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Preface

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Preface

World urban demographics in 2019 have recorded that 55.7% of the world's population lives in urban areas, of which 57% are in Asia. As the fourth largest population globally, Indonesia has 55.2% of the urban population and still faces uneven population distribution. Some cities are recorded with a density of more than 10,000 people / km2. In some areas, the buildings are very dense and unstructured. Moreover, the lack of proper land-use planning also leads to urban slums. The trend of rising local temperatures in various metropolitan cities with high density has led to urban heat islands' formation. This is exacerbated by the lack of urban hazard mitigation instruments involving regional regulations such as zoning and land use. Population growth that increases vulnerability and exposure to the effects of climate change will cause cities to suffer heavy losses.

Sustainable, Environment and Architecture (SENVAR) is an annual conference that offered the platform to share the idea, research, and study of urban environmental changes. In 2020, SENVAR held its 20th conference, which was also known as SENVAR20. With the theme of "Urban Retrofitting: Building, Cities, and Communities in the Disruptive Era," SENVAR20 provided a link between the spatial and socio-economic aspects of the urban environment to mitigate the hazards of the vulnerability of the urban environment. This conference facilitated scholars, researchers, practitioners, decision-makers, students, and stakeholders, as well as city activists, to collaborate in an integrated discussion. Organized by Universitas Pendidikan Indonesia (UPI), the conference was supported by The Ministry of Research and Technology / BRIN and the International Building Performance Simulation Association- Indonesia Chapter (IBPSA-ID).

Originally, SENVAR20 was planned to be held in Bandung, Indonesia, where UPI, as the organizers' institution, was located. However, due to the COVID19 pandemic precautions and the government's travel restrictions in many countries, SENVAR20 was held virtually instead. We decided to carry out the conference instead of postponing it because the pandemic opened the opportunity for the conference participants to discuss how the pandemic is affecting the sustainable built environment and vice versa. It became the starting point for the community to adjust and respond to the recent pressing issues and the new normal caused by the pandemic.

SENVAR20 was conducted virtually on November 10, 2020, using the Zoom Conference platform. It was also being broadcasted live via the UPI Department of Architectural Education's YouTube Channel and Facebook. Despite being held online to avoid face-to-face encounters, the conference managed to gather 270 participants from 14 countries: Indonesia, the UAE, the USA, Malaysia, Thailand, Argentina, Japan, Australia, Germany, India, Turkey, Vietnam, Bangladesh, and Korea. As the conference was conducted virtually, we managed to deliver the conference efficiently in a timely manner. To make the most of our time, we provided 12 breakout rooms divided according to conference topics. All authors and presenters were given equal opportunity in the plenary session to present their ideas by using 10 minutes pre-recorded video in the zoom's breakout rooms. It was then followed by live discussions/QnA sessions moderated by appointed scholars from various institutions and expertise. To our delight, being separated by space and time differences did not deter the participants from being actively engaged in the discussion.

Considering SENVAR20 being the first SENVAR Conference held virtually, it was successfully conducted due to the cooperation and enthusiasm of all parties involved. Therefore, we would like to sincerely thank the authors, reviewers, participants, and the team of organizers who have contributed to the success of SENVAR20.

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Peer review declaration

All papers published in this volume of IOP Conference Series: Earth and Environmental Science have been peer reviewed through processes administered by the Editors. Reviews were conducted by expert referees to the professional and scientific standards expected of a proceedings journal published by IOP Publishing.

- **Type of peer review:** Double-blind
- **Conference submission management system:** http://senvar.event.upi.edu/form
- **Number of submissions received:** 120 articles
- **Number of submissions sent for review:** 82 articles
- **Number of submissions accepted:** 80 articles
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- **Average number of reviews per paper:** 2 review
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Drought hazard assessment in urban areas: A case of Bantul Regency, Special Region of Yogyakarta

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Drought hazard assessment in urban areas: A case of Bantul Regency, Special Region of Yogyakarta

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Abstract. Drought has a significant impact on many sectors. Urban areas also have tended to more vulnerable to the drought events since it consists of complex urban systems and high urban population. This study addresses to assess the drought hazard level in Bantul Regency and compares the results with urban development. This study used both primary and secondary data collection methods, i.e., field observation and document review. Precipitation data collected from 12 rainfall stations in Bantul Regency from 2008-2018. This study was conducted by using quantitative research methods. Drought hazard levels were analyzed using the Standardized Precipitation Index (SPI) method. While urbanization levels were assessed using a scoring technique. The results reveal that the drought hazard is not always in line with urban development but is also influenced by other factors. Drought in urban areas is more complex. It is not only affected by precipitation factors as meteorological drought in general, but also natural, population, and activity characteristics that affect the balance of water supply and demand. Further, the distribution of rainfall stations also influences the validity of rain data and its calculations. Drought disaster mitigation in urban areas requires more attention from stakeholders regarding the sustainability of cities.

1. Introduction

Drought is one of the natural hazards that frequently occur in many regions. It possibly occurs in both high and low precipitation areas. Even though drought is not as physically devastating as other natural hazards, it costlier and affects a wide range of many sectors, i.e.,

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environment, economic, and social [1]–[3]. Some studies highlight that drought is a natural hazard that has multiple impacts than other natural hazards, such as agriculture [4]–[6], water demand and supply [5], [7], food production [5], [8], [9], as well as socio-economic impacts [10], [11].

