2022

AJ&K DISTRICT GDP ESTIMATES USING NIGHTLIGHTS DATA

Generating Evidence for Policy Using Satellite Data

Planning & Development Department, GoAJ&K

Message From

Additional Chief Secretary Development
Planning & Development Department, GoAJ&K

It is indeed a matter of great pleasure for me to introduce and appreciate the valuable report on "AJ&K District GDP Estimates by Using Nightlights Data". The study has been conducted on internationally recognized methodologies to determine the size of economy at spatially disaggregated level by using the intensity of light luminosity (nightlights) as measured by satellite imaginary as a proxy for economic activity. The primary objective of this study is to quantify AJ&K's GDP, its geographical distribution at district level and variations overtime, using satellite imagery mainly night-time luminosity. This study would also help to improve the understanding of regional comparative socioeconomic development in AJ&K. The is in line with the call under the 2030 Agenda of Sustainable Development Goals for a data revolution to supplement conventional sources of official statistics with more innovative sources.

Gross Domestic Product (GDP) is the value of all goods and services produced within a country each year. GDP is the single most important indicator to capture economic activity of a state. However, in AJ&K, there was a gap in understanding contribution of manufacturing and services sectors to AJ&K's economy. Although there is a dire need for an extensive research-based exercise to bridge this gap, but that activity may take too much time, substantial efforts, and huge resources. GDP estimation through nightlights data offers an alternative approach to utilize a reliable proxy to collect economic data at regional and district levels for evidence-based policy making.

I would like to appreciate the valuable contributions and efforts made by the Planning and Development Department, GoAJ&K for bringing this study together. I am also thankful to officials of all government departments in AJ&K who participated in this study and gave their valuable inputs. I am very hopeful that the Azad Government of the State of Jammu & Kashmir will capitalize on the findings of this study and integrate the economic dimension with the social and environmental determinants to accelerate sustainable development in the region. I am confident that this report will serve as a useful reference point for all relevant stakeholders for effective and evidence-based policy making for sustainable development in Azad Jammu & Kashmir.

Fayyaz Ali Abbasi
Additional Chief Secretary (Dev.)

Acknowledgement

We would like to express our deepest gratitude and appreciation to Planning & Development Department, Azad Government of the State of Jammu & Kashmir, for taking the initiative to estimate AJ&K's district GDP by using nightlights data. We would like to acknowledge the contributions of different departments of GoAJ&K for their active contributions and support in conducting this important study.

Our special appreciation goes to Ch. Muhammad Rasheed, Minister for Planning & Development and Power Development Organization, Mr. Muhammad Usman Chachar, Chief Secretary and Mr. Fayyaz Ali Abbasi, Additional Chief Secretary (Dev.), Government of Azad Jammu and Kashmir, for their ownership, keen interest and guidance in estimation of district GDP of AJ&K by using nightlights data.

We would like to thank Mr. Jamil Ahmed Khan, Chief Economist, Mr. Yasir Bashir, Chief P&DD, Mr. Syed Ali Husnain Gillani, SDGs Coordinator and colleagues from Bureau of Statistics, Planning and Development Department AJ&K for their support and feedback on this study.

We would like to acknowledge the support of all departments for their participation in the consultative meetings, sharing their valuable experiences and best practices. Finally, we would like to thank all participants of the consultative workshops held in AJ&K for their valuable input.

(Mahmood Anjum)
Chief Statistics

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Citation

The document may be cited as:
"AJ&K District GDP Estimates Using Nightlights Data", Azad Government of the State of Jammu and Kashmir, 2022.

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Table of Contents

List of Figures

List of Tables

List of Acronyms

AJ&K	Azad Jammu and Kashmir
BoS	Bureau of Statistics
CPEC	China-Pakistan economic corridor
DMSP	Defense Meteorological Satellite Program
GDP	Gross Domestic Product
GIS	Geographic Information System
KP	Khyber Pakhtunkhwa
LSM	Large-scale manufacturing
MODIS	Moderate Resolution Imaging Spectroradiometer
NTL	Night-time lights data
PBS	Pakistan Bureau of Statistics
P&DD	Planning & Development Department
SSM	Small-scale manufacturing
VIIRS	Visible Infrared Imaging Radiometer Suite
WDI	World Development Indicators

Executive Summary

The availability of economic growth data with certain periodicity at sub-national level is essential for efficient policy design and its robust analysis. However often due to resource and capacity constraints, estimating economic growth and real GDP for a developing country at sub-national level is a task full of challenges. To overcome such constraints in the standard statistical data collection, economists recommend the use of alternate sources of information such as nightlights data generated through satellite imagery. The use of nightlights as a proxy for economic activity rests on the assumption that most consumption and investment activities entail lighting, hence the intensity of nightlights can be used to gauge the intensity of economic activity. Whereas, using nightlights as a measure to estimate economic activity has certain advantages, there are some limitations as well which need to be kept in consideration. Economic activity estimates from nightlights not only capture the contribution of informal sector but also being independent of official data these are expected to be devoid of its typical deficiencies. However, nightlights data is not considered a good alternate for estimating agriculture's contribution to GDP. This study therefore develops a framework through which we discretely quantify the quantum of farm and non-farm-based activities so that overall estimates are precise and accurate.

For a developing country like Pakistan, access to sub-national economic figures by the relevant tier(s) of the government is important for three major reasons: (i) to identify location-based potential for growth and to study the prevalent regional disparities, (ii) to design future policy interventions and to determine if there is a need to adopt place-based approach, and (iii) determine regional and local contribution to the provincial and national GDPs. At present officially released GDP figures for Pakistan pertain to national level statistics only. There are some efforts at provincial level as well; in Punjab the Planning and Development department and in Khyber Pakhtunkhwa (KP) the Regional Accounts wing have estimated economic activity since 2005. The KP province has also recently estimated district level GDP using the nightlights data[1].

Motivated by the study done in case of KP province using nightlights as a proxy for economic activity, this project is designed and funded by the Planning and Development department of Azad Jammu and Kashmir government with the main objective to quantify AJ&K region's GDP. This study and the data developed under it shall be useful for policy related work by the AJ&K government and also for conducting academic research related to design and evaluation of public sector projects. The study primarily uses nightlights data as proxy for economic activity. Other satellite imagery-based data sources to be utilised in the project are forest cover spatial

[1] The report is available on SEED website at https://bit.ly/3lEFg2a

data and MODIS (Land use and Land cover data) besides survey-based data collected and published by PDD, AJ&K. The project progressed in close collaboration with the relevant departments of AJ&K government. The official statistical and spatial data available with PDD has been utilised to calibrate satellite data and also validate the estimates. The inter-temporal analysis of nightlights data also indicates the growth of urban centres over time, along with changes in density of economic activity in core-periphery regions and local economic development due to public sector investments in transport infrastructure such as those developed under CPEC programme.

The research methodology for the project is based on studies published in highly ranked academic journals and World Bank reports. As such the current study will contribute to the existing literature by providing more recent and detailed estimates of economic activity for Pakistan at national, provincial and district level for AJ&K region. This study is amongst the first of its kind for Pakistan and AJ&K that accounts for informal economic activity as well segregated contributions for the agricultural and non-agricultural components in the GDP at sub-national level.

Brief results from the study indicate that districts of Kotli and Mirpur occupy the top two ranks in overall size of local economy and Neelum and Haveli districts occupy the bottom two ranks over the period 2010-2020. In terms of per-capita GDP, Mirpur has the highest rank and Sudhnoti has the lowest rank, and it is 13 times less indicating huge disparity among districts. Similarly, the top five ranked districts on the basis of size of GDP, contribute around 80% to the AJ&K's economy in 2010 and this percentage increases to 90% in 2020 indicating growing disparity over time.

Urbanization that promotes economic opportunities in the industries and services sector has remained stagnant in the region. The sectoral share of industry across districts indicates that districts that have higher share in non-farm economic sectors are the ones that hold higher ranks in terms of overall size of economy. Spatial pattern of high GDP districts indicates the possibility of an economic cluster formation. However, intra-district urban growth shows some pattern of sprawl which needs further validation through field surveys. An increased focus on urban planning in AJ&K will ensure better economic output in future and avoidance of potential disasters from natural calamities.

1. Introduction

Constraints in the availability of spatial data and limitations imposed by computational technologies with the justifiable approach to keep economic models parsimonious, a greater part of mainstream research in economics – both theoretical and empirical –conveniently ignored the significance of geographical space. Nonetheless, economic issues invariably involve questions concerning place specificity of economic activities as well as concerns related to overcoming distance constraints. The exclusion of space or location from economic models has often been justified on account of tractability or non-availability of requisite data at a granular level. However, with recent technological advancements, the availability of spatial data on global level and improvement in computational skills have opened new avenues of research. Economists have not only started estimating spatial significance of economic activity but advances in technology have led to the development of many new tools that help incorporating spatial variables such as location or distance in economic analysis.

Focusing on estimation of economic activity, Gross Domestic Product (GDP) is a well-known measure that for a specific time period, provides the total value of all goods and services produced within an economy. The GDP of a country is an all-inclusive indicator of a country's economic performance. The use of GDP as an economic pointer creates some opacity due to its aggregate form, yet it is widely relied upon to provide an overall snapshot of an economy and used to estimate its size and growth overtime. The GDP of an economy can be calculated through production, expenditures or incomes and can be adjusted for inflation and population to provide meaningful insights. Callen (2012) elaborates that GDP measurement can be done in three different ways:

- The production approach sums the "value-added" at each stage of production, where value-added is defined as total sales less the value of intermediate inputs into the production process.
- The expenditure approach adds up the value of purchases made by final users—for example, the consumption of food, televisions, and medical services by households; the investments in machinery by companies; and the purchases of goods and services by the government and foreigners.
- The income approach sums the incomes generated by production—for example, the compensation employees receive and the operating surplus of companies.

Typically, the national statistical agencies [2]calculate the national GDP using surveys of all industries and trade flows. However, despite the effort undertaken, the data limitations in

[2] In Pakistan the national statistical agency is Pakistan Bureau of Statistics. The Bureau of Statistics under the Planning and Development department form the relevant provincial / regional agency.

case of developing countries often lowers the confidence in these figures. Henderson et al., (2009) highlight that in case of developing countries GDP is often badly measured. The measurement errors arise from (a) proportion of informal sector contribution in the overall economy, (b) low degree of economic integration across regions and (c) resource and capacity constraints of the national statistical agencies. Besides the estimation problems listed above, it is imminent that use of nationally aggregate GDP will not be able to explain the welfare distribution of economic growth or output as economic agents and entities are spatially spread across a country.

The spatial heterogeneity in location choices of economic agents as well as the presence of place specific natural advantages highlights the fact that contribution to and share in final economic aggregate will vary across space. Hence it is important to have consistent data on economic activity for smaller geographical units to understand growth at sub-national levels. Besides, reliable impact assessment of previous policies and robust design of future growth strategies hinges on availability of such estimates. Despite its significance, the challenges associated with GDP estimation at sub-national levels such as provinces or districts become all the more pronounced due to capacity constraints, lack of prior experience and limitations faced in data collection and compilation at that level. In Pakistan, provinces have recently gained functional autonomy after the passage of 18th constitutional amendment in 2010. Following this, they are gradually building their institutional capacities. However, due to various political exigencies, the local governments at district level have rarely operated as a functional tier of government and hence lack trained personnel and necessary resources. Both provincial and district governments hold extremely important positions in the overall governance structure and all efforts to improve their capacity shall bear long run benefits for the society. It is added for the reader's information that districts are at the third level of administrative division below provinces and divisions but hold special significance as they form the top tier of local government structure.

The study of economic activity at a granular level is also important because much of the success of public policy instruments depends on economic conditions immediately surrounding the targeted groups of people. Current growth of development economics and policy experiments focusing on health, governance, local finance etc. demands statistics that are not aggregated at country-level but bifurcated along the lines of various smaller administrative and geographical units. To overcome the constraints and potential errors in obtaining reliable estimates of economic output at the national and sub-national level, the economic literature has several examples where the researchers have resorted to the use of various proxies generated from satellite imagery. One such proxy that is being most widely used in recent times is the amount of light that can be observed from outer space (Henderson, et al., 2009). Besides nightlights that has been found to be a reliable proxy for economic activity in the industrial and services sector, another measure used is the Land Use Land Cover data which has been found useful in literature (see Keola, 2015) to capture the contribution

of the agriculture sector. This study uses a robust framework based on the satellite imagery data to arrive at estimates of economic growth in AJ&K region of Pakistan.

This report is structured as follows. The document begins by stating the research objectives along with relevant justification. This is followed by a review of relevant literature. We then discuss the datasets to be used in the study and proposed methodology. The document concludes by highlighting the significance of estimates validation and pointing out the limitations.

2. Research Objectives

Keeping in consideration the above discussion, this study is focused on Pakistan's Azad Jammu and Kashmir (AJ&K) region.

The primary objective of this study is to quantify AJ&K's GDP, its geographical distribution at district level and variations overtime, using satellite imagery mainly night-time luminosity. In particular, the project provides an understanding of:

- the volume of economic activity in AJ&K and how it is related to national and provincial GDPs
- spatial distribution of economic activity across AJ&K at district level
- regional disparities and economic growth patterns
- changes in economic activity overtime, particularly for the main urban centres and determining city/urban area GDP
- Land use and urban growth trends across AJ&K

We elaborate our research objectives for this study as follows:

The **first objective** of this research is to quantify the GDP of the AJ&K region and its 10 districts. GDP figures and other national accounts statistics have been available in Pakistan at country level, but no official counterparts of such reports at regional / district level are available for the AJ&K region. Also, the economic activity related to AJ&K region is not included in the national accounts' figures of Pakistan. The statistical information about the socioeconomic variables related to the region are disseminated through a publicly available annual document titled "Statistical Yearbook" published by the Planning and Development department of AJ&K. Besides, another document titled "AJ&K at a Glance" provides more historical information since it is being published since 1985. Both the documents are valuable as they provide data at regional and district level that includes a sectoral focus as well.

The **first objective** for this study is to estimate the regional economic output primarily by using the intensity of nighttime lights (hereafter NTL) as captured by the satellite images of the earth. Nighttime luminosity is a variable that has proven to be a very useful source of information in representing economic and demographic conditions of administrative units of varying sizes in several developing countries wherever such data is missing (see Henderson et al. (2012) that relates this with GDP growth rates of over 100 countries).

The **second objective** of the study is to deal with the challenges of accuracy of nightlights in predicting GDP, particularly due to the following concerns:

a) significant contribution of agriculture sector to the local/regional economy as nightlights are not considered a good proxy for this

b) low intensity of light in small towns and low level of urbanization

c) occasional energy outages

d) presence of large forest covers that limit land use for agriculture or industry

An improvement in the estimate of economic activity has been achieved by enhancing the scope of application of remote sensing data. For this, nighttime lights data has been supplemented with other relevant sources of information for grasping the local economic environment. This is because NTL data is largely considered a reliable proxy for economic activity in industries and services sector -both formal and informal, and to arrive at overall economic activity it is important to add the share of agriculture. The argument regarding use of supplementary data seems more convincing in a setting where agriculture is the dominant part of economic activity. We will therefore use Land Use Land Cover (LULC) datasets to augment the luminosity data.

The low level of urbanization in case AJ&K region poses another challenge in the of NTL particularly for identifying the boundary of urban and rural regions using satellite imagery. As the focus of our study is the estimation of economic activity and this varies hugely in these two regions it is important to delineate them. To overcome this concern, this study uses multiple approaches including Brightness Gradient and Quantile Plotting methods.

The nightlights (NTL) data is considered a reliable proxy for non-farm economic activity as all consumption or investment activities in manufacturing or services sector are expected to generate nocturnal lights. The NTL data is based on nighttime satellite imagery averaged over a period of one year and is therefore mostly independent of electricity billing / metering/theft etc. issues which somewhat addresses the last concern listed above. Each pixel in the NTL data represents luminosity captured around 1 square kilometer land area which further averages out individual household level variations.

