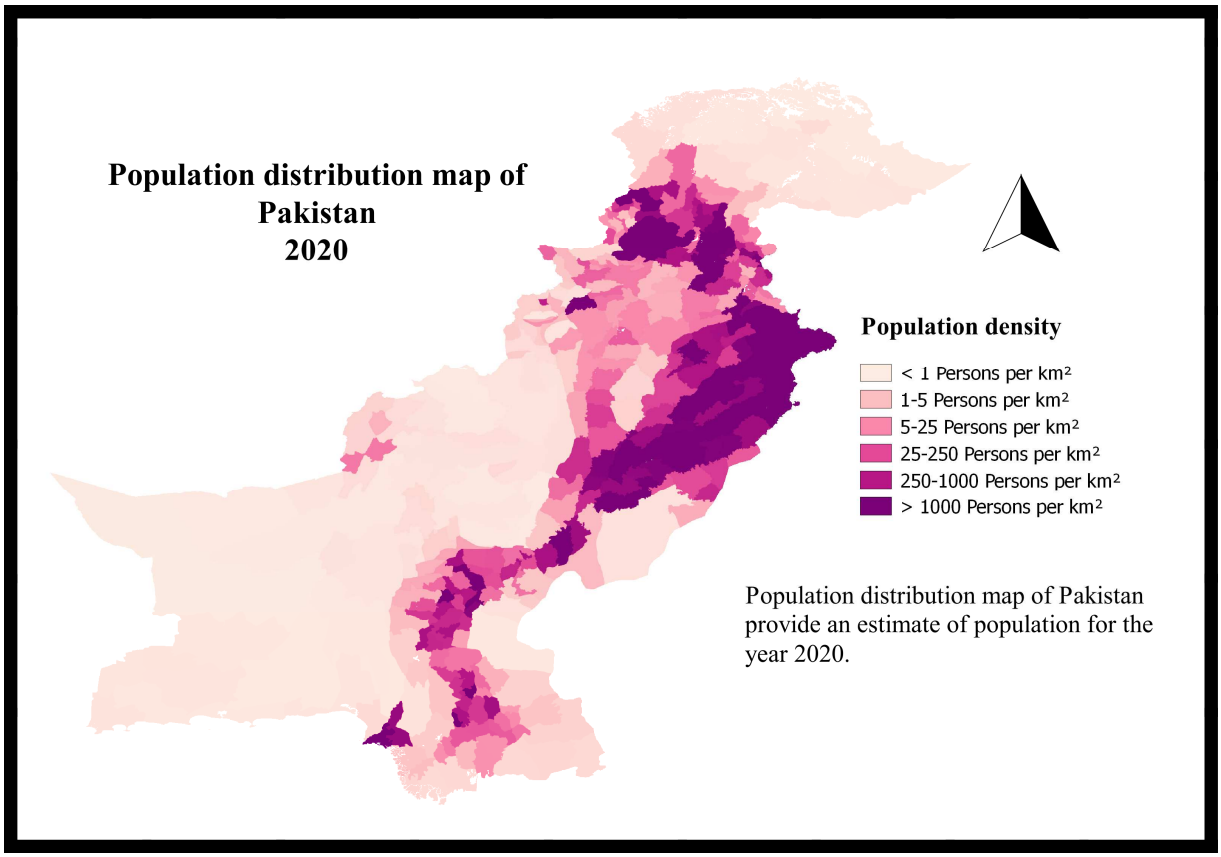
Country: USA

Contact Voice Telephone: +1 845-365-8920

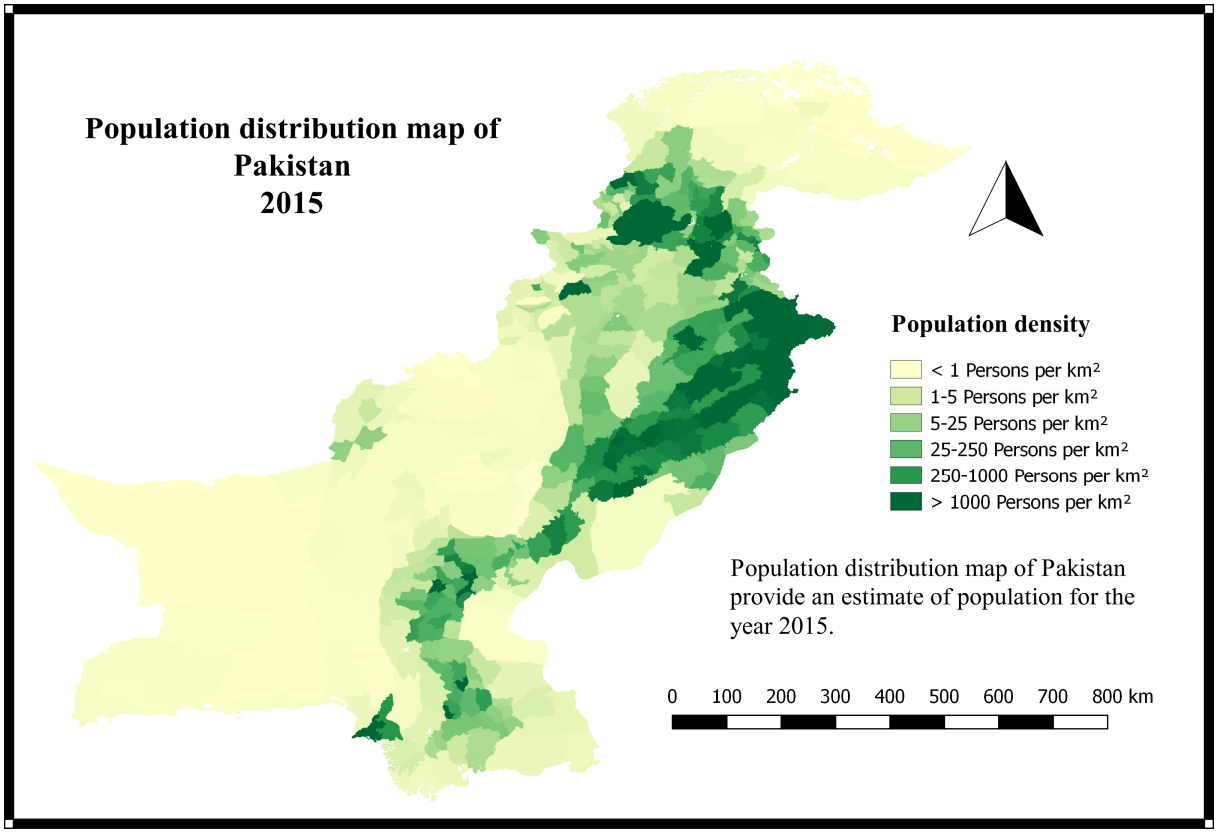
Contact TDD/TTY Telephone:

Contact Facsimile Telephone: +1 845-365-8922

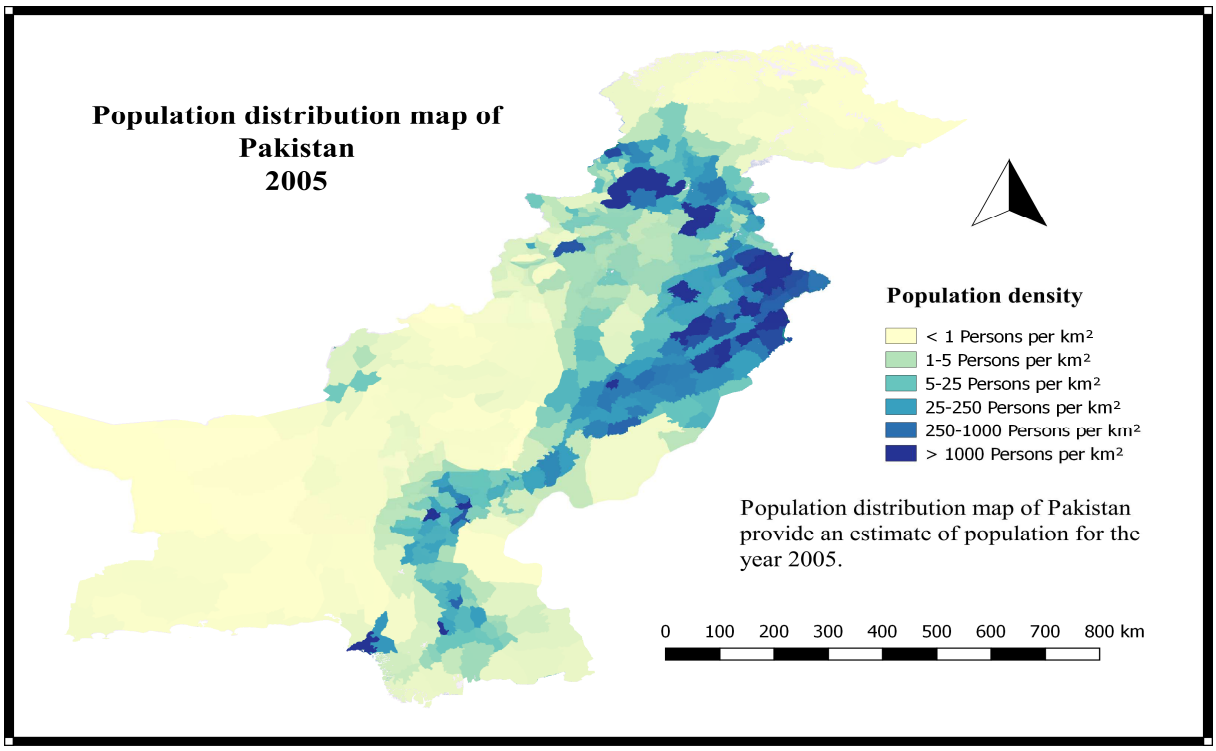
Contact Electronic Mail Address: ciesin.info@ciesin.columbia.edu
Cross Reference (Citation Information)
Originator: Centre for International Earth Science Information Network - CIESIN - Columbia University
Publication Date: 2016
Title: Gridded Population of the World, Version 4 (GPWv4): Administrative Unit Centre Points with Population Estimates
Edition: 4.00
Geospatial Data Presentation Form: vector, tabular, database, map
Publication Place: Palisades, NY
Publisher: NASA Socioeconomic Data and Applications Centre (SEDAC)
Other Citation Details:
Online Linkage: http://dx.doi.org/10.7927/H4F47M2C