El Nino is one of the causes of drought in Asian countries. It causes changes in the rainfall pattern and intensity as well as results in catastrophic events, such as droughts and flooding. Urban areas as the space for population concentrations and various activities may alter the microclimate, which affects temperature and wind conditions [12].

Drought is interpreted in various ways. Drought is a natural occurrence associated with low precipitation in the period of months to years [13]. Since drought affects many sectors, the definition of drought is adjusted to the region and activity [1], [14]. Wilhite & Glantz [1] classified the drought definition as a conceptual and operational definition. Conceptually, drought is related to a long period with no rain. It correlates with a physical process, for example, lack of soil moisture, shortage of precipitation, and water shortage. Meanwhile, in operational definition, drought is analyzed based on frequency, severity, and duration by using historical data. The operational definition is commonly used to calculate the probability of drought. Further, Wilhite & Glantz [1] is also categorized drought into four types they are meteorological, agricultural, hydrological, and socioeconomic drought. Meteorological drought often uses as the initial phase of drought hazard since it relates to low precipitation as the main indicator of drought. Meanwhile, socioeconomic drought is associated with the water shortfall whose impact influence socioeconomic systems.

Drought severity is difficult to determine. It is influenced by the duration, intensity, and spatial characteristics [1], [15]. Furthermore, climate change exacerbates drought events. Climate change affects the hydrological process as well as decreases the precipitation in the dry season [3], [16]. It increases drought frequency, consequence, and duration [13], [16], [17]. Spatial and timing of drought influence the drought consequence. In a high-risk area, it is necessary to develop risk management systems by improving institutional function and adaptive capacity [15]. It also requires considering the severity, probability of occurrence, frequency, and duration of drought [17].

Urban areas are prone to natural hazards due to high population density, activity centers, and the concentration of many assets. Urbanization affects the rapid development of urban areas and exacerbates climate change. Several hazards that susceptible to occur in urban areas, such as drought, flooding, and heatwaves [18], [19]. Those hazards are commonly occurring as the climate change impact. However, drought, which is also associated with water scarcity, is likely severe due to climate change [19]. Climate change alters precipitation, which will affect the hydrological system. This condition will influence the urban water supply system and exacerbate the drought event [20]. Drought potentially affects water availability and triggers water scarcity, particularly in urban areas in line with the concentration of population [21]. At the same time, water is the crucial need to conduct many activities. Thus, drought management requires to notice of the risks of drought based on the estimated hazard and consequences of drought [20], [21].

This study was located in Bantul Regency. Bantul Regency is chosen as the study area since it is directly adjacent to Yogyakarta City and indicates growing rapidly due to

Yogyakarta City's growth and development. It causes the infiltration of urban characteristics to the Bantul Regency, particularly in the northern part, such as in Banguntapan, Sewon, Bantul, and Kasihan Sub-district. This condition can be identified by the high concentration of population and the percentage of built-up areas. These areas have a population growth rate of 1.37% or categorized as medium level and more than 60% built-up areas.

Bantul Regency is one of the disaster-prone areas in the Special Region of Yogyakarta Province. Bantul Regency is prone to both natural and non-natural disasters, i.e., floods, droughts, extreme weather, high waves and abrasion, earthquake, drought, landslide, forest and land fire, tsunami, and disease outbreaks [22]. On the other hand, the Regional Disaster Management Agency or *Badan Penanggulangan Bencana Daerah* (BPBD) of Bantul Regency [22] also showed that the disaster threat indexes in Bantul Regency are categorized as a high level. These disaster threat indexes can be analyzed by using the probability of occurrence as well as historical records of disasters. Drought is considered to have the highest disaster threat indexes compared to other disasters with the point of 0.799. It refers to the opportunity of occurrence, the magnitude of the impact, and the number of people exposed to drought hazards. BPBD also noted that the total area threatened by drought in Bantul Regency is 99.37%, with the percentage of the population exposed to high levels of 99.96% [22].

Bantul Regency is a district in Yogyakarta Province that has geographic, geological, hydrological, and demographic characteristics that potentially cause drought. Further, Bantul Regency is also growing rapidly as the impact of urbanization phenomena. Thus, this study aims to assess the drought hazard level from 2008-2018 in Bantul Regency and compares the results with urban development. To examine the drought hazards level, this study was conducted by analyzing the drought disaster index using precipitation data in Bantul Regency from 2008 to 2018. While assessing urban development, this study used some indicators to show the shifting of urbanization level in Bantul Regency from 2008 to 2018.

2. Methods

This study is located in Bantul Regency. Bantul Regency is located in the south of the Special Region of Yogyakarta Province. Geographically, Bantul Regency located at East Longitude 110º 12' 34" to 110º 31' 08" and South Latitude 7º 44' 4' to 8º 00' 27". Administratively, Bantul Regency consists of 17 sub-districts and 75 villages with a total area of ± 506.85 km^2. Figure 1 shows the administrative boundaries of the study area.