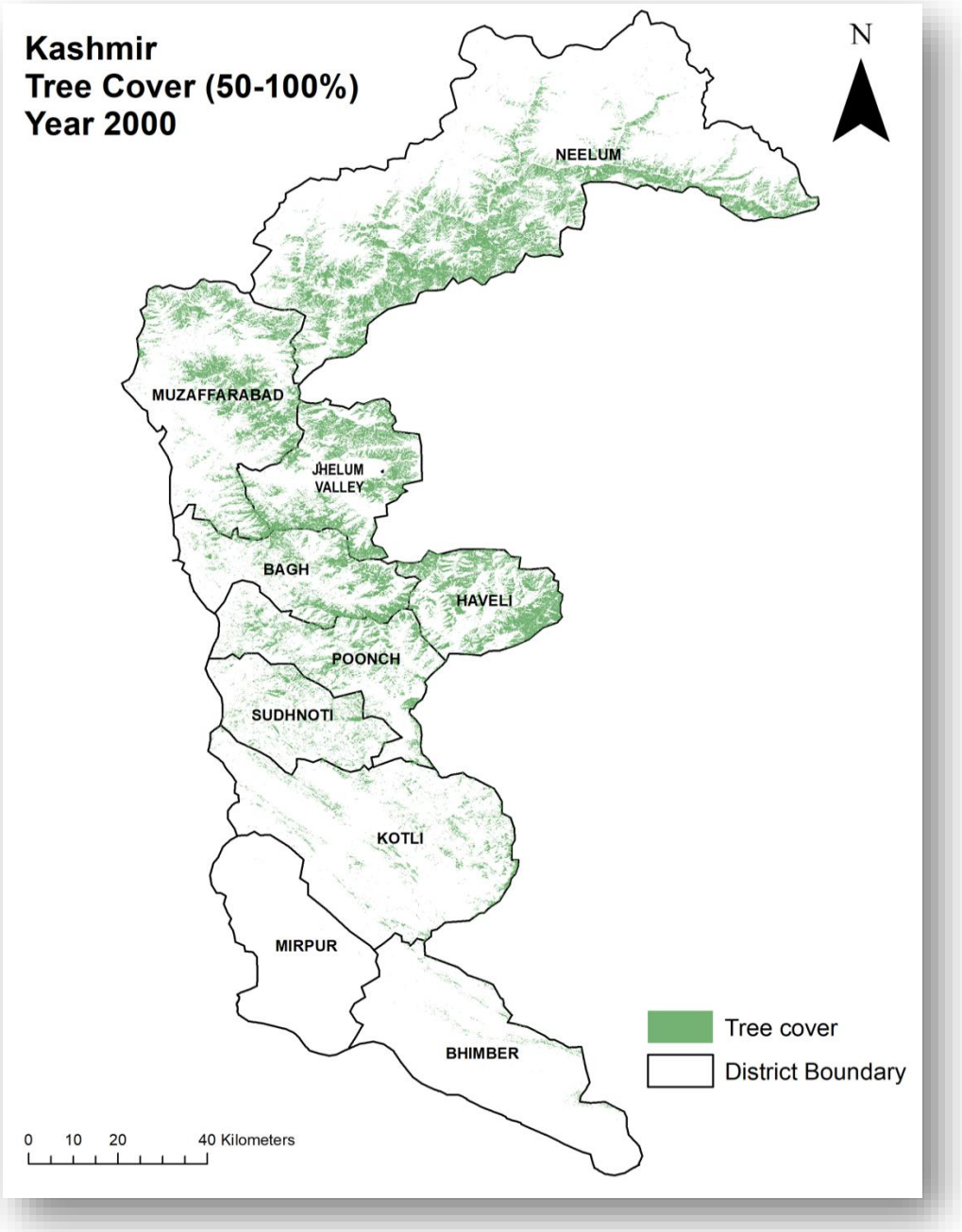


Figure 1: Forest Cover in AJ&K

Source: GLAD (2020)

*Note: The Hattian district has recently been renamed as Jhelum Valley

Further, the NTL data to be used for the study is based on annual composite luminosity and is therefore not affected by seasonal variations in electricity availability. The raw satellite imagery collected on daily basis undergoes extensive processing to include usual lit areas (human settlements, industrial zones, commercial areas) and remove any light sources that may disturb the measurement of human-made lights (forest fires, auroral activities, and extensive lunar light). The National Oceanic and Atmospheric Administration (NOAA) publishes the yearly average of all cloud-cover free observations in a latitude-longitude grid of rectangular pixels that each measure approximately one square kilometer. In this study we

use annual NTL data spread over two decades (2000-2020) and hence it is be devoid of such variations.

The large forest cover as shown in figure 1 in AJ&K region shall also be kept in consideration while using land use data for estimation of agricultural contribution to the regional/local economy.

The **third objective** of the study is regarding exploring the urban focus in the AJ&K region. This involves a more detailed look into the major urban clusters in AJ&K and would add to the usefulness of the study in term of providing important feedback for urban planning and management. This part of the study shall focus on the spatial distribution of economic activity across AJ&K region and to identify urban growth pattern over time. In this part, an inter-temporal analysis shall be useful in determining the overtime growth of urban markets.

3. AJ&K Administrative Description and District Profiles

Azad Jammu and Kashmir often abbreviated as AJ&K is a Pakistan administered region but administratively a self-governing entity constituting the western portion of the larger Kashmir region. The territory shares its northern border with Gilgit-Baltistan and its South and West side with the Pakistani provinces of Punjab and Khyber Pakhtunkhwa respectively. On its eastern side, lies the Indian union administered territory of Jammu and Kashmir. Geographically, the administrative territory of Azad Jammu and Kashmir covers a total area of 13,297 square-km and has a total population of 4,045,367 as per the most recent 2017 national census.

The northern part Azad Kashmir lies in a region that experiences strong tectonic plate activity. A major earthquake in 2005 killed at least 100,000 people and left another three million people displaced, causing widespread devastation to the region's infrastructure and economy. This potential hazard poses serious policy concerns regarding urban planning and management to actively avoid any future catastrophe.

Azad Kashmir's economy largely depends on agriculture, services, tourism, and remittances sent from abroad. The existing socioeconomic data collection provides most information about the agricultural sector. Available information on the industrial sector that includes manufacturing is very limited. Similarly, the documentation of services sector is limited and hence poses constraints in evidence-based policy formulation. A large number of households several districts of the region receive foreign remittances but no official figures about these are available.

Presently, AJ&K is divided into three divisions (Muzaffarabad, Poonch and Mirpur), with 10 administrative districts and 32 Sub-divisions having Muzaffarabad city as the state capital. These districts are further divided into 183 Union Councils and 1,769 Revenue Villages in AJ &K. Following is a brief profile of the 10 districts of AJ&K. A district-wise population density map is shown in figure 2.

Bhimber

Bhimber district is the southernmost district of the 10 districts of Pakistan's dependent territory of Azad Kashmir. It has an area of 1516 km², and the district headquarter is the town of Bhimber. According to the 2017 census, the population of the district is 420,624.

Jhelum Valley

Prior to 2009, the Jhelum Valley district was a tehsil within Muzaffarabad District. The district's headquarters is the town of Jhelum Valley. Jhelum Valley is bound on the north and east by the Kupwara District and the Baramulla District of Indian-administered Jammu and Kashmir, on the south by the Bagh District, and on the west by the Muzaffarabad District. The Jhelum Valley district has a population of 230,529 according to the 2017 census.

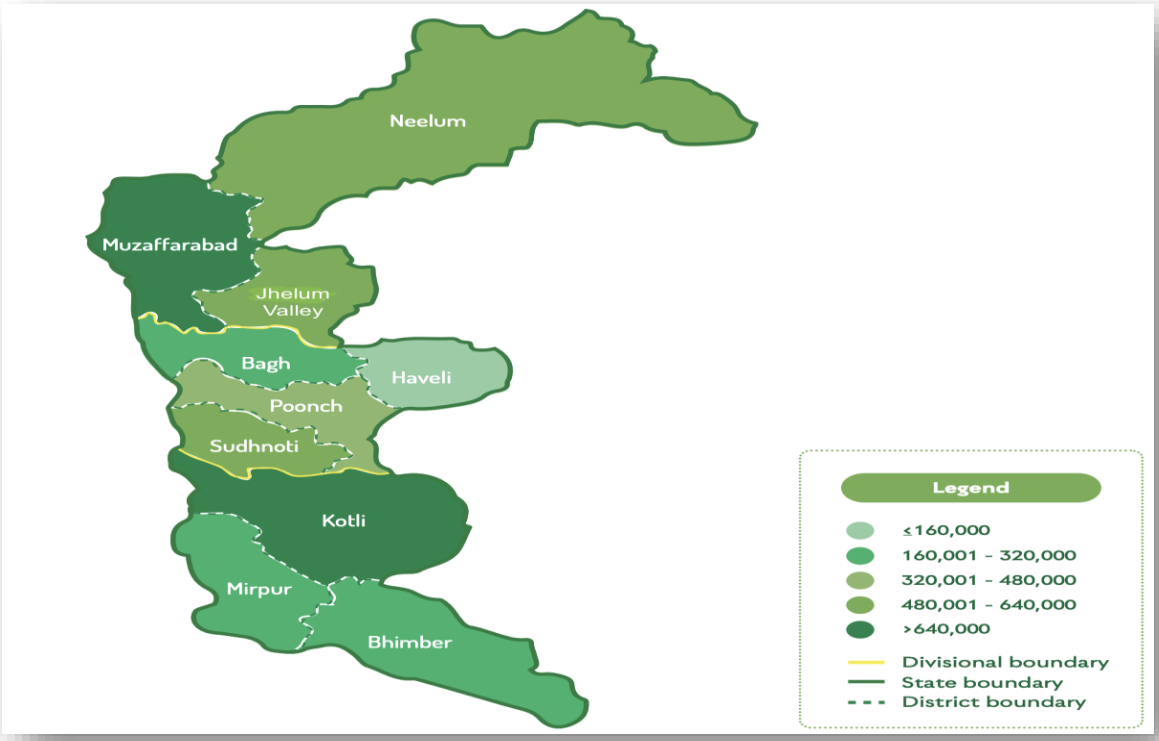


Figure 2: Population Density Map of AJ&K[3]

Haveli

The Haveli district was previously a tehsil of the Bagh district but was elevated to district status in 2009. According to the 2017 census, the district has a population of 152,124. The Haveli District is bounded on the north and north-east by the Baramulla district of Indian-administered Jammu and Kashmir, on the south-east and south by the Poonch district of Indian-administered Jammu and Kashmir, and on the west by the Bagh District and the Poonch District of Azad Kashmir. The Haveli district is situated at a high altitude of approximately 8,000 feet above sea level.

Muzaffarabad

Muzaffarabad is one of the most urbanized districts of AJ&K. The district is located on the banks of the Jhelum and Neelum rivers and is very hilly. The total area of the Muzaffarabad District is 1,642 km². The district is part of the Muzaffarabad division, and the city of

[3] Federal SDGs Unit, Ministry of Planning, Development & Special Initiatives (MoPD&SI), Islamabad, 2020. Role of Productive Sectors in Socio-economic Development of Azad Jammu & Kashmir. *Note: The Hattian district has recently been renamed as Jhelum Valley

Muzaffarabad serves as the capital of Azad Kashmir. The district is bounded on the north-east by the Neelum district and the Kupwara district of Indian-administered Jammu and Kashmir, on the south-east by the Jhelum Valley district, on the south by the Bagh district, and on the west by the Mansehra district and the Abbottabad District of Pakistan's Khyber Pakhtunkhwa Province. The total population of the district according to the 2017 census is 650,370.

Mirpur

The Mirpur district is another urbanized part of AJ&K. The Mirpur district is bounded on the north by the Kotli district, on the east by the Bhimber district, on the south by the Gujrat district of Pakistan's Punjab province, on the south-west by the Jhelum district of Pakistan's Punjab province, and on the west by Rawalpindi district of Pakistan's Punjab province. The district is named after its main city, Mirpur. The Mirpur district has a population of 456,200 and covers an area of 1,010 km².

Neelum

The district of Neelum is the northernmost of 10 districts located within the Pakistani-administered territory of Azad Kashmir. Taking up the larger part of the Neelam Valley, the district has a population of around 191,000 people. It was among the worst-hit areas of Pakistan during the 2005 Kashmir earthquake.

Bagh

The Bagh district had previously been part of the Poonch district and was created in 1988. The Bagh district is bounded on the north by the Muzaffarabad district, the Jhelum Valley district, and the Baramulla district of Indian-administered Jammu and Kashmir, on the east by the Haveli district, on the south by the Poonch district, and on the west by the Rawalpindi district of Pakistan's Punjab province. The total area of the district is 770 km². The total population of the district according to the 2017 census is 371,919

Poonch

The Poonch district is bounded on the north by the Bagh district, on the north-east by the Haveli district, on the south-east by the Poonch district of Indian-administered Jammu and Kashmir, on the south by the Sudhnoti district and the Kotli district, and on the west by the Rawalpindi District of Pakistan's Punjab Province. The district headquarters is the city of Rawalakot. Poonch district has a total area of 855 km² and a population of 500,571 according to 2017 census.

Kotli

The Kotli district is bounded on the north by the Sudhnoti district and the Poonch district, on the north-east by the Poonch district of Indian-administered Jammu and Kashmir, on the south by the Mirpur district and the Bhimber district, and on the west by the Rawalpindi district on Pakistan's Punjab province. It is the largest district of AJ&K by population and the

second largest by land area, after the Neelum district. The district headquarters is the city of Kotli. Kotli district has a total area of 1,862 km² and a total population according to census of 2017 as 774,194.

Sudhnoti

Sudhnoti district is bounded on the north and east by the Poonch district, on the south by the Kotli district, and on the west by the Rawalpindi district of Pakistan's Punjab province. It is located 90 kilometers (56 mi) from Islamabad, the capital of Pakistan. It is connected with Rawalpindi and Islamabad via the Azad Pattan Road. The district headquarters is the town of Pallandri. Sudhnoti has a total area of 569 and a total population of 297,584 according to census of 2017.

The table 1 based on the recent data of Multiple Indicator Cluster Survey (MICS, 2020-21) provides important insights at the district level for some key indicators that shall be useful in understanding sources of income, support from state and constraints in inclusivity of women in the region's labor force.

Table 1: District Level Socioeconomic Indicators

District	Proportion of HH Receiving Remittances	Proportion of HH Receiving BISP Support	Proportion of Women Never Used Computer	Proportion of Women Never Used Internet
	(1)	(2)	(3)	(4)
Neelum	5.7	38.9	93.9	86.2
Muzaffarabad	8.8	19.4	80.7	76.7
Jhelum Valley	11.6	24.4	88.1	84
Bagh	24.8	16.1	83.5	69.4
Haveli	10.3	26.8	93.2	94.2
Poonch	29.9	7.9	80.6	66.5
Sudhnoti	21.1	8.4	90.9	77.8
Kotli	45	10.3	86	64.1
Mirpur	43.6	9.5	75.6	48.6
Bhimber	33.5	5.1	79	53.1

Source: MICS 2020-21

The first column of table 1 shows the percentage of households receiving remittances from abroad. The highest percentage is in the districts of Kotli, Mirpur and Bhimber. Despite these high percentages and the significance of the income from abroad, no official statistics are

available to quantify them. The second column shows the statistics about transfer payments from BISP. Attention is invited to the high percentages given in the data against the districts of Neelum, Haveli and Jhelum Valley. All three of these districts are low in terms of remittance receives and hence it clearly shows that remittances have a major role in local incomes and there is an urgent need to create local employment opportunities as a fall in remittances is likely to leave households in relatively better-off districts in a vulnerable situation. Columns 3 and 4 of the same table show the technology related constraints faced by women and thus explains limited potential of their participation labor force and even e-commerce opportunities.