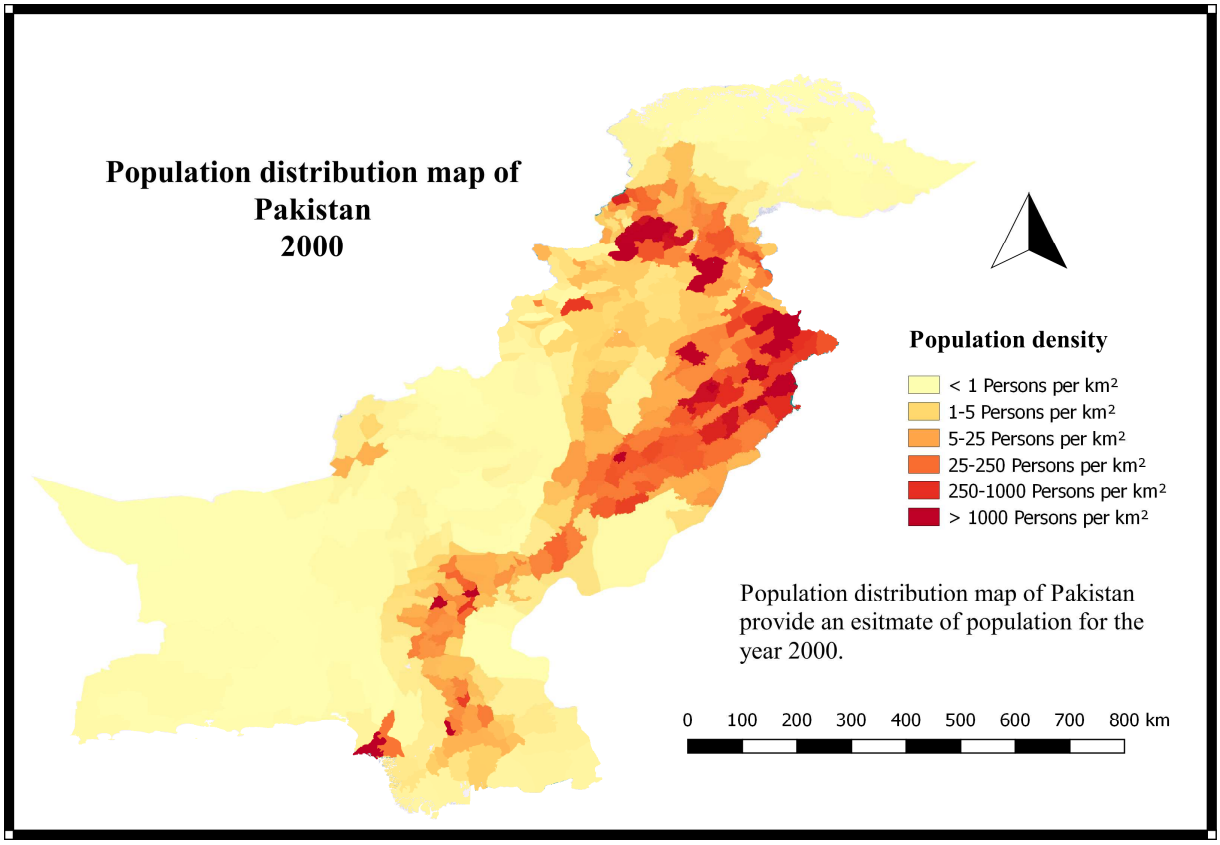
Population density in different regions of Pakistan for the year 2020 (Source: SEDAC).



Population density in different regions of Pakistan for 2015 (Source: SEDAC)



Population density in different regions of Pakistan for 2005 (Source: SEDAC)