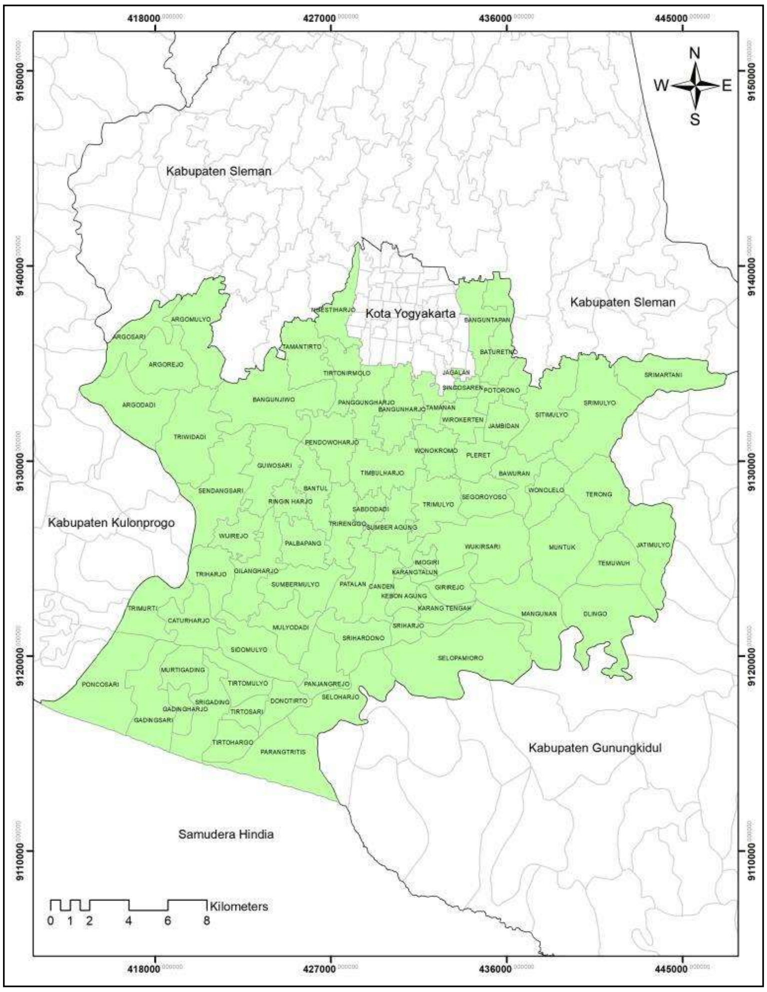


Figure 1. The study area of Bantul Regency

This study was conducted by using quantitative research methods since this study aims to assess the level of drought hazard and urbanization phenomena in Bantul Regency and analyzed by using scoring methods. Data was collected using both primary and secondary data collection methods. The primary data collection method was conducted by field observation to observe urban characteristics and drought events in Bantul Regency. While the secondary data collection method was performed with document review using precipitation data, i.e., rainfall data collected from 12 rainfall stations scattered over 17 sub-districts of Bantul Regency, Village Potential data (PODES), Book of Sub-district in Figure published by the Central Bureau of Statistics or *Badan Pusat Statistik* (BPS) of Bantul Regency year of 2009 and 2019, and various articles related to hazards in the study area.

This study used daily precipitation data from 2008-2018 from 12 rainfall stations in Bantul Regency, namely (a) Sta. Ringinharjo, (b) Sta. Nyemengan, (c) Sta. Gandok, (d) Sta. Kotagede, (e) Sta. Pundong, (f) Sta. Barongan, (g) Sta. Ngetal, (h) Sta. Kebonongan, (i) Sta. Piyungan, (j) Sta. Sedayu, (k) Sta. Ngestiharjo, and (l) Sta. Dlingo as shown in Figure 2.

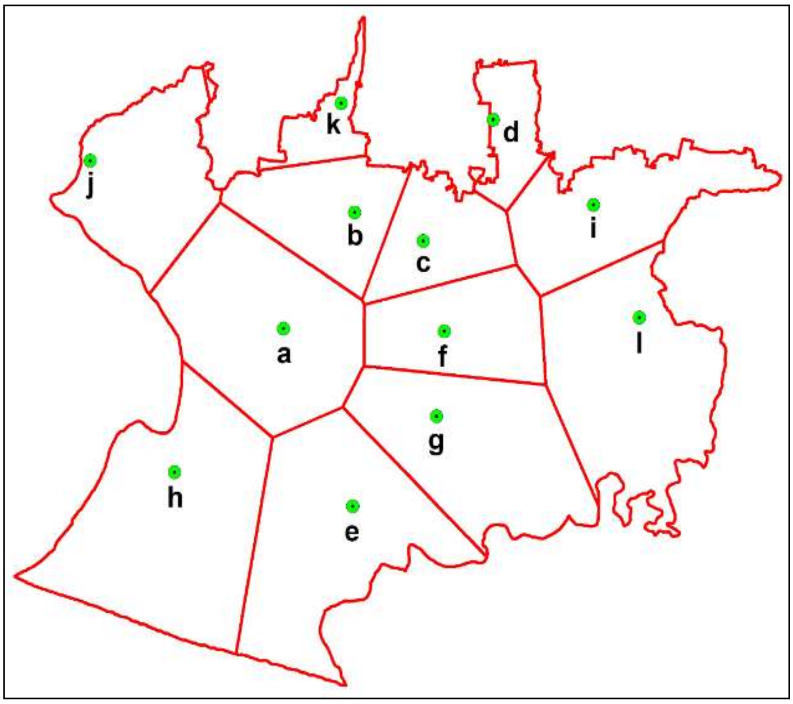


Figure 2. The location of 12 rainfall stations in Bantul Regency

As noted by Triatmodjo [23], the location of rainfall stations affects the measured amount of rain and likely to cause errors. Hence, it requires taking the consistency test to examine and verify the correctness of rain data. One of the methods that can be used is Rescaled Adjusted Partial Sums (RAPS). Precipitation data used in the consistency test is the annual precipitation data from each station.