Table 2: Major Occupations - Muzaffarabad

	Muzaffarabad (Rural)		Muzaffarabad (Urban)	
Occupation	**Male**	**Female**	**Male**	**Female**
Agriculture, forestry and fishing	19.6	86.2	2.6	24.4
Manufacturing	13.4	0	10.7	0.7
Electricity, gas, steam and air conditioning supply	0.9	0	0.7	0
Water supply; sewerage, waste management	0	0	0.8	0
Construction	22.6	0	17.9	0
Wholesale and retail trade	13.3	0	25.4	0
Transportation and storage	4.5	0	6.9	0
Accommodation and food service	5.1	0	2.2	0
Information and communication	0	0	0.9	0
Financial and insurance activities	0	0	0.2	0.9
Real estate activities	0.4	0	0.2	0
Professional, scientific and technical activities	0	0	1	1.1
Public administration and defence	7.3	0	13.9	3.2
Education	9.2	13.8	9.2	58.3
Human health and social work activities	0.6	0	1.8	5.9

Source: LFS 2018-19

The tables 2-4 based on Labor Force Survey (LFS[4] 2019-19) show the dominant occupations across urban and rural regions in three major districts (Muzaffarabad, Poonch and Mirpur) of AJ&K when segregated on gender.

[4] The latest round of LFS for which microdata is available with PnD AJ&K

Table 3: Major Occupations -Poonch

	Poonch (Rural)		Poonch (Urban)	
Occupation	**Male**	**Female**	**Male**	**Female**
Agriculture, forestry and fishing	14.3	62.9	3.7	22.8
Manufacturing	8	1.6	8	0
Electricity, gas, steam and air conditioning supply	1.1	0	0.3	0.8
Water supply; sewerage, waste management	0	0	0.5	0
Construction	20.2	0	16.2	0
Wholesale and retail trade	23.2	0	27.4	1.1
Transportation and storage	8.8	0	11.7	0
Accommodation and food service	4.1	0	4.1	0
Information and communication	0.8	0	0.7	2.2
Financial and insurance activities	0	0	1.1	1.2
Professional, scientific and technical activities	0.4	0	1.9	1.1
Administrative and support service	1.4	0	1.4	0
Public administration and defence	3.9	1.7	8.2	3.3
Education	8.3	14.9	10.8	63.5
Human health and social work activities	1.7	6.1	1.4	3.2
Other service activities	2.2	0	1.3	0.8
Activities of households as employers	1.7	12.8	0.4	0

Source: LFS 2018-19

Table 4: Major Occupations -Mirpur

	Mirpur (Rural)		Mirpur (Urban)	
Occupation	**Male**	**Female**	**Male**	**Female**
Agriculture, forestry and fishing	22.8	33.8	6.4	14.3
Manufacturing	9	2.2	12.5	6.9
Electricity, gas, steam and air conditioning supply	1.2	0	0.8	0
Construction	21.1	0	16.6	0
Wholesale and retail trade	18.2	1.3	24.6	1.5
Transportation and storage	8.2	0	9.3	0
Accommodation and food service	2.6	0	3.7	0
Financial and insurance activities	0.5	0	1.6	0
Professional, scientific and technical activities	0.6	1.5	1.2	0.9
Administrative and support service	1.3	0	2.1	1
Public administration and defence	4.8	0	6.9	0
Education	5.8	41.8	6.1	59.3
Human health and social work activities	0.9	5.6	1.5	9.3
Other service activities	2.2	1.3	3.1	1
Activities of households as employers	0.5	12.4	0.9	3.4

Source: LFS 2018-19

In case of Muzaffarabad the concentration of women in agriculture in rural areas and education and agriculture in urban areas clearly shows a margin of their participation in the manufacturing industry specially in micro and small enterprises.

In case of Poonch, the wholesale and trade sectors have potential for accommodating women workers. Similarly in rural regions the health and social services sector has no representation from women. The last row of tables 3 and 4 shows the encouraging statistic whereby women entrepreneurs outnumber the men in rural Poonch. Similar pattern is observed in case of Mirpur district.

Clearly there are several occupations that have the potential to provide employment opportunities and add to the economic output of the district and the AJ&K region.

Table 5 shows the current residents mix between locals and migrants in case off three districts of AJ&K. Muzaffarabad and Mirpur have around 6-7 percent migrants, but locals dominate the population of Poonch. The migration trend in case of Mirpur is largely rural to urban, however, for Muzaffarabad and Poonch a sizeable number of migrants are from other urban locations. The analysis of rural to urban migration versus urban to urban (possibly small town to large city) migration trends could lead to important policy implications in terms of provision of skills development and jobs and hence the economic growth of the region. Some education related indicators at district level can be seen at Appendix A.

Table 5: Migration Trends-Selected Districts

District (Urban)	Percentage residents Living Since Birth	Migrated from Rural Area	Migrated from Urban Area
Muzaffarabad	92.8	65.9	34.1
Poonch	99.1	44.8	55.2
Mirpur	94.3	90	10

Source: LFS 2018-19

4. Review of Literature

Current decade has witnessed tremendous increase in the use of intensity of lights emitted at night to estimate economic activity. Despite the sensitivity of this measure depending upon geographical extent of analysis and the type of economic variables – output, poverty, population density etc. it can be safely said that nighttime lights data adds to our understanding about regional economic development especially in case of developing countries, which typically lack availability of reliable data – see Chen et al. (2011).Henderson et al. (2012) is probably the best example in this stream of literature that appropriately explains the context around the utility of nighttime lights in economics research. According to Google Scholar,[5] this paper has been cited 2210 times since its publication, but its popularity mainly lies in the derivation and implementation of an elegant methodological framework that brings growth in nighttime lights and income together. Using data on more than 150 countries, the authors estimate an elasticity between growth of GDP and growth of lights to be around 0.3 concluding that nighttime lights are best utilized when augmenting official statistics of low and medium developing countries.

Since the time of Henderson et al. (2012)'s landmark paper, profusion of studies has emerged that have tried to capture economic activity using nighttime lights data. One of the prime examples of similar methodological application is Bickenbach et al. (2016) which tries to replicate it at sub-national levels focusing on Brazil and India. Other research endeavors associating output and luminosity at sub-national levels include Bhandari et al. (2011) that finds a 0.34 percent increase in district-level GDP of India following a 1 percent increase in nighttime lights and Sutton et al. (2002) that focuses on gross state product of US states. Many other researchers have also commented on the power of nighttime lights for studying GDP (both level and growth) in terms of parameters often reported for checking statistical significance. For example, Doll et al. (2006) estimates R-squared of around 0.9 on average between lights and GDP aggregated at different scales using data on 11 European countries.

The use of lights emitted at night is not limited to cross country analysis. Indeed, a strand of literature is growing that targets a narrower geographical region in the country- city or district and uses nighttime lights for quantifying various social and economic indicators at this level. The research topics covered at this level are plenty but drawing inferences from nighttime lights about measurement and dynamics of urbanization stands out– see Zhou et al. (2015); Ma et al. (2015); Tan, M. (2015); Alder et al. (2017); Baragwanath et al. (2019); Harari, M. (2020) among many others.

[5] As of April 2022

The heterogeneity in the composition of economies, whether national or at sub-national level, demands caution in use of NTL intensity for bridging the existing data gaps. Foregoing studies highlight the importance of nighttime lights in economics literature but in case of developing nations, other sources of information are necessary to complement the power of this unique data in predicting local economic activity. In developing world, agriculture contributes greater part of GDP and agriculture, unlike manufacturing or services, is an activity that emits very low nighttime lights.

As it has been highlighted and argued that predicting output at sub-national levels is not very effective in cases where the land area comprising targeted sub-national unit is small or when the share of agriculture output is higher in the GDP or economic activity taking place at the local level it is important to review the sectoral contribution in the regional economy before employing NTL for GDP estimation.

The economy of AJ&K region has traditionally been agricultural in nature and number of urban centers – major source of light emission – are few relative to other provinces of the country. Figure 3 shows the intensity and trend of nighttime luminosity with respect to provinces of Pakistan, and it is visible that AJ&K is not one of the major areas of the country that emits light. These facts require adoption of an appropriate methodology to estimate economic activity in case of AJ&K.

Table 6 below indicates that based on employment figures, the share of agriculture in AJ&K is around 20% and hence the economic output estimation needs to incorporate this in the regional GDP figures. Overall, in AJ&K, agriculture, industry and services sector contribute 19.42%, 27.17%,53.41% respectively to the local economy. Moreover, table 7 highlights the level of informality in non-farm economic activities and hence points out that use of NTL to estimate the quantum of their contribution to regional/local economy shall be useful as opposed to the traditional survey-based approaches.

Table 6: Employment by Sector

Employed - Distribution by Major Industry Divisions in AJ&K						
Major Industry Division	**Rate (%)**					
	2014-15			**2017-18**		
	Male	**Female**	**Total**	**Male**	**Female**	**Total**
1	2	3	4	5	6	7
Agri/Forestry/Hunting/ Fishing	10.74	0.15	10.89	15.34	4.08	**19.42**
Manufacturing	5.72	0.18	5.90	7.02	1.14	**8.16**
Construction	20.95	0.09	21.04	18.96	0.05	**19.01**
Wholesale & Retail Trade	19.52	0.46	19.98	17.22	0.13	**17.35**
Transport/Storage & Food Service activities	8.17	-	8.17	6.69	0.06	**6.75**
Financial & Insurance activities	1.55	0.04	1.59	0.71	0.11	**0.82**
Other Services activities	**2.32**	**-**	**2.32**	**2.02**	**0.15**	**2.17**

Source: AJ&K Labour Force Survey 2017-18

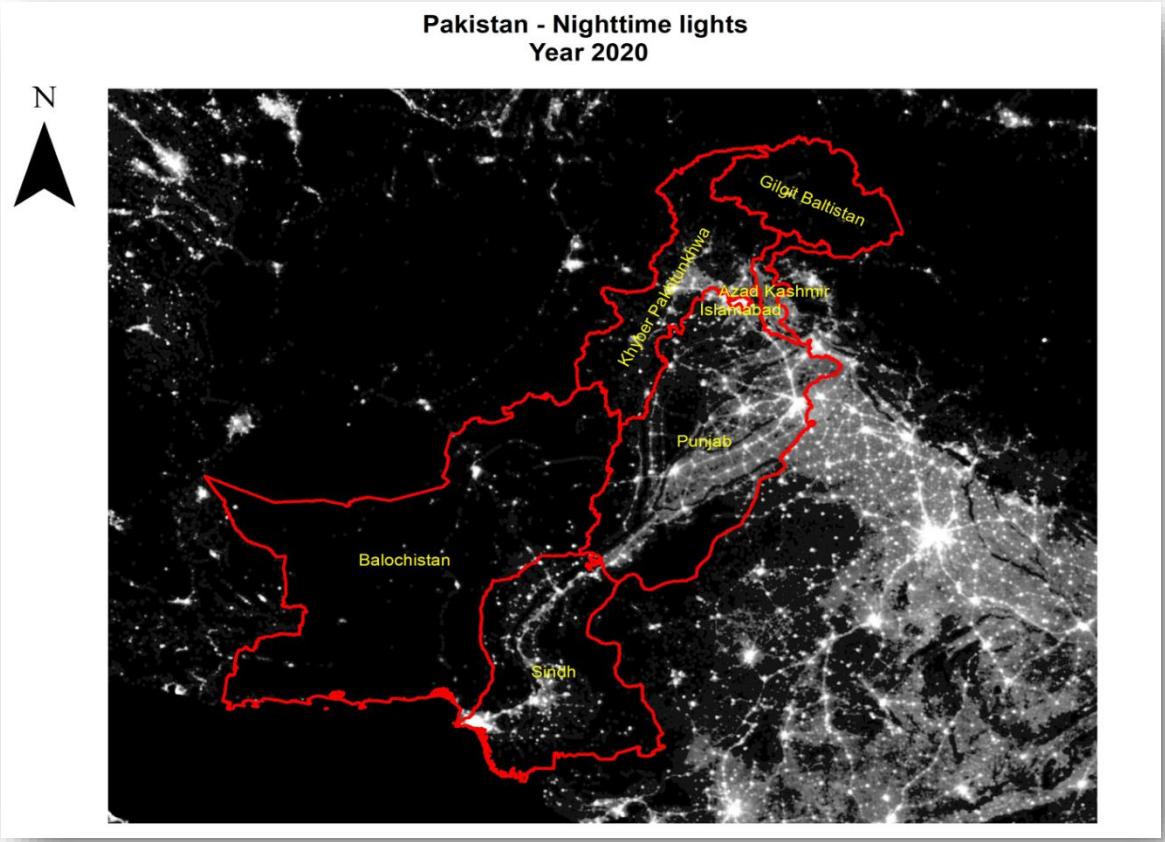


Figure 3: NTL in Pakistan and AJ&K

Greater share of agriculture in the economic outlook of developing countries like Pakistan does put limitations on the use of nighttime lights data. However, availability of other sources of information have paved the way for alternate methodologies that could overcome such limitations. Ghosh et al. (2010) uses Landscan rural population data and percentage contribution of agriculture towards national GDP along with nighttime lights and creates a gridded dataset of economic activity. On the other hand, Keola et al. (2015) employs Henderson et al. (2012) estimation strategy but runs separate regressions for agriculture and non-agriculture output growth rates. Employing Moderate Resolution Imaging Spectroradiometer (MODIS) land cover dataset, the authors use various land classification categories as inputs in the regression explaining agriculture growth rate. It is being suggested that combined land area classified as Grassland, Cropland and natural vegetation is better determinant of agriculture output whereas luminosity measure should only be used for non-agriculture growth rate. Land cover data was also used by Yue et al. (2014) as ancillary to nighttime lights for studying regional GDP of China's Zhejiang province. This study also attempted to use the MODIS data for estimation of agricultural economic output, however, the differences in the cropland area between satellite imagery and official statistics lowered our confidence and hence diverted to an alternate approach (see Appendix B).

Table 7: Extent of Informality by Sector

Informal Sectors Workers - Distribution by Major Industry Divisions in AJ&K						
Major Industry Division	Rate (%)					
	2014-15			2017-18		
	Male	Female	Total	Male	Female	Total
1	2	3	4	5	6	7
Manufacturing	8.15	0.24	8.39	11.00	1.92	**12.92**
Construction	31.44	0.14	31.58	31.38	0.07	**31.45**
Wholesale & Retail Trade	30.93	0.73	31.66	28.61	0.22	**28.83**
Transport, Storage & Communication	12.40	-	12.40	10.22	0.09	**10.31**
Financial & Insurance activities	0.56	-	0.56	0.14	-	**0.14**
Other Services activities	**3.06**	**-**	**3.06**	**3.38**	**0.26**	**3.64**

Source: AJ&K Labour Force Survey 2017-18

Available (unofficial) estimates of provincial GDPs for the four provinces of Pakistan are usually obtained by disaggregating national accounts figures at lower spatial levels (see Arby, M. F. (2008) and Bengali et al. (2005) – or ones that concentrate only on one region of the country – see Burki, S. J. et al. (2012)). Nevertheless, previous literature – despite being outdated – provides insights which are useful for further studies on the topic. Table 8 shows the share of agriculture, industry, and services sectors in all the four province's GDP over a period of the last 45 years (Arby 2008).

Table 8: Sectoral share (%) in province's GDP

	1971-75	1976-80	1981-85	1986-90	1991-95	1996-00	2000-05
KP							
Agriculture	38.12	32.76	29.32	26.84	24.31	22.25	21.32
Industry	17.85	18.62	20.98	21.74	22.28	22.24	22.46
Services	44.03	48.63	49.7	51.42	53.42	55.51	56.22
Punjab							
Agriculture	43.14	38.65	34.87	32.26	29.75	27.98	25.51
Industry	19.87	21.3	23.05	24.01	24.37	23.59	23.88
Services	36.98	40.04	42.08	43.73	45.88	48.43	50.61
Sindh							
Agriculture	27.88	25.41	22.28	19.40	18.63	20.08	17.83
Industry	27.21	26.55	29.74	31.14	29.86	28.20	28.40
Services	44.91	48.04	47.98	49.46	51.51	51.72	53.77
Balochistan							
Agriculture	32.47	30.06	29.57	27.77	27.24	29.81	25.77
Industry	23.54	25.52	26.31	24.86	26.18	22.35	25.17
Services	43.99	44.42	44.13	47.37	46.57	47.83	49.06

Source: Arby, M. F. (2008). 5-year averages calculated by authors themselves

In the case of Pakistan, not many studies have used nighttime lights to explore economic and social phenomenon. To the best of our knowledge, only few research works have employed such novel dataset. Mahmood et al. (2017) calculates elasticity of luminosity measure with respect to large-scale manufacturing output for various districts of Pakistan covering all the provinces whereas Ali, (2016) uses light at night in the context of inferring welfare implications of the power outages. More recently Beyer et al. (2018) have estimated district level economic activity using nightlights data while capturing agricultural component through rural population.