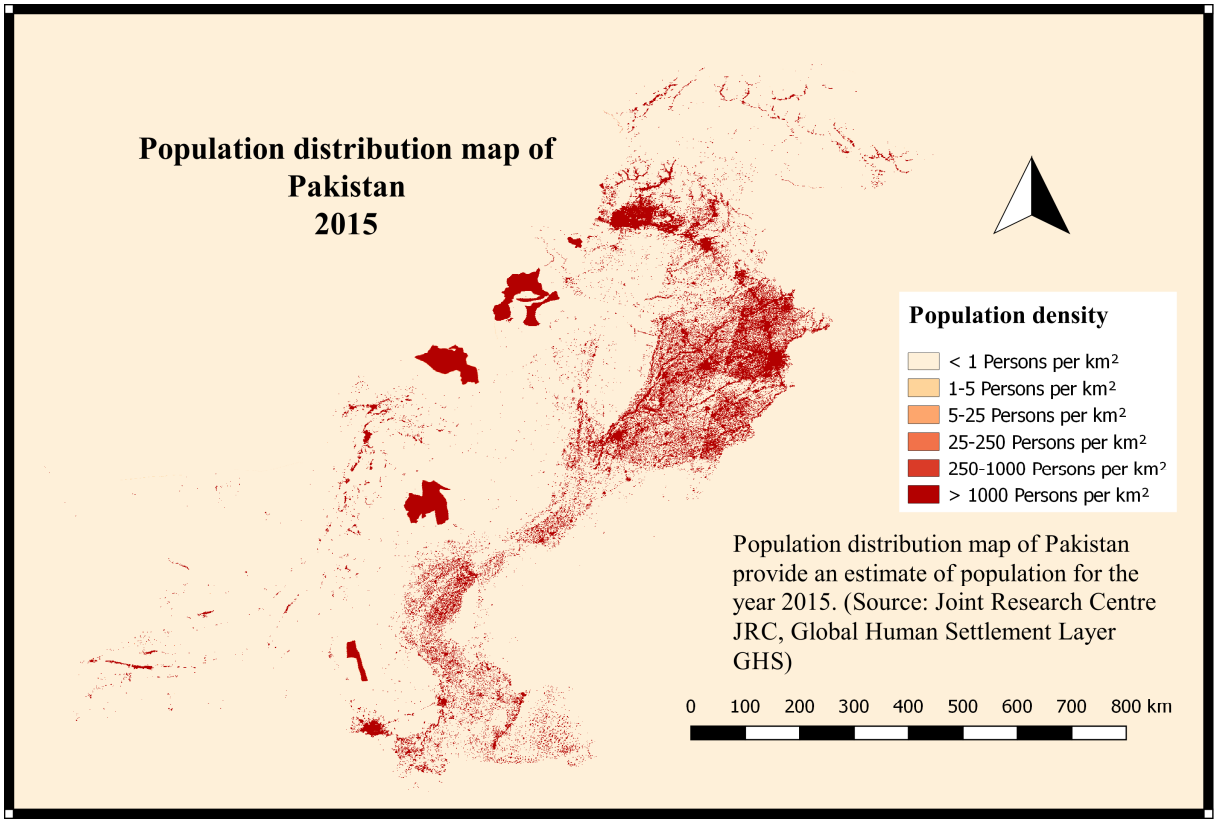
Population density in different regions of Pakistan for 2000 (Source: SEDAC).

<u>Joint Research Centre (JRC) Global Human Settlement Layer (GHSL)</u>

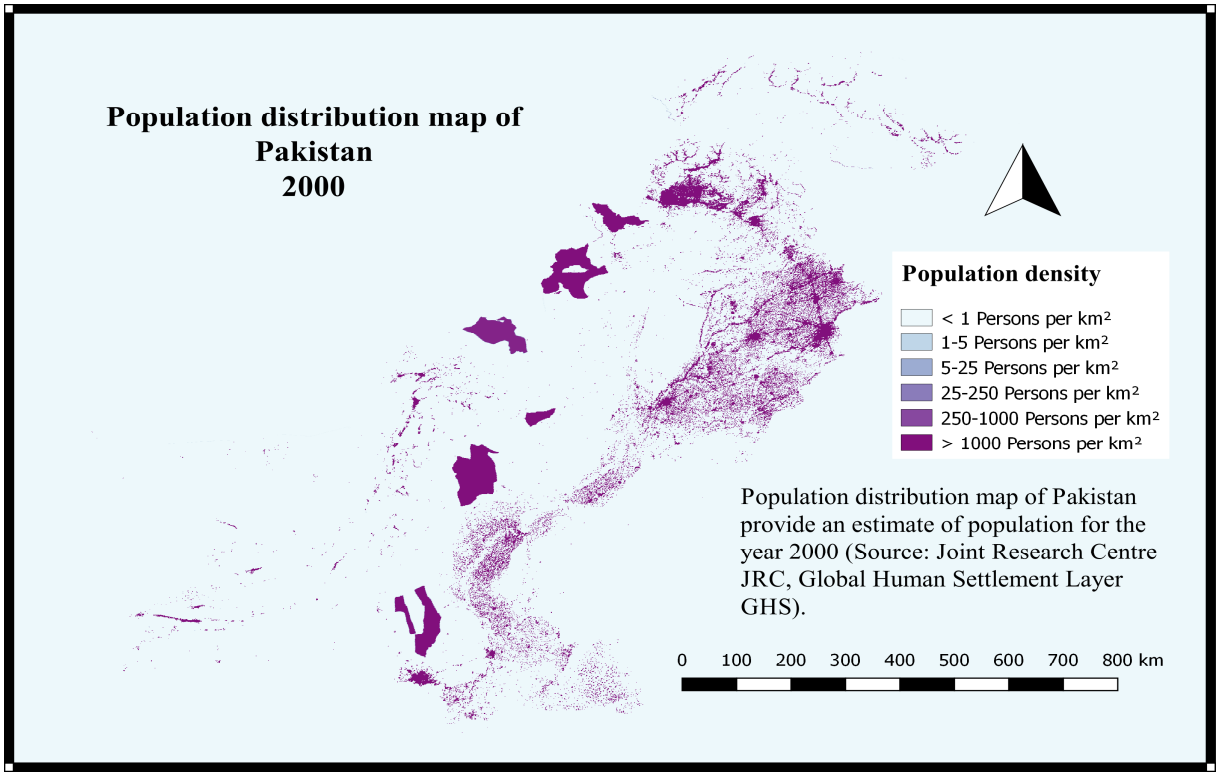
This spatial raster dataset depicts the distribution and density of population, expressed as the number of people per cell. Residential population estimates for target years 1975, 1990, 2000 and 2015 provided by CIESIN GPWv4 were disaggregated from census or administrative units to grid cells, informed by the distribution and density of built-up as mapped in the Global Human Settlement Layer (GHSL) global layer per corresponding epoch.
Product name: GHS_POP_GPW4_GLOBE_R2015A
Projection: World Mollweide (EPSG:54009)
Resolutions available: 250m, 1Km
Description: distribution and density of population, expressed as the number of people per cell
Dataset name (size): Resolution of 250m - World Mollweide (EPSG:54009)
GHS_POP_GPW41975_GLOBE_R2015A_54009_250 (280MB)
GHS_POP_GPW41990_GLOBE_R2015A_54009_250 (787MB)
GHS_POP_GPW42000_GLOBE_R2015A_54009_250 (824MB)
GHS_POP_GPW42015_GLOBE_R2015A_54009_250 (1.1GB)