The analysis was conducted in two steps. The first step aims to assess urban characteristics based on the level of urbanization using a scoring analysis technique. The indicators used are population density, percentage of built-up area, the availability of facilities (education and health facilities), the total of telephone users, and the electricity users. The total score of all indicators is summed, then normalized between ranges of 0-1 and classified into five classes. The classification of the urbanization level is shown in Table 1.

Table 1. The level of urbanization

Urbanization Level	Range
Very Slow	0 – 0.2
Slow	0.201 – 0.40
Medium	0.401 – 0.60
Quick	0.601 – 0.80
Very Quick	0.801 – 1.00

The second step purposes are to analyze the drought hazard level using the Drought Hazard Index (DHI). The steps to analyze the DHI are 1) Converting daily precipitation data to monthly and annual precipitation data for each rainfall station, 2) Calculating the consistency of annual precipitation data by using the RAPS method, 3) Calculating the drought index using Standardized Precipitation Index (SPI) Method, 4) Calculating the Drought Hazard Index (DHI) to determine the level of drought hazard, 5) Normalizing the results of the DHI value between ranges of 0-1, and 6) Classified into five classes of drought hazard.

In this study, the Standardized Precipitation Index (SPI) is used to calculate the drought index. The SPI is commonly used to analyze hazard index due to its simple to use. The SPI was developed by McKee et al. [24]. The SPI is widely used to measure drought and lack of rainfall for distinct timescales, i.e., 1, 3, 6, 9, 12, 24, and 48 months. This method also has a simple procedure and standardization as well as designed to have flexibility in location and time scale. The World Meteorological Organization (WMO) has also recommended SPI for droughts analysis [2]. SPI is a popular method to use globally. Many studies also have used SPI to analyze drought hazards, such as Shahid & Behrawan in Bangladesh [3], Dabanli in Turkey [11], Nasrollahi et al. in Iran [2], etc.

This study used a month timescale since this study uses the last ten years of precipitation data (2008-2018) as well as considering the socioeconomic impact flourishes on a longer temporal scale. The SPI-based drought classification is presented in Table 2.

Table 2. Drought level based on SPI

Drought Level	SPI
Extreme wet	SPI ≥ 2.00
Very wet	2.00 > SPI ≥ 1.50
Moderate wet	1.50 > SPI ≥ 1.00
Normal	1.00 > SPI ≥ -1.00
Moderate drought	-1.00 ≥ SPI ≥ -1.50
Severe drought	-1.50 ≥ SPI ≥ -2.00
Extreme drought	-2.00 ≥ SPI

Reference: [24]

Drought Hazard Index (DHI) is calculated based on its location through weighting and rating analysis based on the SPI value and the probability of occurrence (%). The Drought Hazard Score (DHS) results were obtained from multiplying between the weight value and the rating value results. The DHS is calculated for each SPI value from 2008-2018. To calculate DHI, the area contour map and DHS are multiplied. Then, DHI is normalized between ranges of 0-1, as shown in Table 3. The result of DHI is also figured in mapping to show the drought distribution spatially. Furthermore, the result of hazard analysis is also compared with urban characteristics.

Table 3. DHI level based on hazard index in Bantul Regency

DHI Level	Hazard Index
Very hazardous	> 0.91
Hazardous	0.66 – 0.90
Rather hazardous	0.30 – 0,65
Less hazardous	0.11 – 0,32
No hazardous	< 0.10