Exploring Urban Growth Trends

A region-based analysis of economic activity reveals that urban centers are the major contributors towards the national GDP. As succinctly highlighted by Glaeser et al. (1995), "the story of growth of cities is similar to that of the growth of countries". As the structure of an urban center eases out the constraints in achieving high productivity, therefore spatial allocation and temporal growth of urban clusters are good indicators of how successful a nation has been in alleviating the perennial problem of inequality. The rapid pace of urbanization in South Asian countries especially Pakistan and the growth of its cities has the potential to unleash future economic growth. This is obviously subject to certain caveats as highlighted by (Ellis and Roberts, 2015) wherein they have characterized the current state of South Asian urbanization as "messy" and "hidden". It is therefore very important to study and analyze cities' economy, but unfortunately very little information or data is available for this.

Table 9: Population and urban areas

Province	Population	Proportion of total population	Urban Population (%)	Rural Population (%)	# Mega Urban Areas
Punjab	110,012,442	52.95	63.63	36.36	5
Sindh	47,886,051	23.05	52.02	47.98	2
KP	30,523,371	14.69	16.52	83.47	1
Balochistan	12,344,408	5.94	27.55	72.45	1
Islamabad	2,001,579	0.97	50.45	49.54	-
AJ&K	4,045,367		17.36	82.63	-

Source: Pakistan population census 2017

The focus of available economics literature and this proposed study on the urban clusters is due to the immense economic potential of cities. Belleflamme et al. (2000) underscores the traditional division of these gains into two: one resulting from production of similar goods by

firms locating nearby – localization economies; and ones coming from conducting overall economic activity in a specific geographic area – urbanization economies. These benefits are so important that they have been shown to be responsible for employment growth, technological change, innovation, and knowledge spillovers into other areas – see Glaeser et al. (1992); Henderson et al. (1995); Feldman et al. (1999); Smith, P. J. (1999).

Table 9 gives a snapshot of number of people and mega urban centers – areas with population greater than 1 million – with respect to four provinces of Pakistan. Many countries in Western Asia and Eastern Africa have populations less than this figure. Table 10 gives district level demographic information about the AJ&K region.

Table 10: Demographic Information for AJ&K region

District and Gender-wise Rural & Urban Population of AJ&K (Census 2017)								
District	Nos						Transgender	G. Total
	Rural			Urban				
	Male	Female	Total	Male	Female	Total		
1	2	3	4	5	6	7	8	9
Muzaffarabad	238,672	239,699	478,371	89,361	82,598	171,959	41	**650,371**
Neelum	90,362	92,949	183,311	3,971	3,951	7,922	18	**191,251**
Jhelum Valley	108,890	104,561	213,451	8,443	8,633	17,076	02	**230,529**
Bagh	143,646	158,443	302,089	33,847	35,971	69,818	12	**371,919**
Haveli	75,959	70,604	146,563	3,040	2,515	5,555	06	**152,124**
Poonch	184,406	201,869	386,275	55,416	58,870	114,286	10	**500,571**
Sudhnoti	131,408	142,927	274,335	11,617	11,626	23,243	06	**297,584**
Kotli	325,719	369,208	694,927	40,322	38,920	79,242	25	**774,194**
Mirpur	139,070	135,698	274,768	92,215	89,201	181,416	16	**456,200**
Bhimber	188,674	199,931	388,605	15,756	16,247	32,003	16	**420,624**
Total	**1,626,806**	**1,715,889**	**3,342,695**	**353,988**	**348,532**	**702,520**	**152**	**4,045,367**

Comparing figures from tables 9 and 10, the small number of populations categorized as urban in each district of AJ&K indicates that urban economic activities have a large potential for growth. Moreover, lack of megacities in AJ&K will and can have negative effect on the poverty levels across the province as it has been found that incidence of poverty is inversely related with the size of town or city – see Hashim (2014). Like many developing countries, Pakistan is going through rural-to-urban migration process and limited number of urban areas mean that the existing cities will face pressure on the supply of various amenities like housing, water, etc. Such distortions in demand and supply could result in negative social and economic outcomes for both rural and urban residents. Keeping these realities in mind, we endeavor to extract the spatial extent of the urban centers of the province and quantify the growth of these over time. This exercise will help us in analyzing how the growth in cities matched with the growth in local population. This information can potentially be used in

determining extent of urban sprawl or compactness- information required for efficient urban planning and city management.

Our proposed research will not only augment growing literature on nighttime lights and economics but also help explain sub-national development in low-income countries like Pakistan. Our work will bring more improvement to the existing literature as we intend to use land use/ land cover data for segregating agricultural activity. We hope that our work will help in designing better economic and public policy reforms by uncovering areas or districts in the province that lag in terms of share in modernization.

5. Data Sets

The global nightlight data that we use for this study is derived from nightlight imagery collected by the Defense Meteorological Satellite Program (DMSP/OLS). The original NTL data series pertains to the period 1992-2013. The cleaned up version contains the lights from cities, towns, and other sites with persistent lighting,. Ephemeral events, such as fires have been discarded. Then the background noise was identified and replaced with values of zero. Data values range from 0-63 indicating various level of luminosities with 0 being no light and 63 the brightest light.

The original global night-time lights time series from DMSP was produced using Operational Linescan System (OLS data) from six individual satellites. Over time, the orbits of each satellite gradually shifted to an earlier overpass time, sliding from a day / night orbit to a dawn / dusk orbit. The DMSP sensors collected sufficient night-time data worldwide for annual night-time lights product generation as long as the overpass occurred later than 19:30. Recently, NOAA added additional years to the DMSP equatorial crossing time chart and based on this new information, an extended annual DMSP night-time lights time series from 2014-2020 has been made publicly available.

Apart from the nighttime lights data, we intend to use the datasets listed below. Table 11 indicates the information about the relevant agencies and status of data availability.

- Data regarding, agriculture, manufacturing and services sector available with BOS AJ&K
- 1998 and 2017 Censuses of Pakistan uses these to extract total, urban and rural population figures of the districts of AJ&K region. Also these were used to calculate projected populations for intermediate years.
- **World Development Indicators (WDI).** We will use these to extract information about Pakistan's GDP, manufacturing output, agricultural output and other national accounts statistics.
- **Landscan**. This is spatial dataset representing global population distribution and available on request for the academics from https://landscan.ornl.gov/landscan-datasets. The time covered is 2000-2019. Although Landscan is considered a reliable source of spatial population distribution but for AJ&K its utility was found be limited.
- **The Global Land Cover and Land Use Change, 2000-2020.** The GLAD Global Land Cover and Land Use Change dataset quantifies changes in forest extent and height, cropland, built-up lands, surface water, and perennial snow and ice extent from the year 2000 to 2020 at 30-m spatial resolution. Each thematic layer was validated independently using a statistical sampling. This is spatial dataset is freely available at https://glad.umd.edu/dataset/GLCLUC2020/.
- **MODIS** (i.e., MCD12Q1) datasets that provide classification values of vegetation cover of KP. We use this dataset to extract land-use and land-cover states of KP for the years

for which the data is available. MODIS is freely available but, unlike nighttime lights data, is downloaded in terms of tiles that cover specific portions of land area. Further GIS-related processing would be required to make such tiles into a format from which we can make inferences about land cover information.

- **Shapefile data**: This refers to GIS data in digital vector format that contains information about geometric objects. In our case, these objects correspond to boundaries of administrative units of Pakistan at various levels i.e., national, provincial, divisions, districts, and tehsils. We use two sources of shapefile data: first is publicly accessible data available for downland at US Census Bureau's website (https://www.census.gov/geographies/mapping-files/time-series/demo/international-programs/demobase.html) and second data source comes from Pakistan Bureau of Statistics (PBS).
  For AJ&K, the shape files with district and tehsil boundaries were obtained from LAND USE PLANING section of Planning and Development Department.

Table 11: Data Related Information

	Dataset	Area coverage	Time coverage	Availability
1	Population Census	National, provincial, district	1998, 2017	Yes
2	Statistical Data AJ&K at a Glance and Statistical Year Book	Provincial, district	1985 to 2021	Yes
4	Labor force statistics	Provincial	2003-04 to 2017-18	Yes
5	Agriculture census	National, provincial, district	2010	Yes
6	Nighttime lights	National, provincial, district	1992 to 2020	Yes
7	National accounts	National	1992 to 2020	Yes
8	Provincial accounts	Provincial	1992 to 2005	Yes
9	MODIS (GIS)	National, provincial, district	2001 to 2020	Yes
10	Landsat (GIS)	National, provincial, district	1992 to 2020	Yes
11	The Global Land Cover and Land Use Change (GIS)	Global	2000 to 2020	Yes
12	Shapefile (GIS)	National, provincial, district		Yes
13	Census Population grid (GIS)	National, provincial, district	1998	Yes
14	Multiple Indicator Cluster Survey (MICS)	Provincial	2020-21	Yes

6. Methodology

Quantifying size of Regional Economy

The GDP of the AJ&K has neither been estimated independently so far nor does the economic output of the region included in the National Accounts figures. The survey-based data collection for economic indicators related to the region has also remained sketchy due to the special status of the area and security issues involved in data collection and hence factual assessment of economic activity beyond agriculture is difficult. The PBS documentation on National Accounts does not discuss this specifically as well.

In this study, we aim to quantify the GDP of the AJ&K region. The following were the main challenges in this. First the traditional methods of GDP estimation based on income earned, expenditure made, or production output approaches cannot be applied due to non-availability of the requisite data. The only data that is regularly collected pertains to agricultural activity. Moreover, this approach at best shall provide entire AJ&K's economic output as being estimated in case of Khyber Pakhtunkhwa and Punjab provinces and shall not provide more important information of economic activity which is spatially disaggregated at the district level.

This study therefore resorts to unconventional data sources such as those collected through satellite imagery. The daylight satellite imagery is useful in identifying landcover and land use types and the nightlight satellite imagery is a convenient way of differentiating urban and rural regions. The rural regions are mostly the areas with low lights intensity whereas the urban regions are identified as the ones with relatively more bright lights. Segregating urban and rural regions is the next important challenge as rural areas mostly contribute towards agricultural activity and urban regions relate to non-farm activity mainly in the manufacturing and services sector. In case of AJ&K region the large areas covered under forests in several districts such as Neelum etc. pose another important concern. It is important to separate low-lit regions into forests and croplands as they relate to two different economic activities with different economic contributions.

After spatial segregation into urban, rural and forest areas, the third challenge is to determine the respective population falling in these regions. Currently no reliable spatial maps for population are available. In this study we tried to use Landscan and US census spatial maps, but these did not confirm with PBS figures and hence were dropped. Finally, this population that falls in urban, rural or forest region has to be accounted for its economic contribution towards the district or region's economy.

Having stated the main challenges in estimating the economic activity, we now state our stepwise approach towards the estimation of the GDP at the region and district level.

First Step

This step involves understanding the sectoral composition of the regional economy across and within primary, secondary and tertiary industries. A review of the AJ&K's economy's composition and its comparison with provincial economies of Pakistan using employment statistics by major industry division from LFS 2018-19 reveals that its closest match is with the KP province. Based on World Bank's document[6] supporting this contention, we therefore assume that returns to factors of production in AJ&K is similar to that in KP province which is a reasonable assumption based on similarities in terrain, topography and sectoral components of each major industry in the two territories. With this method, the value addition from each sector is considered similar and hence we can utilize the published GVA figures of KP province to derive similar value addition in case of AJ&K.

The GVA figures for KP province for the years 2011-12 to 2019-20 are shown below in the table 12. The GVA figures as shown in table are then used to calculate per capita values in case of KP province and these are then applied to AJ&K&K. The agricultural component of the economy is attributed to arise mainly from rural population and non-agricultural component comprising of Industries and Services sector to the urban population. Inhabitants of forested areas are accounted for separately. Another benefit of this approach is that the estimated figures confirm to the base year (2005-06) prices and are hence comparable across provinces and nationally as well. The application of this approach requires that in each district of AJ&K we should be able to spatially identify urban, rural and forest areas. This is covered in the steps 2 and 3.

Table 12: GDP of Khyber Pakhtunkhwa on Constant Basic Prices of 2005-06

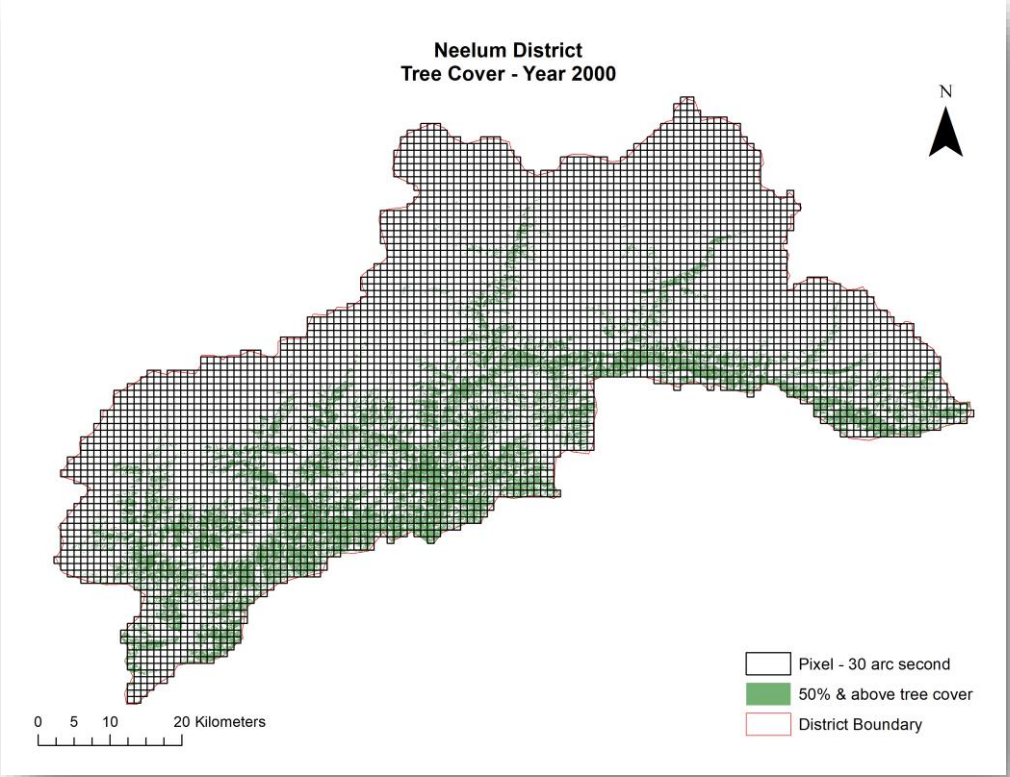
Description	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20
GVA of Agriculture Sector	197503	205670	215281	214386	220539	222868	230370	236047	239582
GVA of Industries Sector	214364	219448	231067	243584	265981	271893	297846	324665	303207
GVA of Services Sector	481543	518721	545197	570126	610984	651440	711820	720266	681074
GDP of Khyber Pakhtunkhwa	893410	943839	991545	1028096	1097504	1146201	1240035	1280979	1223863

Source: Regional Accounts Wing, PnD KP

[6] World Bank report 'Pakistan 2005 earthquake- preliminary needs and damage assessment"

Second Step

Considering the high percentage of land covered by forests in the AJ& K region it is important to separate forests from agricultural and urban land uses. For this we use satellite imagery based spatial data from The Global Land Cover and Land Use Change[7] which provides locations and percentage of forests within a 30 m pixel. As these pixels are much smaller than the NTL pixels which are around 1km, they provide forest location information at a very high resolution with much more reliability. We calculate forest percentages within each of these smaller pixels and categorize the larger NTL pixel as 'forest' if forests cover exceeds 50% or more of its area as shown in the figure 4 for the districts of Neelum and Muzaffarabad. The pixels categorized as 'forest' are then excluded from each district area as they can neither be used for agricultural or non-agricultural economic activity that relates to urban and rural regions respectively.