Resolution of 1Km - World Mollweide (EPSG:54009)
GHS_POP_GPW41975_GLOBE_R2015A_54009_1k (141MB)
GHS_POP_GPW41990_GLOBE_R2015A_54009_1k (144MB)
GHS_POP_GPW42000_GLOBE_R2015A_54009_1k (148MB)
GHS_POP_GPW42015_GLOBE_R2015A_54009_1k (155MB)
Legend: Values are expressed as decimals (Float) and represent the absolute number of inhabitants of the cell.

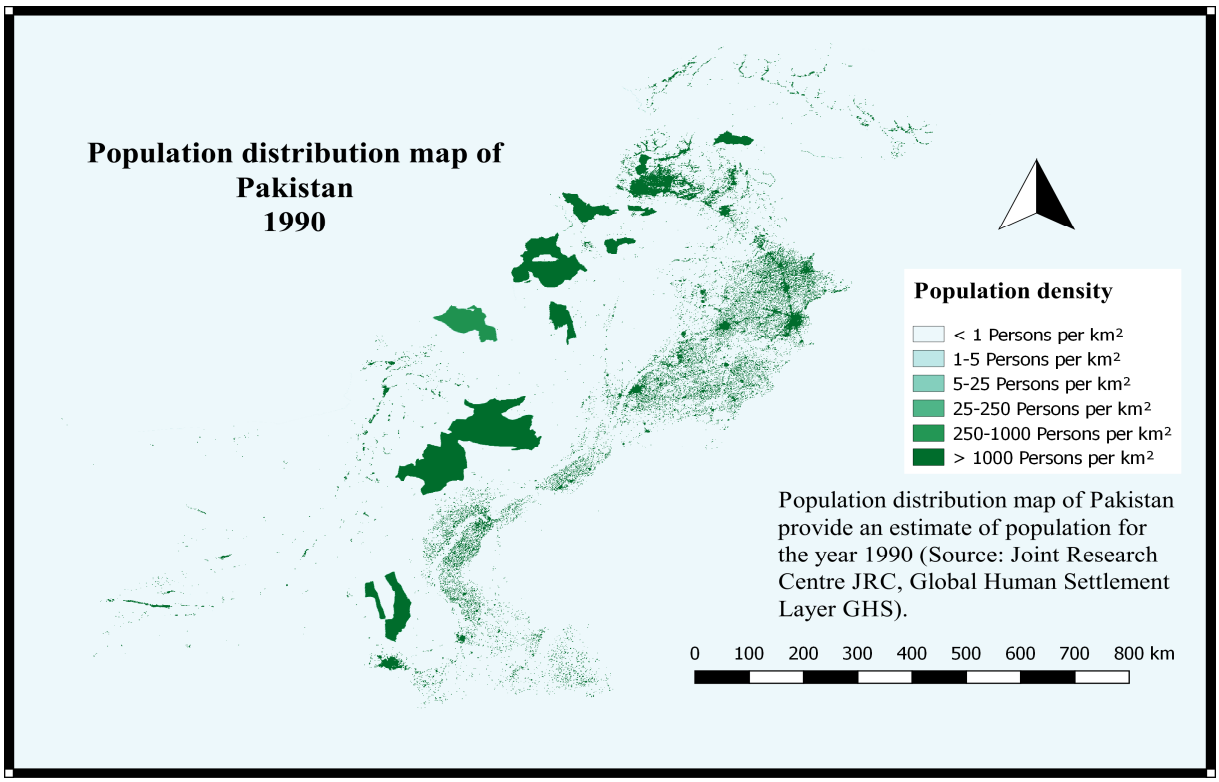
Here we have population map of Pakistan which is showing the population density but due to insufficient data the map doesn't have clear population picture of the whole Pakistan.