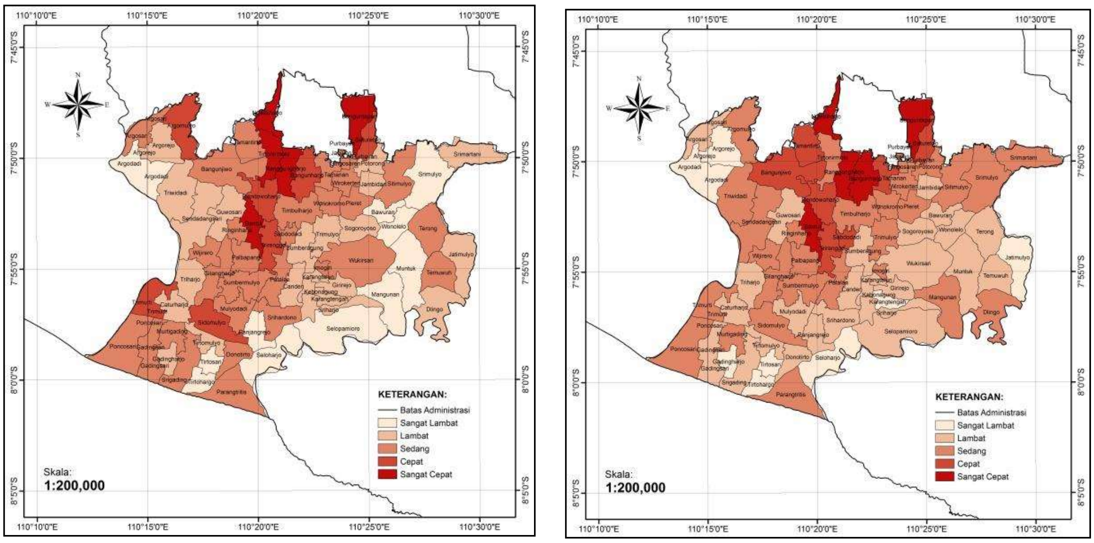
3. Finding and Discussion

3.1. Urban characteristics of Bantul Regency

Bantul Regency is one of the areas in the Special Region of Yogyakarta Province, which is affected by the development of Yogyakarta City. It can be observed from the growing population, population density, and non-agricultural characteristics in the Bantul Regency area, particularly those areas which is directly adjacent to Yogyakarta City. Based on the Central Bureau of Statistics (BPS) of Bantul Regency in 2019 [25], there are four sub-districts in Bantul Regency which have the highest population; they are Kasihan (129,233 people), Banguntapan (120,015 people), Sewon (117,200 people), and Bantul (63,678 people) Sub-district. At the same time, the areas with the highest annual population growth rate are Banguntapan (2.44%) and Kasihan (1.90%) Sub-district. Further, the areas with the highest population density are Banguntapan (5,125 people per km^2), Sewon (person per 4,315 km^2), Kasihan (person per 3,991 km^2), and Bantul (person per 2,901 km^2).

The urban development characteristics of the Bantul Regency were analyzed by calculating the urbanization level. Urbanization shows not only an increase in the number of the urban population, but also characteristics change of the population to be more urbanize in wide aspects, i.e., economic, social, political, and culture. As noted by Firman [26], urbanization has a wide and complex meaning because it includes many processes. Urbanization always occurs since it involves shifts and developments in socio-economic conditions.

In this study, five parameters are used to analyze urbanization that is population density, percentage of built-up area, the availability of facilities (education and health facilities), the total of telephone users, and the electricity users. This study compared the urbanization phenomenon in 2008 and 2018. Spatially, the figure urbanization level from 2008-2018 is shown in Figure 3.



(a) (b)

Figure 3. (a) Urbanization in 2008; (b) Urbanization in 2018

Based on the urbanization scoring analysis results, during the period of 10 years (2008-2018), there are 24 villages (32%) experienced an increase in urbanization. The increase in urbanization is caused by the increase in urban characteristics in 24 villages, both in terms of population density, use of built-in land, the availability of education and/ or health facilities, and the number of users of electricity and/ or telephone facilities.

The development of urban characteristics grows rapidly in four sub-districts, which are directly adjacent to Yogyakarta City; they are Banguntapan, Kasihan, Bantul, and Sewon. It is due to the urban characteristics infiltration of the Yogyakarta City as a trade and service area as well as supporting residential functions. The presence of a collector road network connected to the city of Yogyakarta also influences the development of those areas. However, nowadays, the urbanization phenomenon in Bantul Regency is more complex. The shift of the urbanization level is shown in Figure 4.

There have been significant developments in the suburbs, such as in the eastern part of Bantul, namely in Pleret, Imogiri, and Piyungan Sub-district. Based on the field observations, those areas are currently addressed as one of the locations for new residential development in the Bantul Regency. It potentially grows as a new magnet for the surrounding area. In the Piyungan Sub-district, 100% of villages have been experiencing urbanization. While in Pleret Sub-district, there are 60% of villages have been encountering rapid urbanization.

In the southeast and southern areas of Bantul Regency, such as in Dlingo, Imogiri, Srandakan, and Kretek Sub-district are also potentially developing into urban areas due to the existence of tourism activities that can encourage the development of physical, social, and economic conditions in those areas to be more urban. At the same time, the western region of the Bantul Regency tends to experience slow urbanization because it is still dominated by rural areas. However, the existence of a Yogyakarta International Airport may

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trigger the development of those areas through the development of road and housing infrastructures.