[7] https://glad.umd.edu/dataset/global-2010-tree-cover-30-m

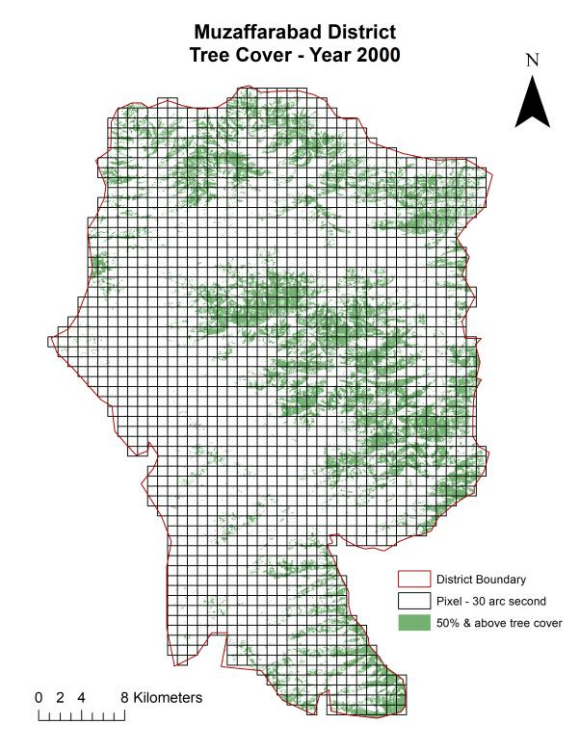


Figure 4: Forest Pixels in Muzaffarabad District

Third Step

This step involves the spatial segregation of each district in rural and urban areas after exclusion of forest pixels and hence the determination of farmlands and city/town locations in each district of the AJ&K. We use nightlights at this stage as light intensity is a reliable proxy for investment and consumption in the non-agricultural sector and hence changes in intensity of light along the border of an urban settlement can be used to determine the boundary.

We use a quantile-based approach to map urban extent in each district as developed by Zhou et al (2018). The key idea behind this approach is to determine a threshold that allows separating urban areas from its surrounding surface types (e.g., suburban and rural). The figure 5 demonstrates this approach where the nightlight intensity represented through DN values (DN values represent the intensity of light and range between 0-63) changes rapidly around boundaries between urban, and rural areas.

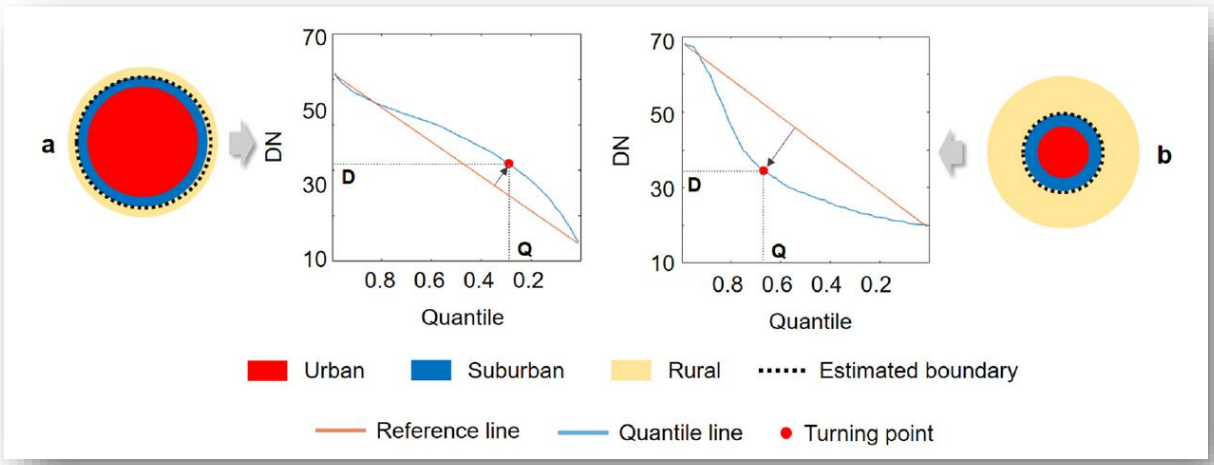


Figure 5: Urban Extent Mapping based on the Quantile Analysis of NTL (Zhou et al, 2018)

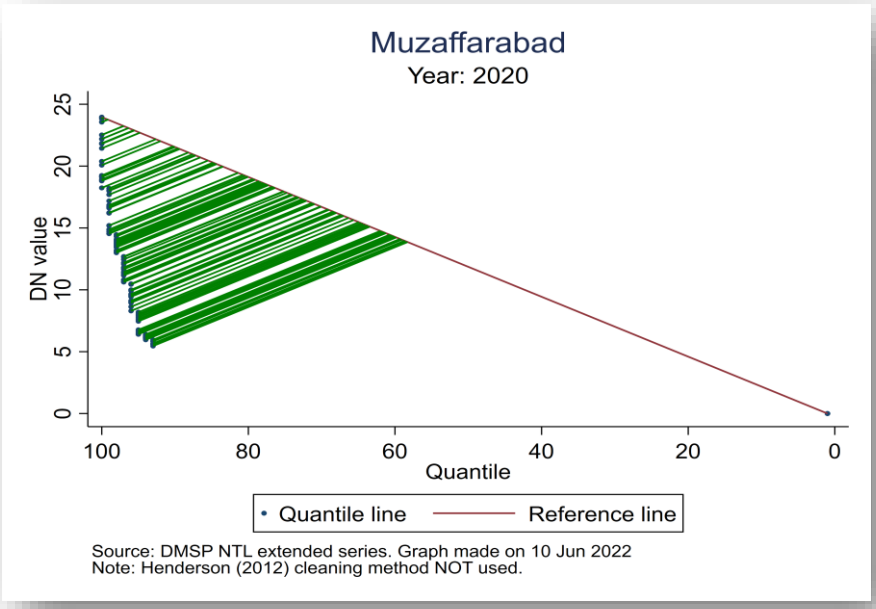
As shown in figure 5, the quantile curve (i.e., DN value at different quantile levels) for an urban dominated cluster with relatively higher DNs always locates above the reference line (figure 5a), which shows a linear decrease of DN value from the highest to lowest quantile level without gradient change of DN values, whereas, for a rural dominated potential cluster (figure 5b), the quantile curve falls below the reference line. The approximate boundary between different types (i.e., urban, suburban, and rural) can be determined from the turning (inflection) point (red dot in Fig. 5), with the maximum gap between the quantile and reference curves.

Explaining figure 5, a conceptual model of urban extent mapping based on the quantile analysis of NTL data in a potential urban cluster for urban (a) and rural (b) dominate potential clusters is shown in figure 5. Quantile lines represent DN values at different quantile levels, decreasing from 0.99 to 0.01 with a step of 0.01. Reference lines represent linearly decreasing DN values at different quantile levels for two potential urban clusters. Turning points are identified locations (quantile level at Q with a threshold of DN value at D) with the maximum gap between these two lines.

Thus, the key for this approach is to determine the location of identified threshold (turning point), i.e., boundaries between suburban and rural, or urban and suburban. Based on these boundaries, rural and suburban areas can be removed sequentially from the potential cluster to derive the final urban extent.

We examined temporal dynamics of quantile patterns in each district of AJ&K for which the graphs are shown below. The use of this method results in pointing out the district specific DN values around which the urban -rural boundary is formed and hence spatial separation of the two areas on the basis of nightlights becomes achievable.

Figure 6 shows the application of quantile plots for the districts of Muzaffarabad, Jhelum Valley and Mirpur for the year 2020. Table 13 lists the threshold DN values segregating urban and rural regions for all the districts of AJ&K for the years 2010-2020. It is interesting to observe the variation in these values across least urbanized districts such as Haveli and most urbanized districts such as Mirpur.



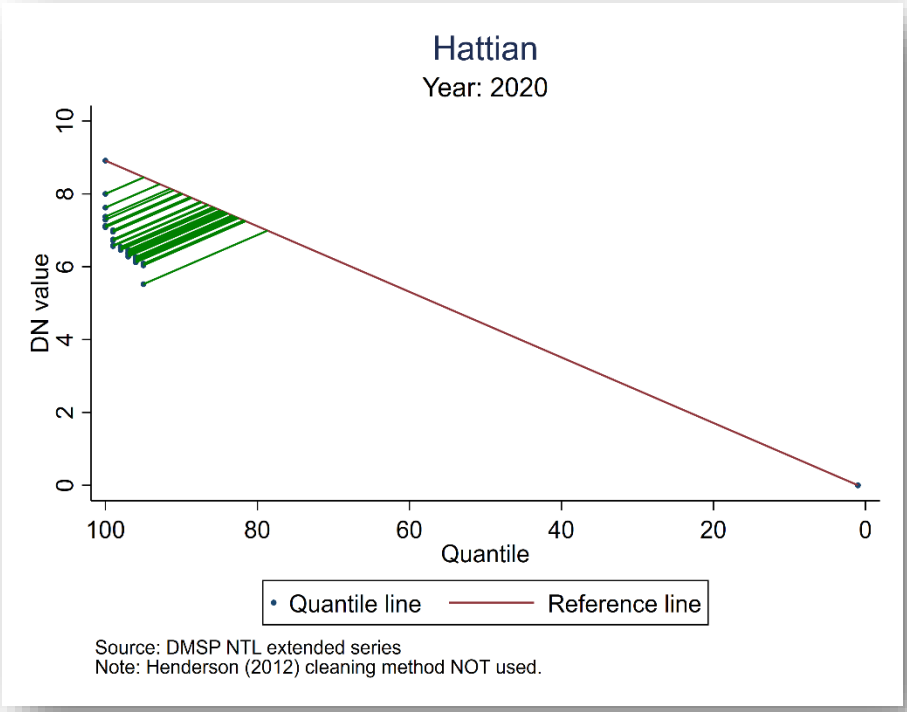


Figure6: NTL Quantile Plots for Selected Districts

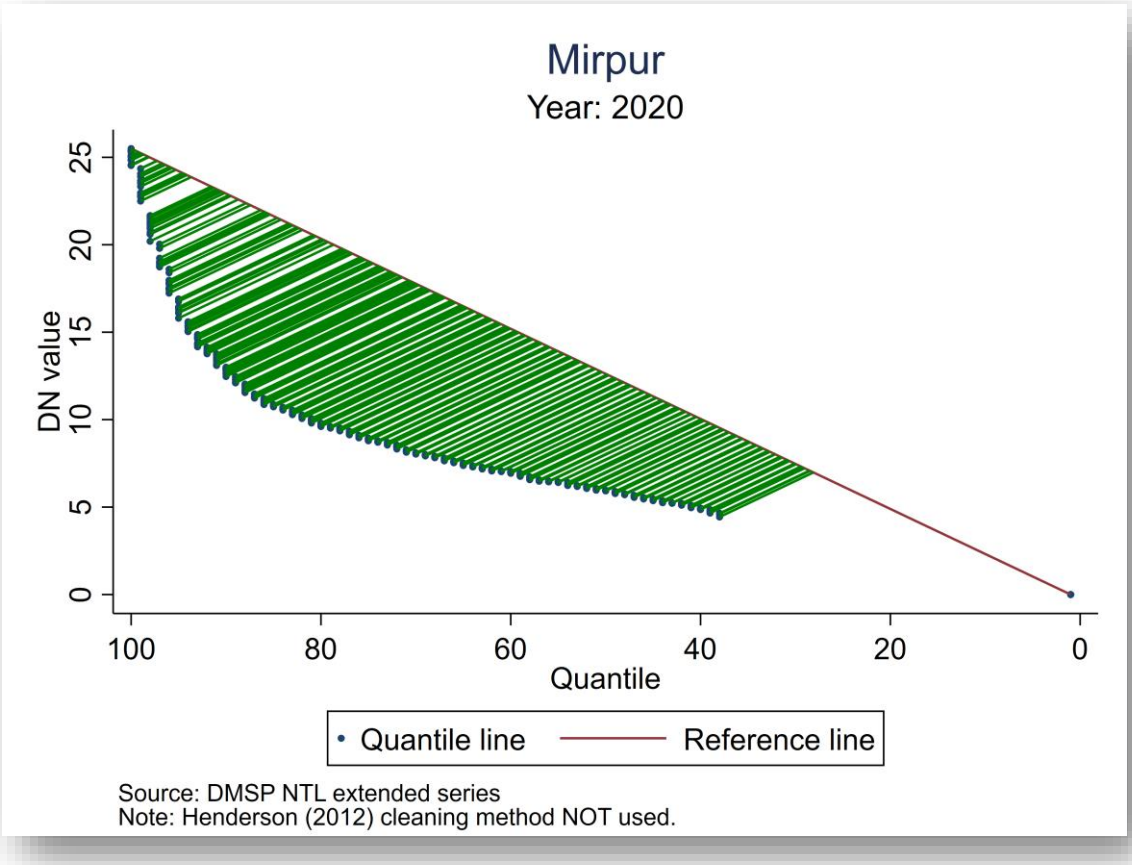


Figure 7 (contd): NTL Quantile Plots for Selected Districts

District	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Haveli	3		4	2.6		3.0	3.0	3.5	3.1	4.0	5.7
Neelum	3	4		3.1	3.9	3.4	2.7	3.3	3.8		
Jhelum Valley	3	4	4	4.0	3.2	4.0	4.6	4.4	3.1	6.2	5.5
Bagh	8	5	5	4.7	5.2	4.0	4.8	4.5	4.5	4.3	5.0
Sudhnoti	4	4	5	2.9	3.8	3.2	3.1	4.2	4.1	3.9	
Poonch	9	9	8	4.8	5.0	4.3	3.2	4.9	4.7	5.3	5.8
Muzaffarabad	7	8	9	6.5	6.9	6.3	6.5	7.1	7.3	7.2	5.5
Bhimber	8	9	10	5.8	5.8	4.9	5.3	5.7	5.8	6.5	6.0
Kotli	11	12	11	8.4	7.9	7.0	8.5	9.1	9.2	9.5	8.1
Mirpur	19	23	24	11.8	11.4	9.7	9.5	10.0	10.6	12.3	11.0

Table 13: Urban-Rural Boundary DN Values

Source: Author Calculation

Fourth Step

In this step the aim is to develop spatial population maps at the district level. For this, the projected populations of 2010, the census population of 2017 and the projected population of 2020 are assigned to the urban rural and forest pixels identified in steps 2 and 3 above. The respective sectoral contribution to the economic activity is then determined using the per capita figures from KP province for the entire AJ&K region.

Next, this step also involves division of regional GDP of AJ&K into contributions made by lower level of administrative units i.e., districts. We achieve this goal by using formula introduced by Beyer et al. (2018) for breaking down known output figure of a larger or national geographical unit into output estimates corresponding to smaller sub-national units. This approach involves retrieving estimated GDP values and using equation (1) for estimating district-level values as shown below.

$$\ln(GDP_{it}) = \left(\frac{light_{it}}{\sum_{i=0}^{i=I} light_{it}} * \frac{MAN_T + SER_T}{GDP_T} + \frac{rpop_{it}}{\sum_{i=0}^{i=I} rpop_{it}} * \frac{AGR_T}{GDP_T} \right) * PGDP_t \qquad (1)$$

Where GDP_T, $PGDP_t$, $light_{it}$ and $rpop_{it}$ refers to actual regional GDP, predicted regional GDP, night-time lights emitted by district i and rural population in district i, respectively. On the other hand, MAN_T, SER_T and AGR_T are the manufacturing, services, and agriculture components in the regional GDP.

Fifth Step

This step focuses on the analysis of District GDP for its use in policy formulation and evaluation. To state some examples, the district level GDP so estimated is then used to rank districts on the basis of their overall contribution to the region's economy, temporal variations in the ranking and also determination of per-capita GDP values.