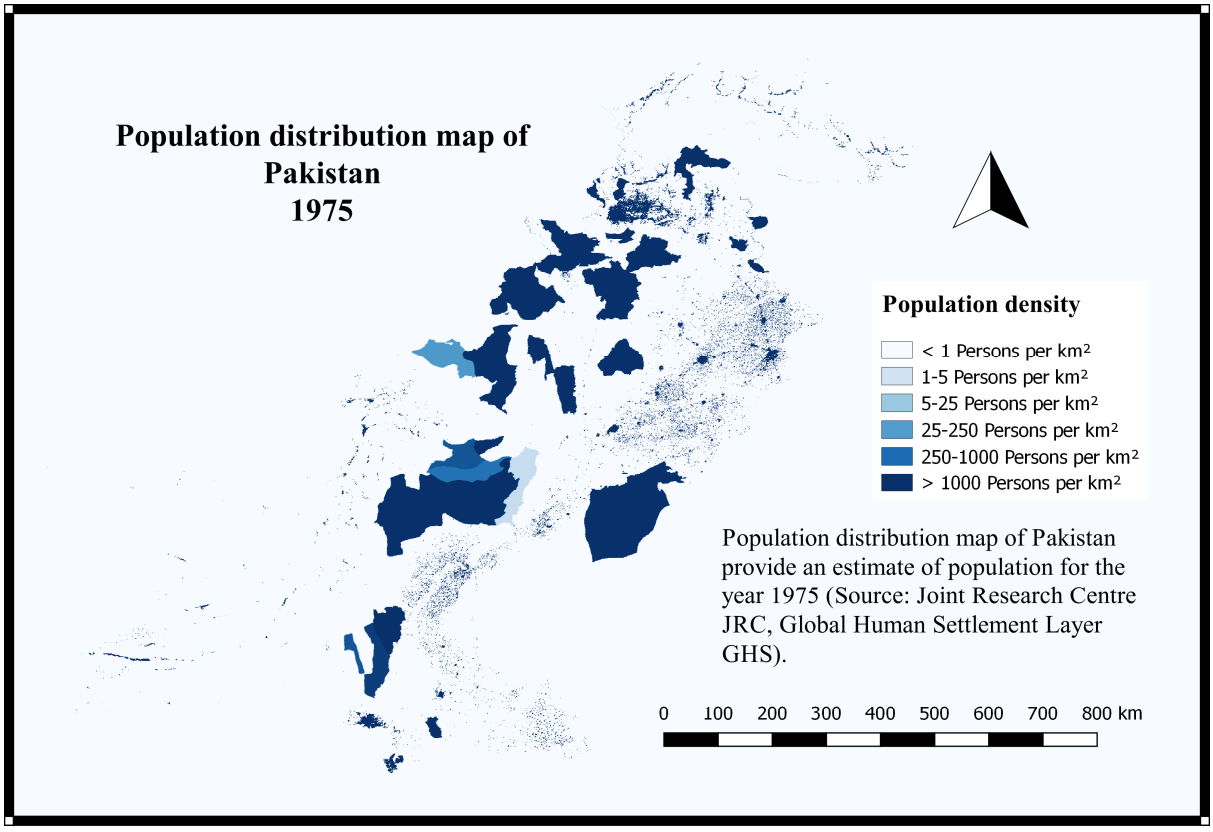
Population density in different regions of Pakistan for 2015 (Source: JRC-GHS).