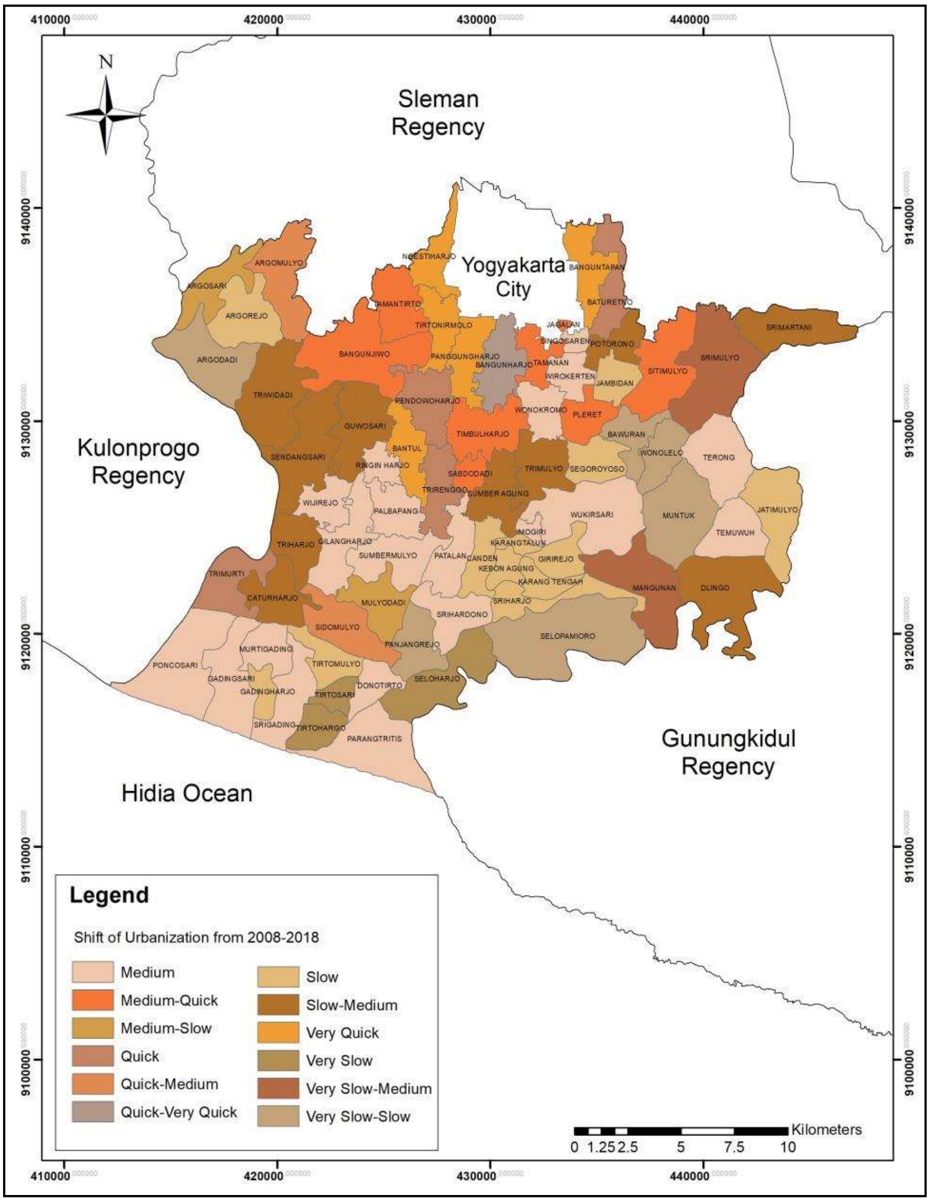
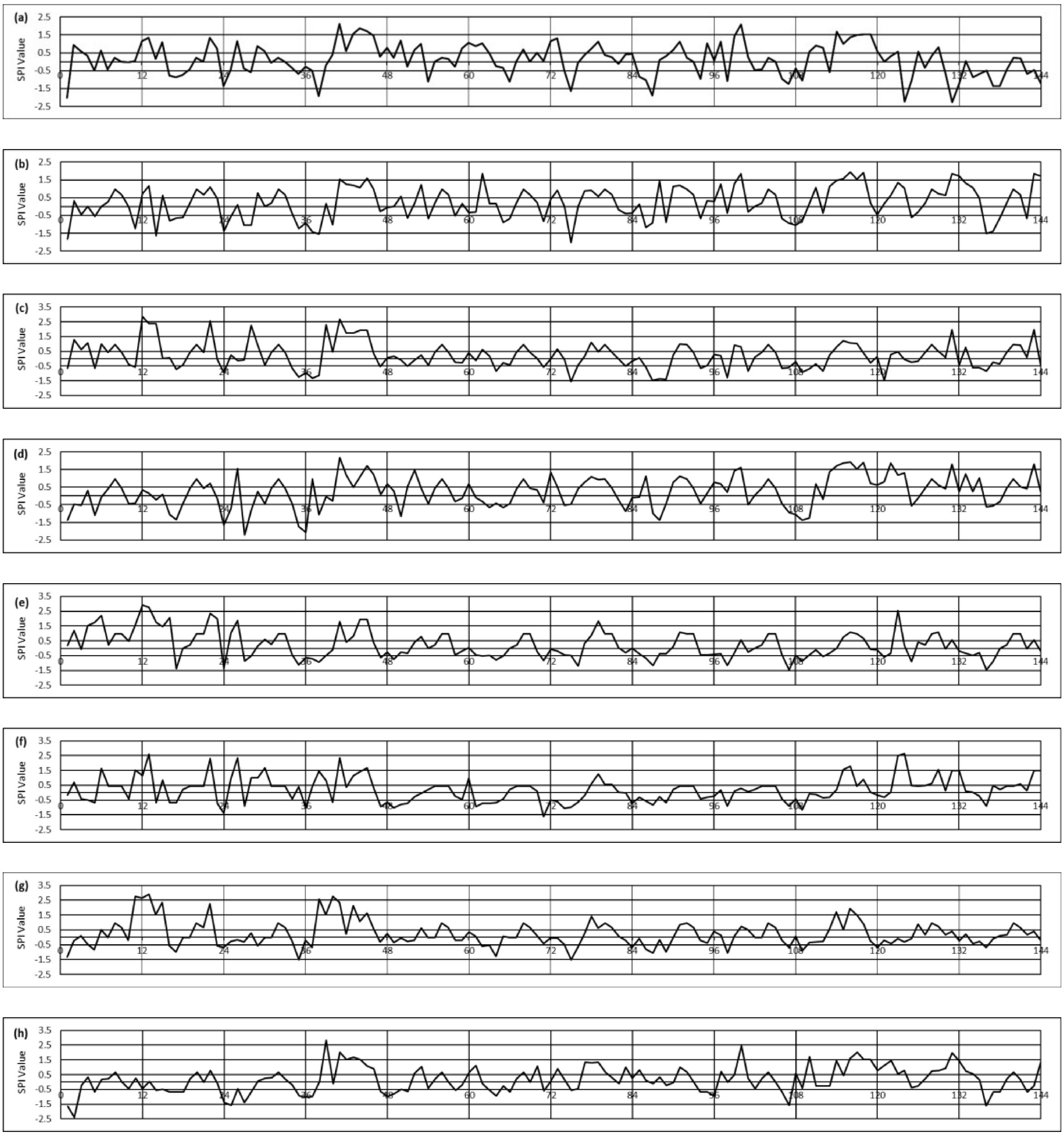