7. Results

7.1. District GDP Estimation and Analysis

Tables 14 and 15 present the results obtained from the five-step approach stated in detail in section 6. Table 14 presents the district level GDP of the 10 districts of AJ&K for three years 2010, 2017 and 2020. The choice of the year 2010 is made to avoid the negative shock from the 2005 earthquake to the local and regional economies with the expectation that reasonable rehabilitation and resumption of economy has taken place by then. The year 2017 provides the national census data and year 2020 is the one for which most recent nightlight data is available at this point.

Table 14: District Level GDP for AJ&K (constant prices 2005-06)

District	Year	District GDP (million PKR)	Percentage Share in AJ&K GDP	Rank
Kotli	2010	23429	23.31	1
Mirpur	2010	18992	18.90	2
Bhimber	2010	14962	14.89	3
Muzaffarabad	2010	11144	11.09	4
Poonch	2010	10635	10.58	5
Bagh	2010	8344	8.30	6
Sudhnoti	2010	7295	7.26	7
Jhelum Valley	2010	3039	3.02	8
Neelum	2010	1452	1.44	9
Haveli	2010	1212	1.21	10
Kotli	2017	48775	31.98	1
Mirpur	2017	24030	15.75	2
Muzaffarabad	2017	21522	14.11	3
Bhimber	2017	21116	13.84	4
Poonch	2017	12406	8.13	5
Bagh	2017	8532	5.59	6
Jhelum Valley	2017	6870	4.50	7
Sudhnoti	2017	5472	3.59	8
Haveli	2017	1928	1.26	9
Neelum	2017	1878	1.23	10
Kotli	2020	47418	33.44	1
Mirpur	2020	41013	28.92	2
Bhimber	2020	22651	15.97	3
Muzaffarabad	2020	12961	9.14	4
Poonch	2020	4924	3.47	5
Bagh	2020	4867	3.43	6
Jhelum Valley	2020	3566	2.51	7
Sudhnoti	2020	1994	1.41	8
Neelum	2020	1350	0.95	9
Haveli	2020	1059	0.75	10

Source: Author's Calculation

Table 14 lists the overall size of the district economy, its share in the AJ&K's GDP and the rank of the district in the respective year. On the basis of these it can be seen that districts of Kotli and Mirpur occupy the top two ranks, whereas the districts of Neelum and Haveli hold the bottom ranks. Interestingly the top five ranked districts contribute around 80% of the regional economy in 2010 and this number increases to 90% in 2020. The individual contribution of the highest ranked district Kotli has increased from 23% to 33% in a decade whereas the contribution of lowest ranked district Haveli has declined from 1.2% in 2010 to 0.75% in 2020. The increasing disparities among districts provide important insights for future planning and public sector expenditure outlays.

The sectoral distribution of district level GDP into agricultural and non-agricultural components (industry and services) for the years 2010 and 2020 is shown in figure 7. The intensity of NTL indicates that Mirpur has persistently the highest proportion of non-agricultural economic activity, whereas Kotli has taken the second place in 2020.

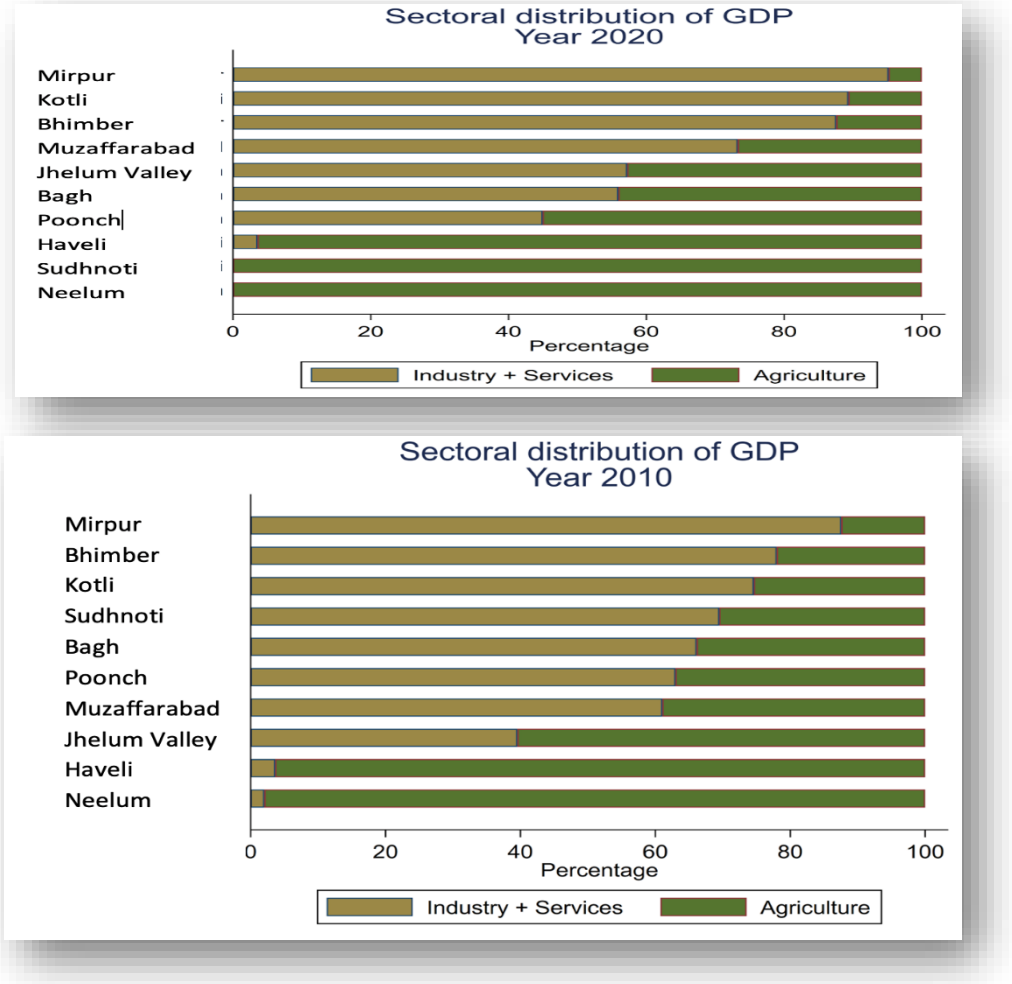


Figure8: Sectoral Distribution of GDP at District Level for 2010 and 2020

Table 15 provides district level GDP per capita figures for the years of 2010, 2017 and 2020. Comparing the figures across 2010 and 2020, it is evident that on per capita basis, Mirpur holds the top rank whereas Neelum and Havelli persistently hold the bottom ranks. The recent

decline in the rank position of Sudhnoti raises concerns and needs to be investigated in more detail. Overall, the GDP of AJ&K estimated in our study is around 1% of the national GDP.

Table 15: District Level Per Capita GDP for AJ&K

District	Year	GDP Per Capita (PKR)	Population	GDP (million PKR)	Rank (GDP Per Capita)
Mirpur	2010	44,375	428,000	18,992	1
Bhimber	2010	36,404	411,000	14,962	2
Kotli	2010	30,626	765,000	23,429	3
Sudhnoti	2010	25,687	284,000	7,295	4
Bagh	2010	23,308	358,000	8,344	5
Poonch	2010	19,841	536,000	10,635	6
Muzaffarabad	2010	17,633	632,000	11,144	7
Jhelum Valley	2010	13,154	231,000	3,039	8
Haveli	2010	8,539	142,000	1,212	9
Neelum	2010	8,249	176,000	1,452	10
Kotli	2017	63,001	774,194	48,775	1
Mirpur	2017	52,673	456,200	24,030	2
Bhimber	2017	50,201	420,624	21,116	3
Muzaffarabad	2017	33,092	650,371	21,522	4
Jhelum Valley	2017	29,799	230,529	6,870	5
Poonch	2017	24,783	500,571	12,406	6
Bagh	2017	22,941	371,919	8,532	7
Sudhnoti	2017	18,389	297,584	5,472	8
Haveli	2017	12,673	152,124	1,928	9
Neelum	2017	9,817	191,251	1,878	10
Mirpur	2020	85,408	480,204	41,013	1
Kotli	2020	58,237	814,221	47,418	2
Bhimber	2020	51,351	441,100	22,651	3
Muzaffarabad	2020	18,744	691,482	12,961	4
Jhelum Valley	2020	14,988	237,894	3,566	5
Bagh	2020	12,336	394,590	4,867	6
Poonch	2020	9,490	518,845	4,924	7
Haveli	2020	6,941	152,590	1,059	8
Neelum	2020	6,666	202,522	1,350	9
Sudhnoti	2020	6,400	311,559	1,994	10

Source: Author's Calculation

Heatmaps showing district ranking on the basis of their per-capita GDP and the overall size of economy are shown in figures 8 and 9 respectively.

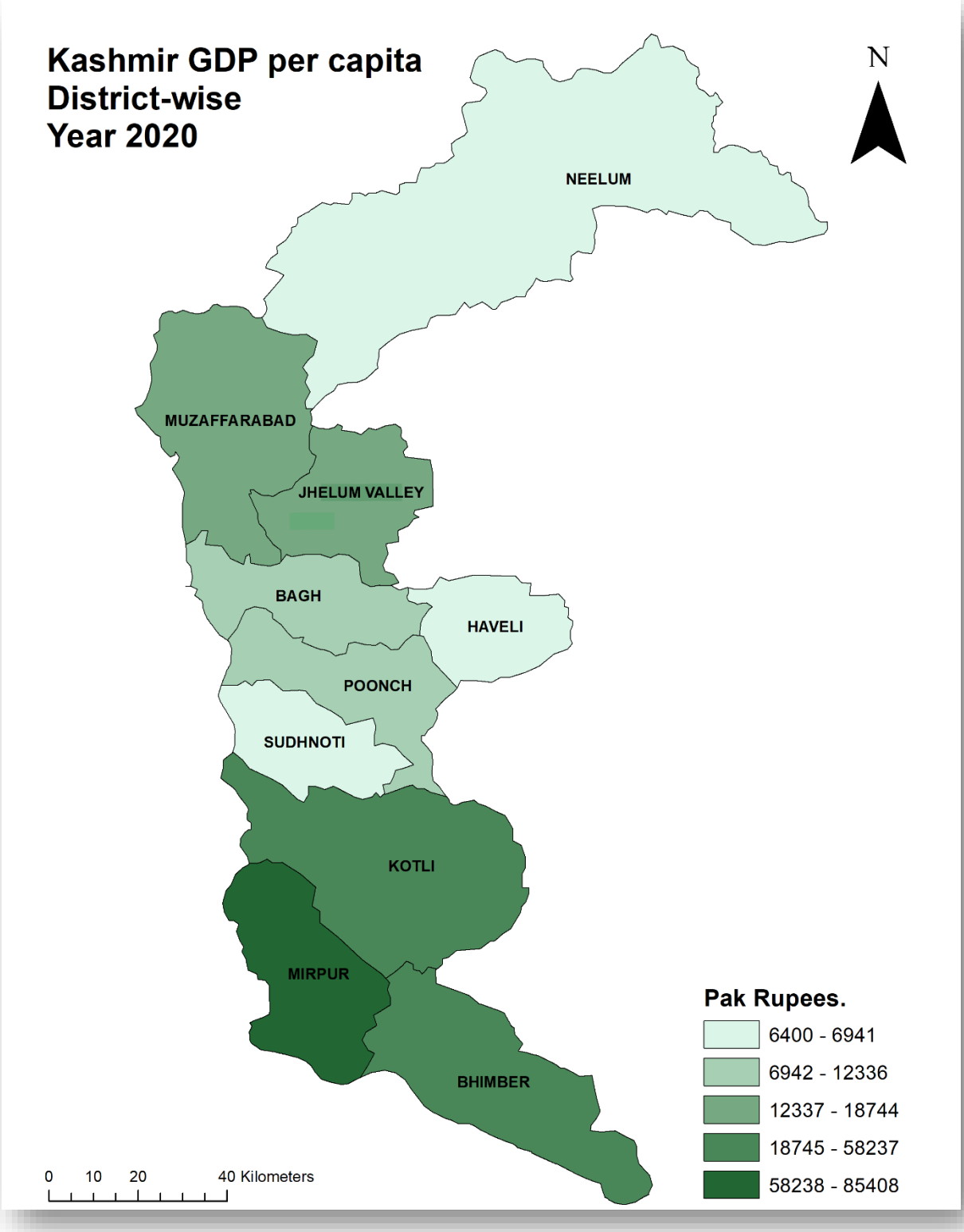


Figure 9: Heatmap of District Economic Ranking on Per Capita Basis

*Note: The Hattian district has recently been renamed as Jhelum Valley

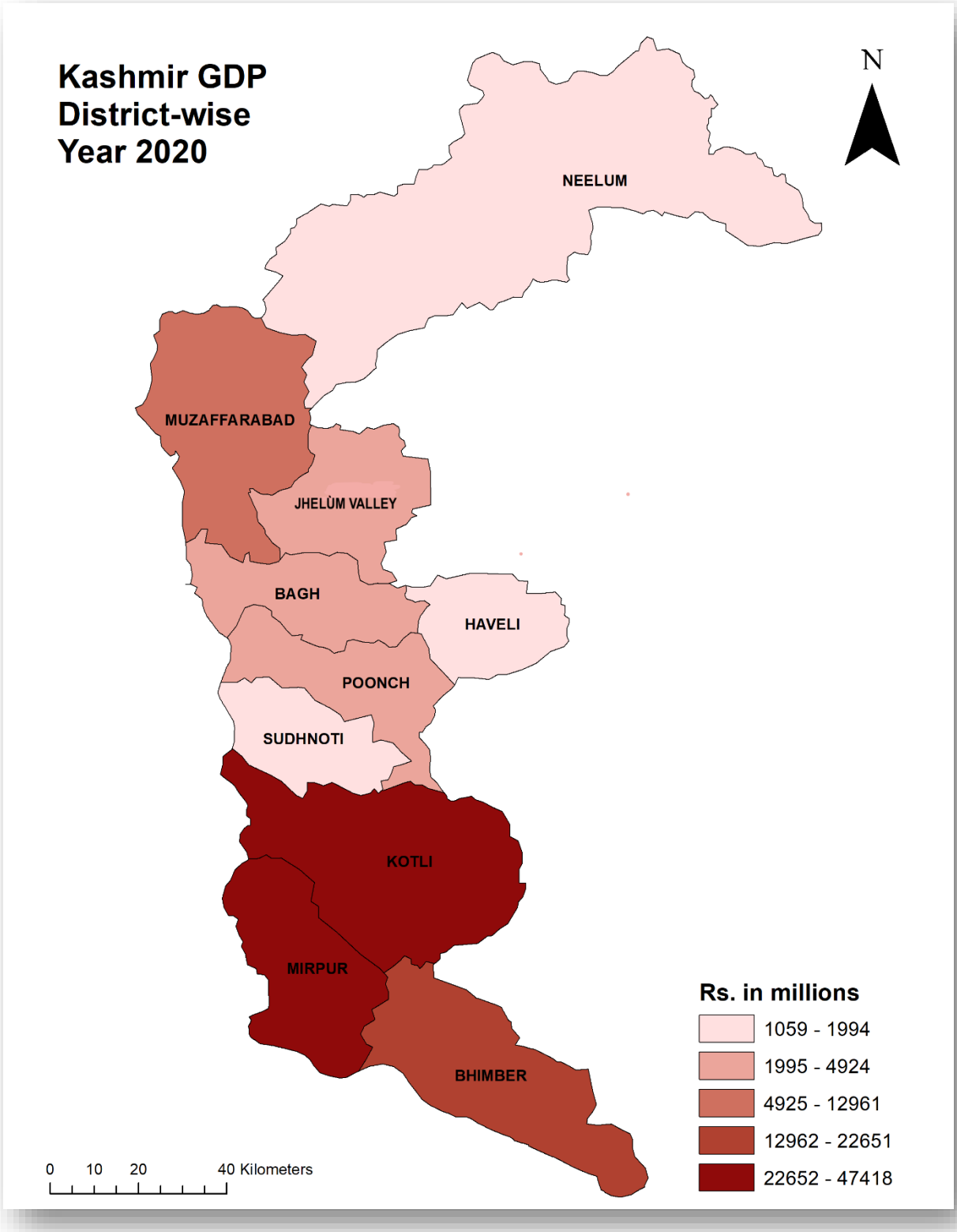


Figure 10: Heatmap of District Economic Ranking on Total GDP Basis (Constant Base Prices 2005-06)