Population density in different regions of Pakistan for 2000 (Source: JRC-GHS)



Population density in different regions of Pakistan for 1990 (Source: JRC-GHS)



Population density in different regions of Pakistan for 1975 (Source: JRC-GHS)

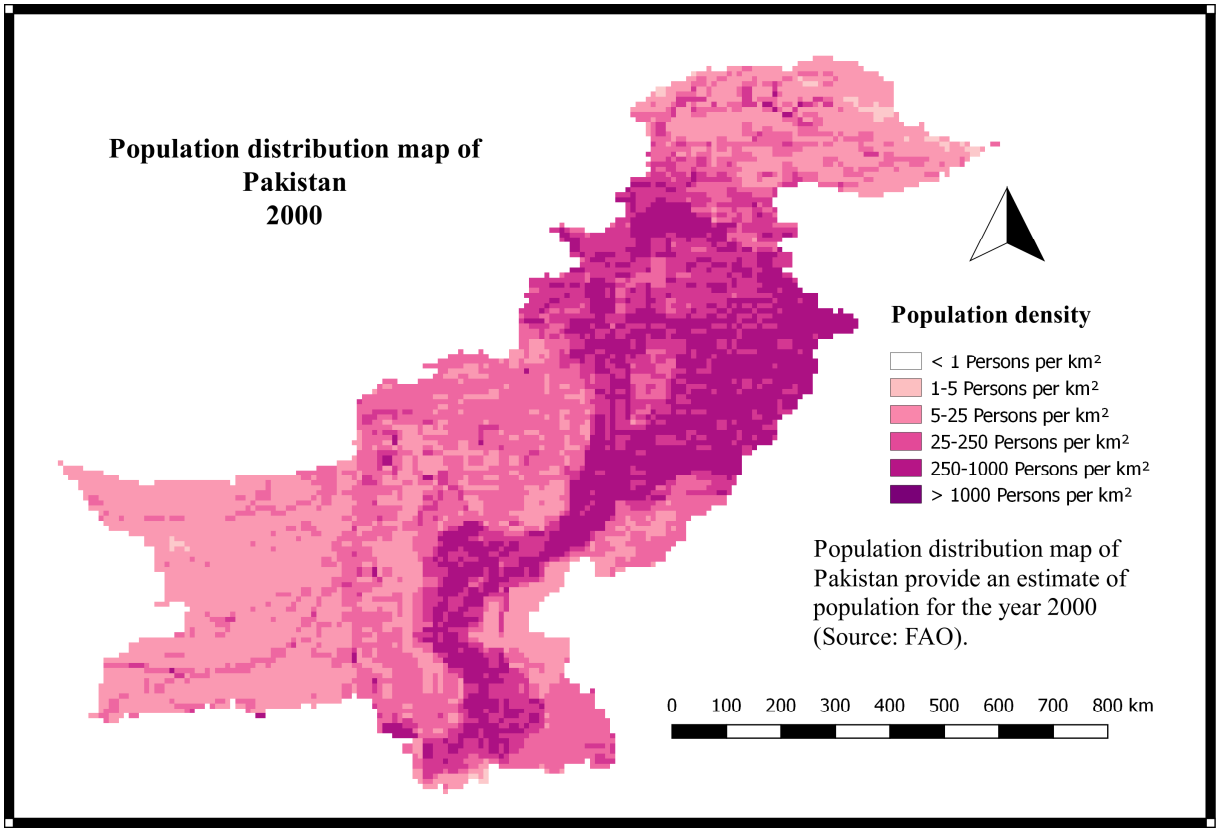
Food and Agriculture Organisation (FAO)

The raster dataset of population density has a spatial resolution of 5 * 5 arc minutes and is in geographic projection. Information regarding population density was derived from Land Scan 2000-Global Population Database. Oak Ridge, TN: Oak Ridge National Laboratory (30 x 30 arcs -seconds) and obtained from the Terrastat Global land resources CD-ROM.

Key	**Value**
Citation	Population Density (Persons/Sq. Km) 2007-02-16 Publication 3.6 Digital map
Abstract	The raster dataset of population density has a spatial resolution of 5 * 5 arc minutes and is in geographic projection. Information about population density was derived from Land Scan 2000-Global Population Database. Oak Ridge, TN: Oak Ridge National Laboratory (30 x 30 arcs -seconds) and obtained from the Terrastat Global land resources CD-ROM.

Purpose	This database will be used mainly for poverty and food insecurity mapping, particularly for analysing where the people live at global scales in relation to: Agroecological zones Marginal or productive lands Major food crop production systems, those important to food security for the rural poor.
Status	Completed
Contact	Freddy Nachtergaele FAO – UN Senior Officer Viale delle Terme di Caracalla Rome 00153 Italy freddy_nachtergaele@hotmail.it
Resource Maintenance	As needed
Keywords	Population Density (Persons/Sq.), Population, Pressure, Degradation, DSMW Digital Soil Map of the World Teme.
Descriptive Keywords	World place
Resource Constraints	Copyright
Spatial Grid representation type	
Metadata language	English
Character set	UTF8
Extent	90, -180, 180, -90
Supplemental	Expresses the total number of persons on a square km basis. Indicator of Population pressure on the land. Linked with land degradation. The dataset is available for download (below) in both ASCII and ESRI GRID formats. A layer (lyr) and legend (. avl) file are provided in the downloads. Structure of the attributes Population density The classes are: 1: 0 2: 1 - 9 3: 10 - 49 4: 50 - 200 5: > 200