Figure 4. The shift of urbanization from 2008-2018 in Bantul Regency

3.2. Drought hazard analysis

Drought hazard analysis is calculated by using daily precipitation data collected from 12 rainfall stations in Bantul Regency. These data were analyzed using SPI. Figure 5 shows the dispersion of SPI in 12 rainfall stations in Bantul Regency. The SPI score tends to low in May to August since they have a long time of days without rain. Further, the location of rainfall stations is also affected the SPI score, as noted by Triatmodjo [23]. As the analysis results, SPI on Sta. Ngetal, Sta. Kebonongan, and Sta. Pundong has SPI score under normal (< -1.00).



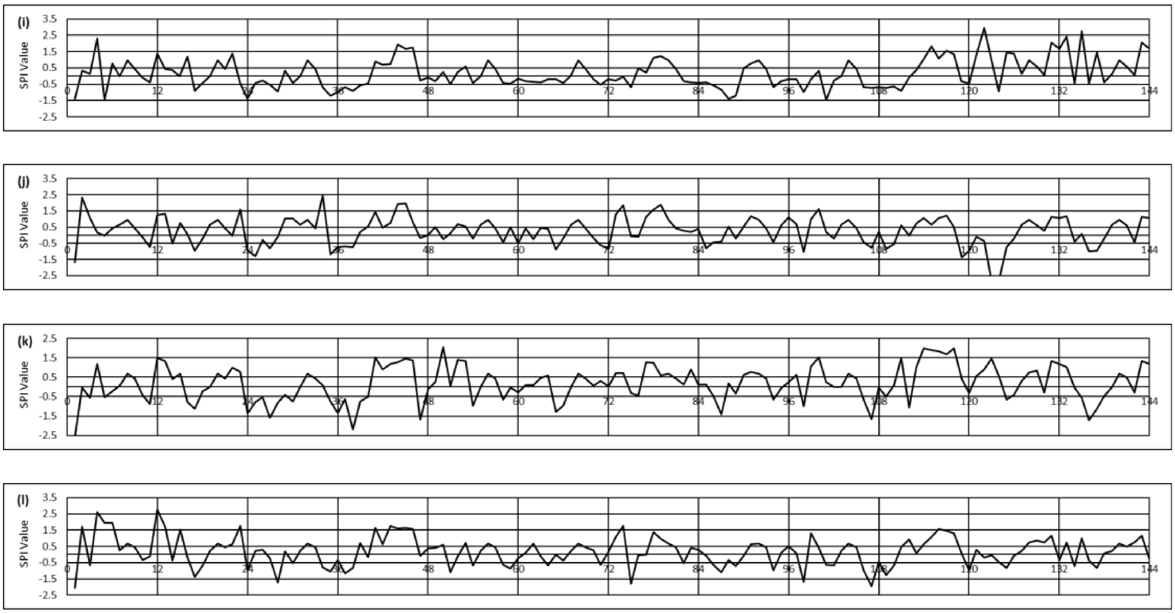


Figure 5. SPI-1 value for 12-year time series with monthly mean values of precipitation (a) Sta. Ringinharjo (b) Sta. Nyemengan (c) Sta. Gandok (d) Sta. Kotagede (e) Sta. Pundong (f) Sta. Barongan (g) Sta. Ngetal (h) Sta. Kebonongan (i) Sta. Piyungan (j) Sta. Sedayu (k) Sta. Ngestiharjo (l) Sta. Dlingo

Furthermore, after being analyzed by DHI, Figure 6 shows the results of the spatial mapping of drought hazard levels in Bantul Regency in 2008-2018. The results show that as many as 31 villages (41.33%) in Bantul Regency are classified as hazardous areas of drought. Meanwhile, 28 villages (37.33%) are classified as rather hazardous areas, 11 villages (14.67%) are classified as less hazardous areas, three villages (4%) are classified as not hazardous areas, and two villages (2.67%) are classified as very hazardous areas. Spatially, the drought-prone areas in Bantul Regency are mostly located in the southern and eastern parts of the Bantul Regency, which have rural characteristics and hilly topography conditions.