*Note: The Hattian district has recently been renamed as Jhelum Valley

7.2. Extracting cities or urban areas

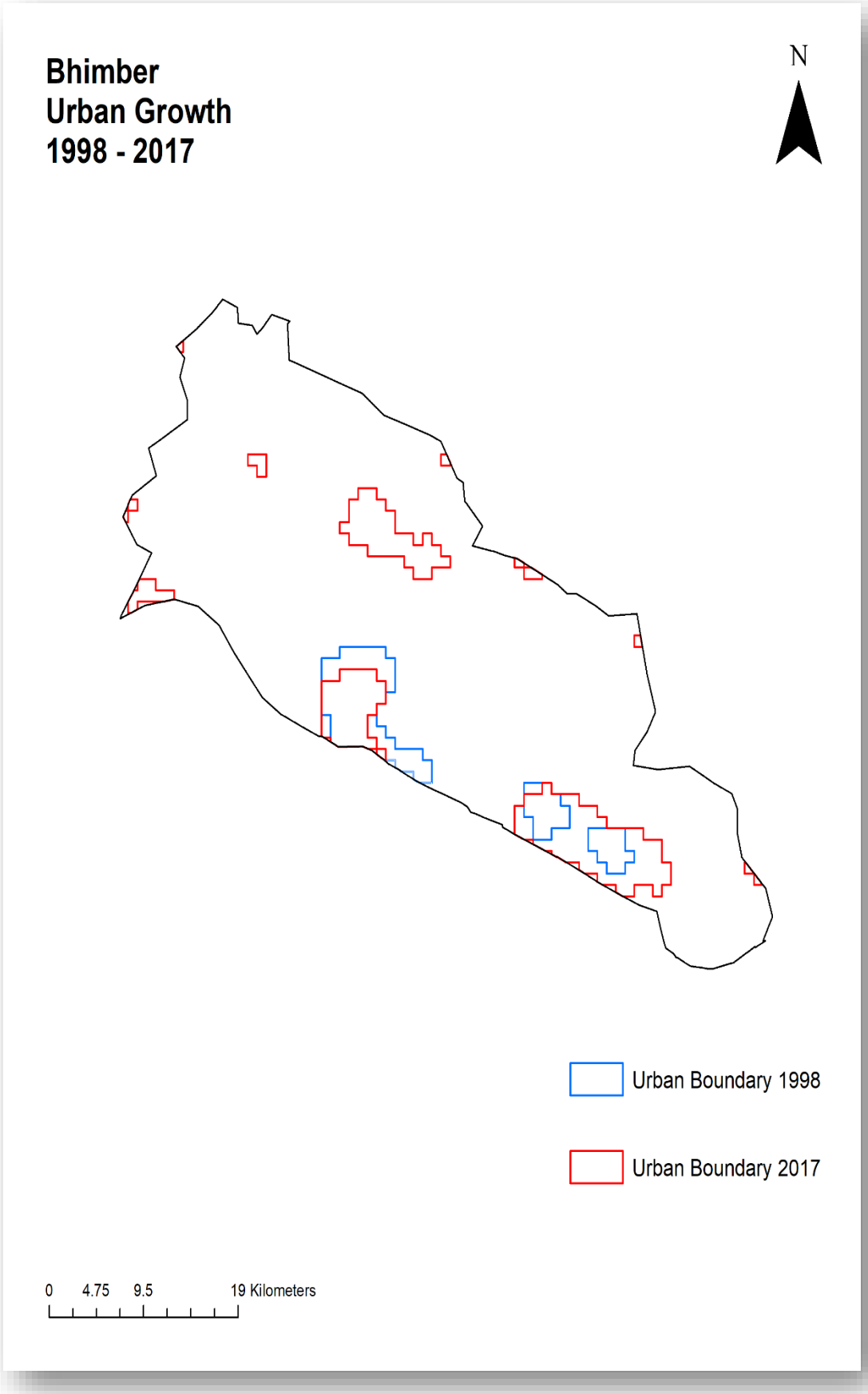
The utility of satellite data is not just limited to the study of the size and growth of economic activity. Another important application of such a novel dataset is related to extraction of geographical boundaries of areas i.e., urban boundaries of districts, etc. considered important concerning various social-economic roles they perform in a larger system of cities. Previously applied methodologies in the literature differ on some levels but all boil down to inferring the spatial extent of an area from the spatial extent of lights emitted at night.

To determine the extent of urban markets, we attempted two methods namely the Brightness Gradient and Quantile Plot approaches. Both methods use inter-temporal variation in urban areas as detected by nightlights to indicate the quantum and the direction of the city growth. The Brightness Gradient method, however, did not yield correct results as for most of the urban areas in the AJ&K region the level of urbanization is very low and hence the variation of NTL at the urban-rural boundary is difficult to capture. We place the Brightness Gradient method details and some results in the Appendix C. The Quantile Plots of the NTL as discussed earlier is our second approach. This method yields robust results about the location and direction of urban growth that can be verified through Google Maps also. The results for the method are reported below:

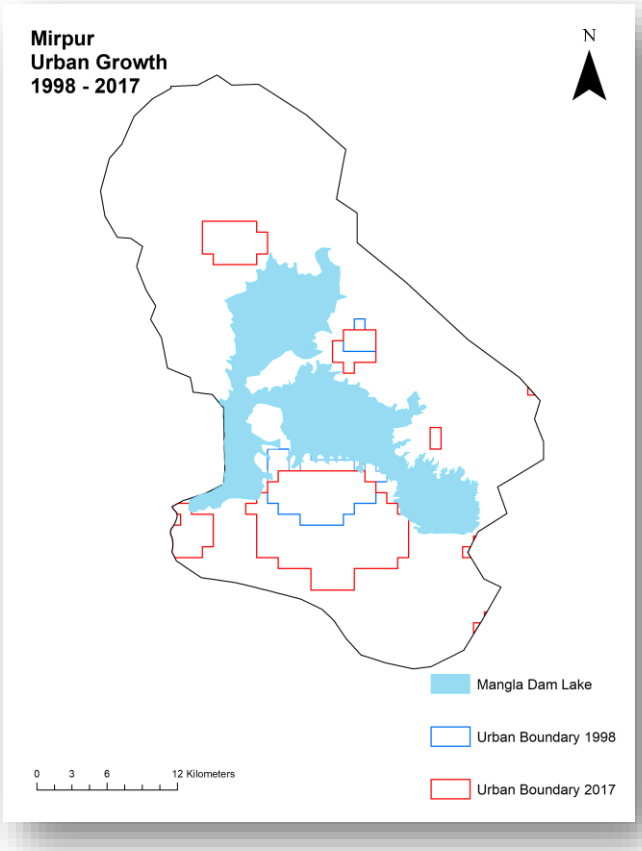
Table 16: Urban Growth Trend- AJK Districts

District	Urban Pixels 1998	Urban Pixels 2017	Total District Pixels	Urban Area Share 1998 %	Urban Area Share 2017 %	Percentage Difference
Bagh	27	63	847	3.19	7.44	4.25
Bhimber	103	188	1658	6.21	11.34	5.13
Jhelum Valley	213	165	812	26.23	20.32	-5.91
Haveli		51	578	0.00	8.82	8.82
Kotli	83	213	2252	3.69	9.46	5.77
Mirpur	76	170	1007	7.55	16.88	9.33
Muzaffarabad	85	144	1654	5.14	8.71	3.57
Neelum	219	26	4413	4.96	0.59	-4.37
Poonch	37	84	978	3.78	8.59	4.81
Sudhnoti	24	33	799	3.00	4.13	1.13

Source: Author's Calculation. NB: Each NTL pixel is around 1 square-km


Bhimber
Urban Growth
1998 - 2017
N
Urban Boundary 1998
Urban Boundary 2017
0 4.75 9.5 19 Kilometers

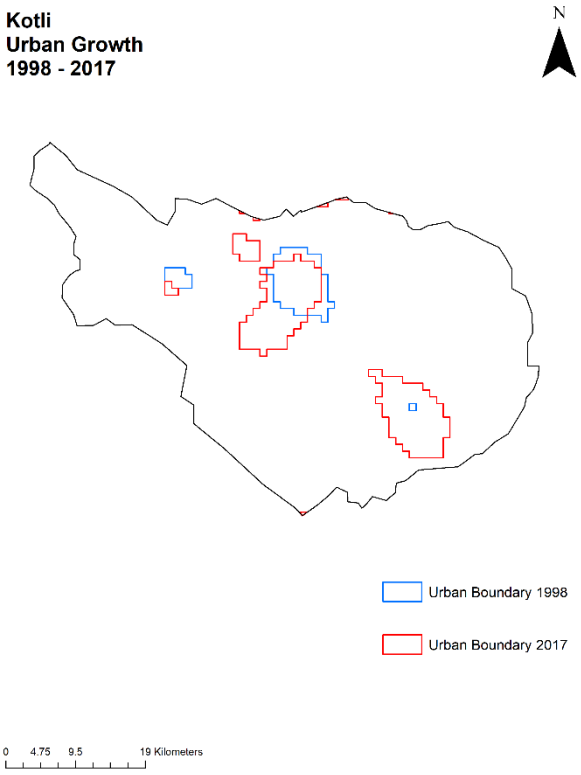
(a)



(b)

Figure 11: Urban Growth Trend in Selected Districts

(a)



(b)

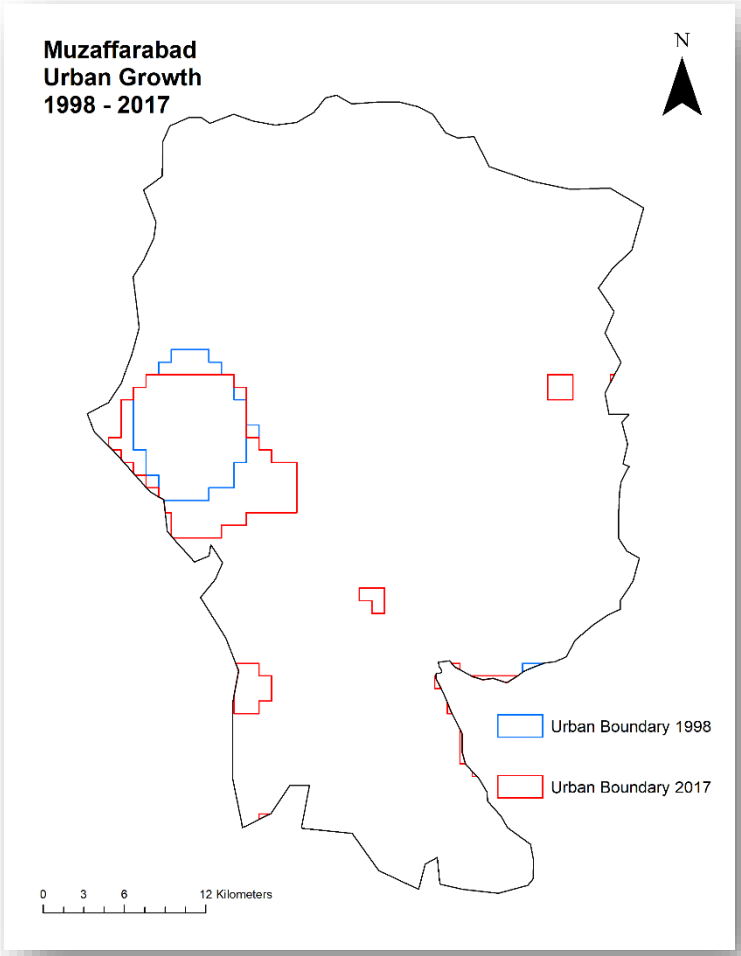


Figure 12: Urban Growth Trend in Selected Districts

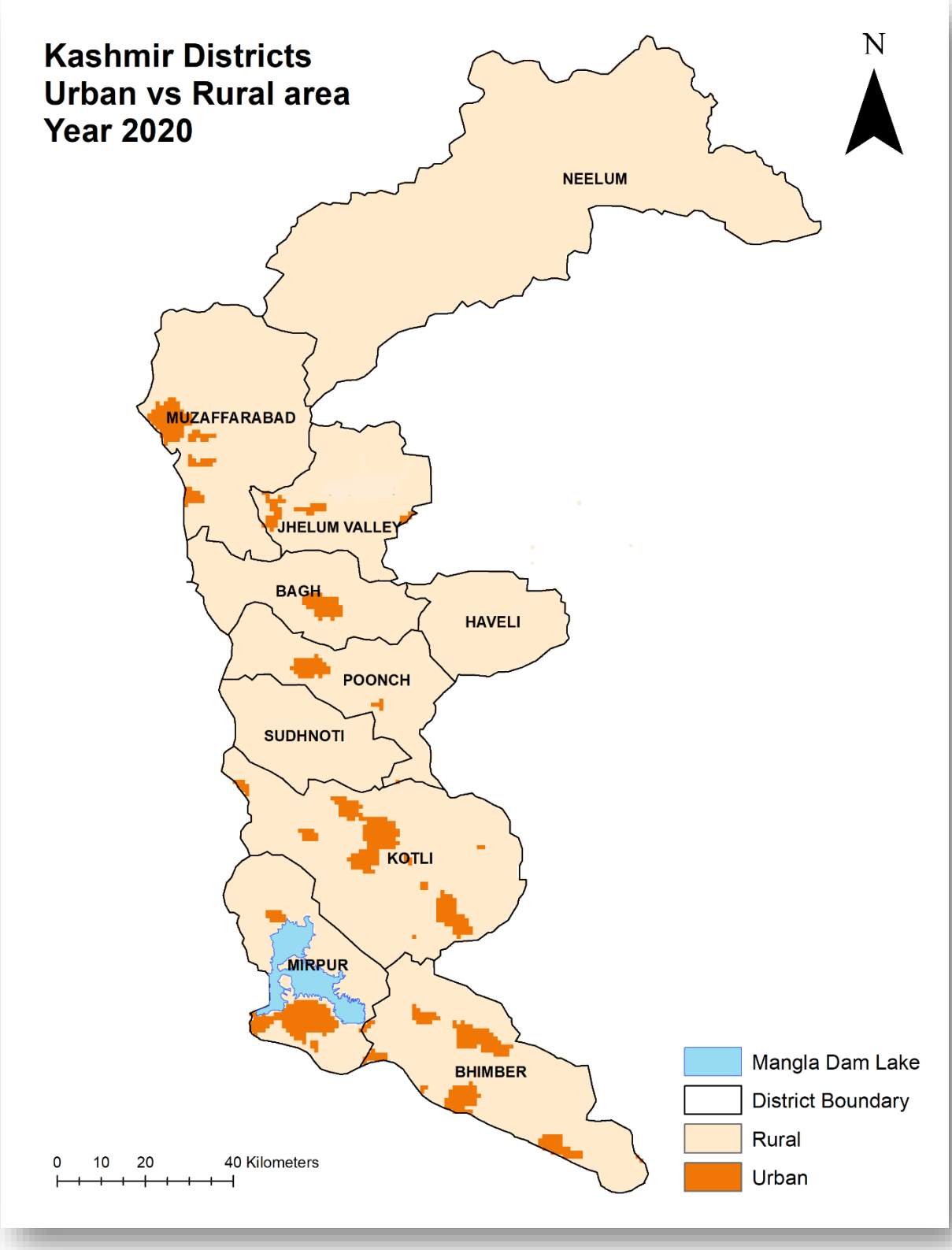


Figure 13: Urban Growth Using Quantile Approach

*Note: The Hattian district has recently been renamed as Jhelum Valley

7.2.1. NTL Quantile Plot Method

The growth of urban areas in the districts of AJ&K is reported in the table 16. As can be seen that except two districts of Jhelum Valley and Neelum we observe positive growth in all districts of AJ&K. The maximum increase in share of urban area is in case of Mirpur and the smallest is in the case of Sudhnoti. Figures 10 and 11 show the direction of urban growth for the selected districts of Bhimber, Mirpur, Kotli and Muzaffarabad. Overall urban settlements in AJ&K in 2020 are shown in figure 12. Finally, it must be noted that the negative urban growth for the districts of Jhelum Valley and Neelum and percentage growth in other districts should not be compared with census figures rates as the two ways of measuring urban growth are based on different definitions.