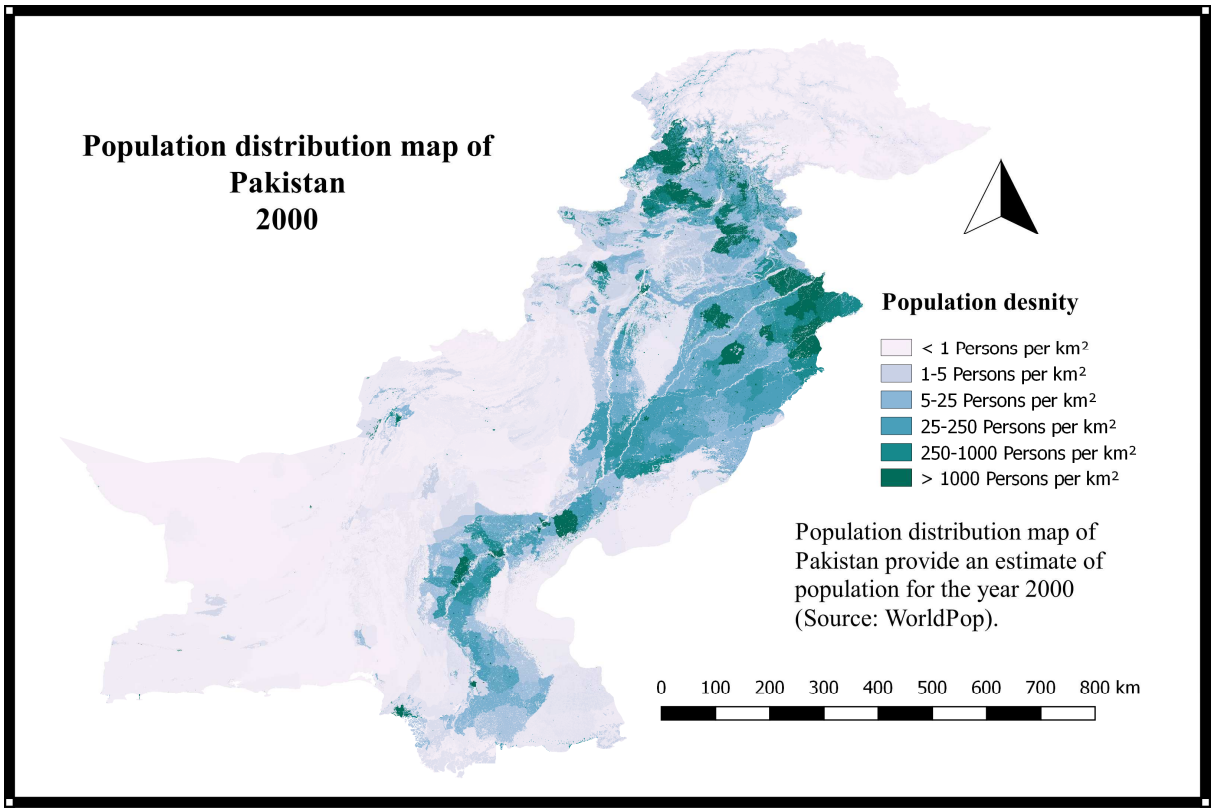
Date stamp	2012-02-22T14:13:34
Metadata standard name	ISO 19115:2003/19139
Metadata standard version	1.0
Reference system information	WGS 1984 Geographic
Individual name	Emelie Healy
Organisation name	FAO UN
Role	Author
Number of dimension	3
Axis dimension properties	Row 2160
Axis dimension properties	Column 4320
Axis dimension properties	Vertical
Cell geometry	Area
Source	http://ref.data.fao.org/web/guest/map?entryId=c1e669d0-bdcd-11db-a0f6-000d939bc5d8&tab=metadata



Population density in different regions of Pakistan provide the estimate of population for the year 2000 (Source: FAO)

World Pop

DATASET: Alpha version 2010 and 2015 estimates of numbers of people per grid square, with national totals adjusted to match UN population division estimates (http://esa.un.org/wpp/) and remaining unadjusted.
REGION: Asia
SPATIAL RESOLUTION: 0.000833333 decimal degrees (approximately 100m at the equator)
PROJECTION: Geographic, WGS84
UNITS: Estimated persons per grid square
MAPPING APPROACH: Land cover based, as described in: Gaughan AE, Stevens FR, Linard C, Jia P and Tatem AJ, 2013, High resolution population distribution maps for Southeast Asia in 2010 and 2015, PLoS ONE, 8(2): e55882
FORMAT: Geotiff (zipped using 7-zip (open access tool): www.7-zip.org)
FILENAMES: Example - VNM_popmap10adj_v2.tif = Vietnam (VNM) population count map for 2010 (popmap10) adjusted to match UN national estimates (adj), version 2 (v2).
DATE OF PRODUCTION: January 2013
Dataset construction details and input data are provided here: www.asiapop.org and here: http://www.plosone.org/article/info:doi/10.1371/journal.pone.0055882



Population density map of Pakistan for the year 2000 (Source: Worldpop)