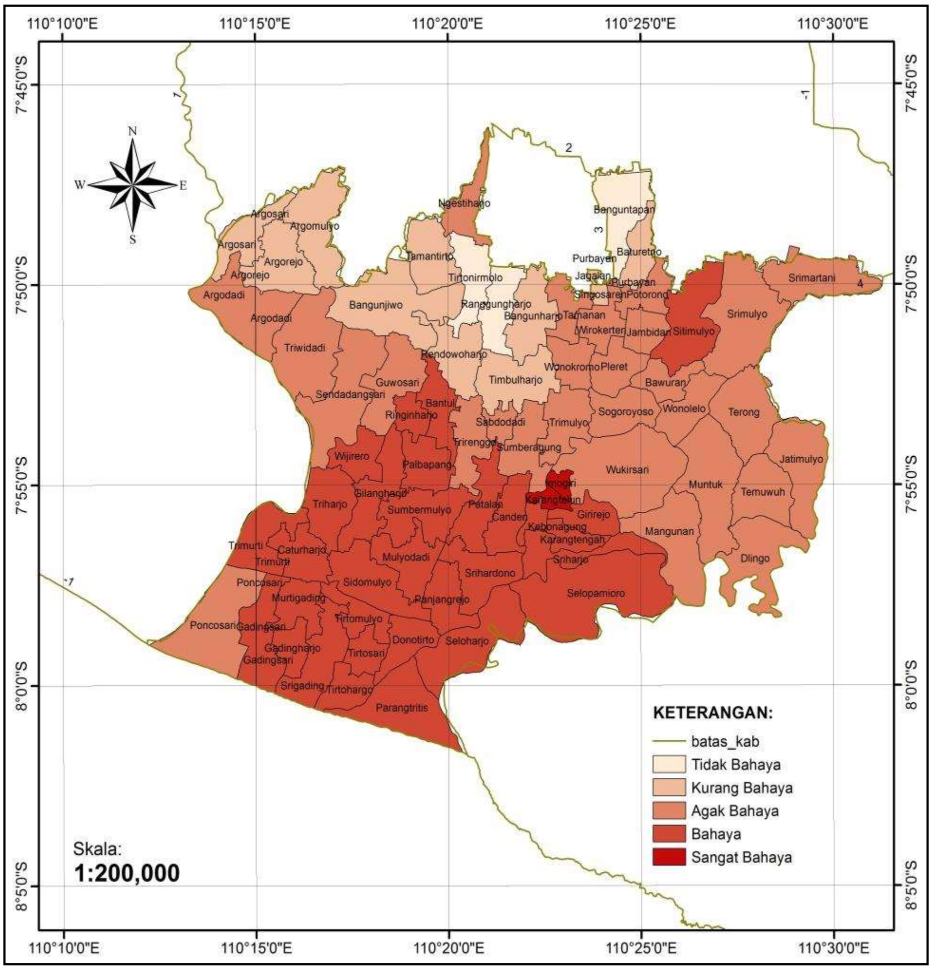


Figure 6. Level of drought hazard in Bantul Regency

Nevertheless, many areas in Bantul Regency tend to suffer drought hazards except some areas in urban areas, such as Banguntapan, Tirtonirmolo, and Panggungharjo Village. It can be influenced by the distribution of rainfall stations, which is spread unevenly, thus affecting the availability of precipitation data. Based on Figure 2, the distribution of sufficient rainfall stations in the eastern and southern regions of the Bantul Regency may affect the amount of rain data that can be collected so that the rain data can cover a narrower area.

3.3. Drought Hazard on Urban Areas

Based on a comparison result between urban areas and drought hazard in Bantul Regency, the drought events are not in line with urban development. Figure 6 shows that the rural and hilly areas tend to experience more hazardous drought events, while urban areas have a low level. It indicates that the drought events in Bantul urban areas are not necessarily influenced by the amount of precipitation or natural meteorological conditions. It is different from the context of drought that occurs in rural areas, which is prone to meteorological drought.

Drought in urban areas may cause by several factors. There are complex factors that lead to urban drought. They are physical factors and anthropogenic factors consisting of climate, hydrology, anthropogenic activities, urban demand, and environment that affect water supply and demands [27]. Moreover, terms of drought in urban areas are also often connoted with water scarcity [27]. Whereas urban drought refers more to an imbalance between water supply and demand, and it is temporary. Further, urban drought can trigger water scarcity, while water scarcity refers to water shortage and could be a long term water stress [27], [28].

Urban drought is connoted with the lack of fresh water due to the increase in demand. It is caused by a high population and the increase of water necessary in many urban sectors. There is an imbalance between water supply and demand. Further, urban drought or water scarcity is also compounded by the impact of climate change [12]. Climate change can cause a decrease in water supply and lead to inadequate access to water resources.

The drought in urban areas is more complicated. It may be caused by the altering of precipitation patterns as well as the high demand for water resources. In addition, urbanization also triggers urban drought. However, assessing drought in urban areas with a precipitation data approach is not enough. It requires considering other factors, such as anthropogenic conditions, even though the presence of rainfall stations also affects the availability of rain data. Urban areas may experience a severe urban drought that is related to sustainable urban development. It should be anticipated such as by notice the probability of a hazard and reduce vulnerability to drought [21].

4. Conclusion

Bantul Regency has been experienced urban growth and development. Urban development extends to the eastern, southeastern, and southern areas of the Bantul Regency. Almost all areas in Bantul Regency also are prone to drought, mainly in the southern and eastern areas. However, urban areas tend to experience moderate to low levels of drought. It can be caused by the uneven distribution of rainfall stations in urban areas so that the rain data collected is also less detailed. Moreover, understanding drought in urban areas also requires a more comprehensive approach. Drought in urban areas is not only understood as a meteorological drought but is also influenced by other factors, such as climate, hydrology, anthropogenic activities, urban demand, and environment [27]. In an urban context, drought is not only influenced by the precipitation condition but is also influenced by human activities as well as greater environmental impacts due to climate change. It has an impact on the balance of water supply and demand, also the availability of water in urban areas. Mitigation efforts are needed to ensure the availability of water in urban areas and minimize the vulnerability impact of drought.

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