7.3. Limitations

The fact that no estimate for the economic output of AJ&K region had ever been undertaken and the national accounts of Pakistan do not report the economic contribution of the region posed a considerable challenge in estimation of the region's GDP and the contribution of its districts.

The limitations posed by non-availability of data on economic indicators related to industrial output and the services sector further constrains the possibility of using conventional methods for GDP estimation.

Finally, the differences in cropland area data as collected through official channels and the one captured by satellite imagery further limited the use of alternate methodologies in estimation of regional economic output.

8. References

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9. Appendix A

Percentage Literacy (Can Read and Write in any language)

District	Male	Female	Total
Muzaffarabad (Rural)	69.6	45.3	57.1
Muzaffarabad (Urban)	83.5	65.5	74.8
Poonch (Rural)	84.2	65.1	74.5
Poonch (Urban)	83.9	71.1	77.4
Mirpur (Rural)	81.4	67.7	74.4
Mirpur (Urban)	79.6	69.1	74.4
Total	80	62.6	71.2

Source: LFS 2017-18

	Muzaffarabad		Poonch		Mirpur		AJ&K
Education Level	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	22.3
No formal education	34.2	17.1	20.2	15.9	19.6	18.3	4
Nursery but below KG	6.2	3.4	3.4	2.8	3.7	3.6	11.4
KG but below primary	13.3	9.8	12	8.1	11	9.9	17.2
Primary but below middle	17.7	14.1	18.1	14.2	17.6	14.5	17.4
Middle but below matric	11.8	13.3	19.3	20	19.4	18.1	14.9
Matric but below intermediate	9.4	16.9	17.4	17.6	15	16.3	6.3
Inter but below degree	3.9	10.7	5.1	8.9	7.2	8.5	0.2
Degree in engineering	0.2	0.4	0.1	0.2	0.1	0.3	0.1
Degree in medicine	0.1	0.3	0	0.1	0.1	0.3	0
Degree in computer	0.1	0.1	0	0	0	0	0
Degree in agriculture	0	0	0	0	0	0	3.9
Degree in other subjects	1.7	7.9	3.1	8	4.2	5.6	2.1
MA/MSc	1.5	5.2	1.3	3.9	1.9	4.1	0.1
MPhil	0	0.8	0	0.3	0.1	0.3	22.3

10. Appendix B

Table 17: Difference between MODIS and Official Statistics- Cropland

Landcover Type for AJK Districts	Cropland Area MODIS (hectares)	Cropland Area Official (hectares)	Difference %
Muzaffarabad	21875.08	53278.77	143.559201
Neelum	205710.9	14438.79	-92.981028
Jhelum Valley	9498.198	21635.57	127.78605
Bagh	5895.21	34741.31	489.314206
Haveli	18093.36	18913.7	4.53392847
Poonch/Rawalakot	5491.948	42719.51	677.857146
Sudhnoti	11731.73	36481.06	210.960617
Kotli	107000	95822.79	-10.445991
Mirpur	69162.46	28373.25	-58.975939
Bhimber	121166.2	56466.01	-53.397887
Total/overall	**575625.086**	**402870.76**	**1435.59201**

11. Appendix C

To depict the pixel-level fluctuations of night-time light (NTL) across human settlements, we use the brightness gradient (BG) method proposed by Ma et al. (2015) to measure spatial changes in artificial night-time lighting signals. BG is defined as the rate of maximum change in NTL from the site to its neighbors (rise) across the corresponding geographical span (run). Thus, the output BG can be calculated as:

$$BG = \frac{NTL\ Rise}{Geographical\ Run} \quad (5)$$

For gridded NTL, the pixel-level BG is regarded as a measure of the maximum change in NTL over one-pixel size between the grid cell and its neighbor cells. Ma et al. (2015) use the average maximum technique (Burrough &McDonell, 1998) to calculate BG for each grid cell. This algorithm applies weighting coefficients that are proportional to the reciprocal of the square of the distance from the processing grid cell for the nearer NTL values. Mathematically, the pixel-level BG for a pixel with reference to its neighboring pixels can be estimated by using the rates of change of NTL in the horizontal (dNTL/dx) and vertical (dNTL/dy) directions from the central grid cell to its eight adjacent grid cells as follows:

$$BG = \sqrt{(\frac{dNTL}{dx})^2 + (\frac{dNTL}{dy})^2} \quad (6)$$

Ma et al. (2015) analyze the brightness gradient across the Chinese city Huainan for 2012. The intra-urban comparisons reveal that grid cells with low BG values are likely to be found in both the central region of the urban area with intensified human activity and high NTL and the rural region with less human activity and low NTL. In contrast grid cells with high BG values commonly appear in the urban-rural transition zone with medium NTL.

The authors further find that the quantitative relationship between BG and NTL is not linear for cities that are not small, isolated, and circular and there is a wide range of brightness gradients associated with the brightest and dimmest pixels. Therefore, the relationship between the pixel-level NTL and BG for a given city can be fitted by a quadratic polynomial:

$$BG = aNTL^2 + bNTL + c \quad (7)$$

where a, b and c represent fitting coefficients. To examine the prevalence of this statistical relationship, we performed quadratic regressions for the pixel-level NTL and BG at a local urban scale using the least-squares method. The results indicate that the quadratic relation is valid for large cities where there is considerable core urban area but does not represent the correct model for smaller cities with scattered urbanization. As such we shall apply the

threshold method to the top eight urban districts but restrict the BG approach to three/four districts where robust quadratic relationships between the pixel-level NTL and BG across KP districts allow us to quantitatively classify the urban area according to conspicuous differences in NTL at a local scale.

For the BG approach, following Ma et al. (2015) we spatially subdivide a city into five different sub-regions involving: low (night-time lights range from NTL_0 to NTL_1), medium-low (fromNTL_1 to NTL_2), medium (from NTL_2 toNTL_3), medium-high (from NTL_3 to NTL_4) and high (from NTL_4 to NTL_5) night-time lighting areas as shown in figure 13. The turning point of the parabola in which the maximum BG and medium NTL, typically occur in the transition zone of urban area and suburban.

This methodology implies that for a given city with a significant quadratic relationship between pixel-level night-time light and spatial brightness gradient, the partition intervals for night-time light imagery are determined by the range of NTL and the fitted coefficients of the quadratic function. This also means that no empirical threshold and parameterization of the split points are required for partitioning night-time light imagery across different cities. Moreover, the primary advantage of the quadratic curve-based partitioning method for DMSP/OLS night-time light imagery is that it reduces the impacts of various urban development patterns because the partition method is based upon the relative quantitative relationship between the pixel-level NTL and BG at a local scale. BG methodology shall be limited to three large districts of Muzaffarabad, Mirpur and Kotli.

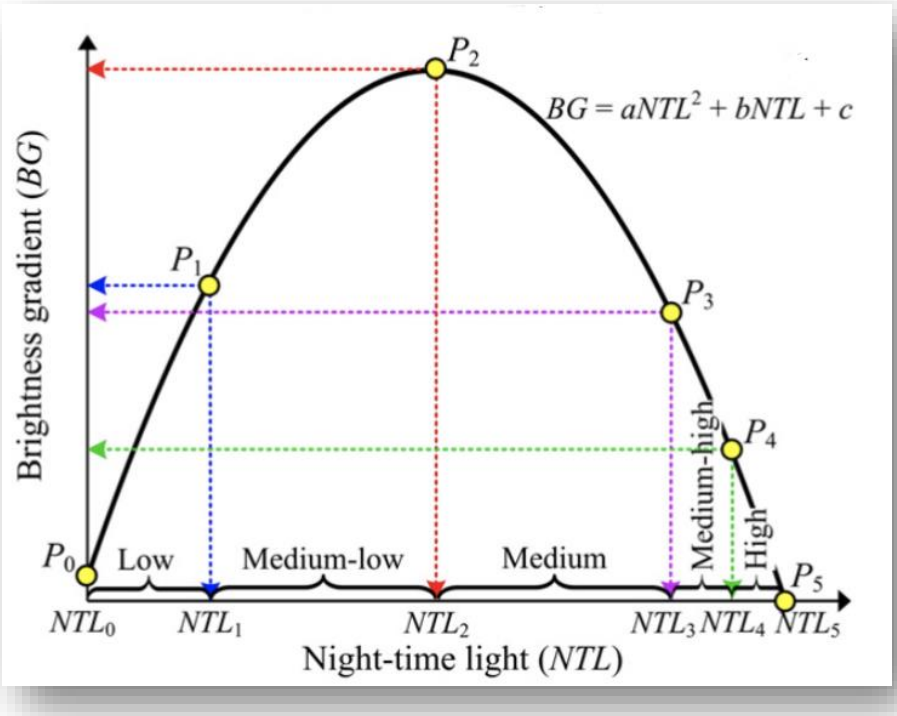
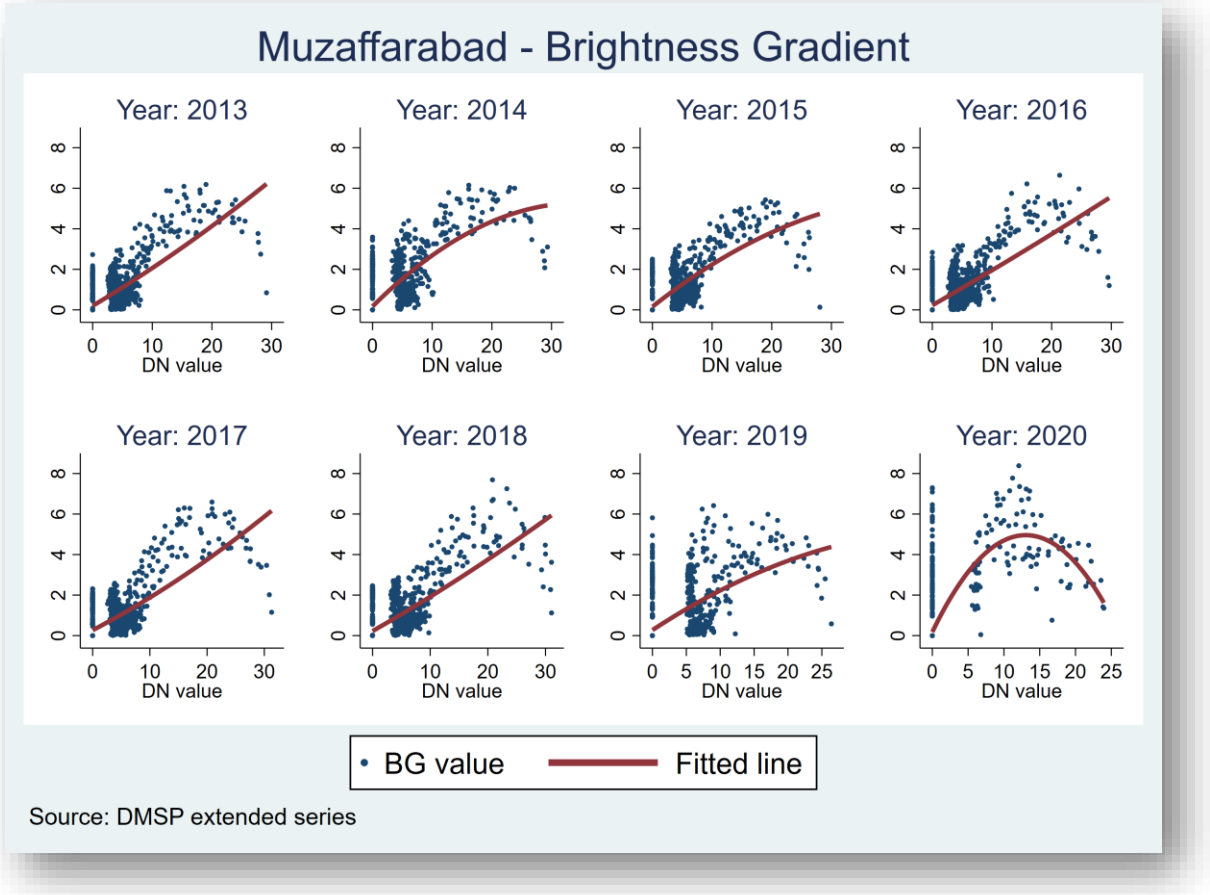


Figure 14:Sub-region Partitioning based on the Quadratic Model Source: Ma et al. (2015)

The BG method works best in case of large cities where we are able to generate a gradient plot similar to one shown in figure 13. However, as the city sizes are typically small in case of AJ&K, we are not able get similar plots as shown in figure 14. We therefore use the NTL quantile plots as discussed earlier and indicate growth of urban areas in all districts of AJ&K over the period 1998-2017.



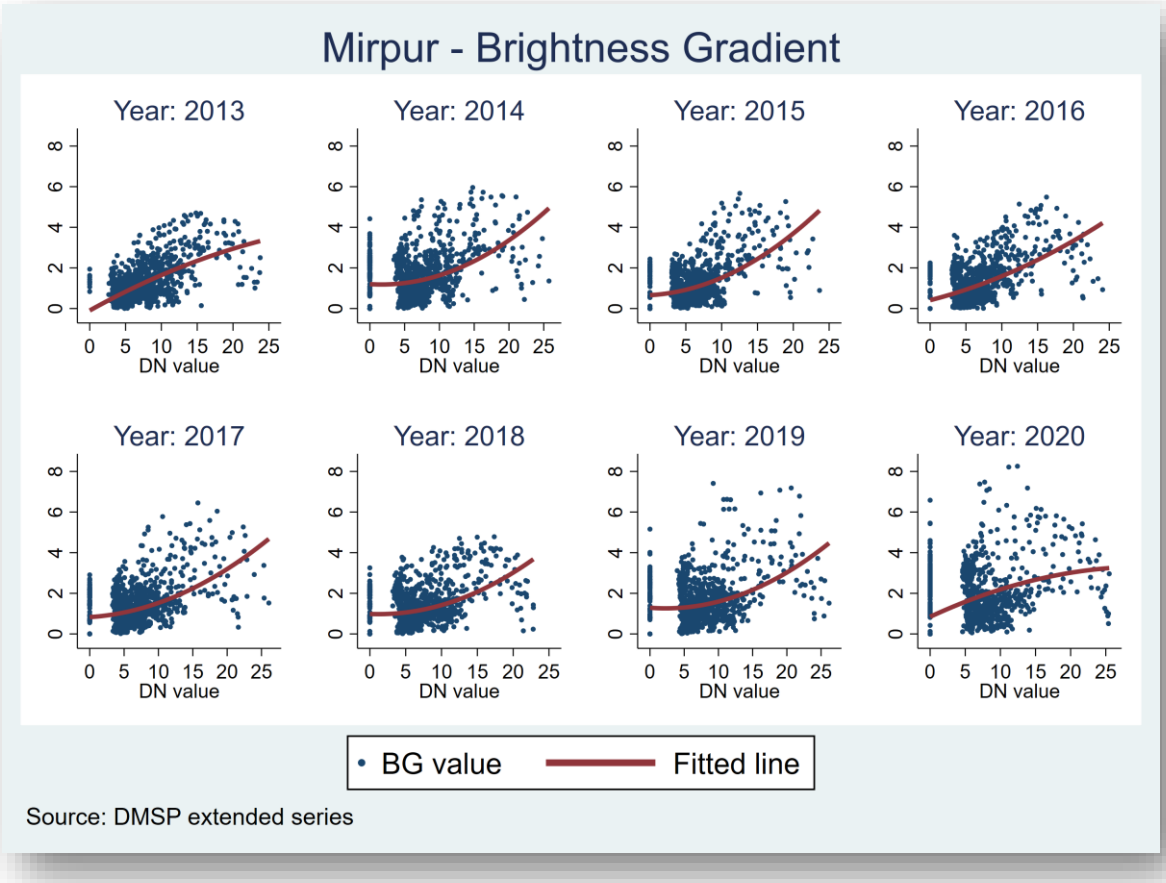


Figure 15: Brightness Gradient Plots for Muzaffarabad and Mirpur Districts (2013-2020)

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