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Groundwater Level Changes in Shallow Aquifer of Yogyakarta City, Indonesia: Distribution and Causes

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ABSTRACT. The population in Yogyakarta City, Indonesia has increased since 1970, resulting in high groundwater utilization. This normally results in a decline of groundwater level in shallow aquifer beneath the city. However, expansion of the city and urbanization effects can also have the opposite effect and lead to a rise of groundwater levels due to urban recharge. This study investigates groundwater level changes in Yogyakarta City during a time period of 30 years between 1985 and 2015. Collected data in this research are groundwater level, rainfall, population density, sewer system, and land use. Overlaying various spatial information reveals a pattern of groundwater level rise in some areas of the city by 0–12 m, whilst in other areas a decline of 0–9 m is discovered. Rising groundwater levels are mainly found in areas moderate to high population density where sewer system networks have been installed. The rising of groundwater levels is thus expected to be caused by urban recharge and sewers leakage.

Keywords: Groundwater level changes · Urban recharge · Sewers leakage · Yogyakarta City · Indonesia.

1 INTRODUCTION

Yogyakarta City is located in the middle of Special Province of Yogyakarta, Indonesia. According to BPS-statistics of DI Yogyakarta Province (2016), by 2015 population of Yogyakarta City counts around 412.704 in 2015. Marwasta (2010) stated that the City of Yogyakarta has been experiencing a major growth since 1970 due to the increase of local population as well as urban migration resulting in the development of more houses and hotels. The rising demand for accommodation which was followed by land use transformations from open and agricultural land towards settlement area has led to higher housing densities. In general, land use changees can affect groundwater resources, A reduced infiltration volume consequently results in declining groundwater levels (Remondi, Burlando, & Vollmer, 2016).

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Yogyakarta's population mostly uses the city's underlying shallow aquifer from which it abstracts groundwater through dug wells or bore wells. Moreover, Asriningtyas and Putra (2006) also stated that potable water supply of Yogyakarta City is largely taken from Sleman Regency which is located in the upstream of the Yogyakarta City. Hendrayana and Vicente (2013) calculated utilization groundwater withdrawal of 28,563,487,181 liter/year in Yogyakarta City. Significant groundwater abstraction from the underlying shallow aquifer due to increasing urban demand and development can affect the groundwater level in many ways. Morris *et al.* (2003) described that regarding a town to city transformation, at the first stage, groundwater levels beneath the city lower whilst wells deepen. Moreover, wastewater is discharged back to ground. As the city expands, on one hand groundwater level begins to rise beneath the city due to cessation of pumping and high urban recharge. On the other hand, significant groundwater level decline in the city periphery which occurs due to large abstraction rates from wells. In the following aquifer beneath the city is abandoned because of deterioration of water quality. Finally, as the city expands further, the water table beneath the city rises again causing flooding and contamination because of leaking of waste-water sewers.

Besides the urban growth, (Karamouz *et al.*, 2013) stated that climate change may also have an effect groundwater level and resources. In relation to groundwater resources, three impacts of climate change are detected: changes in the timing and magnitude of groundwater recharge, changes in the interaction between groundwater and surface water and water retreats. Therefore, it is important to investigate the changes of groundwater level in Yogyakarta City in relation to urban growth and annual rainfall variation to understand the urbanization stage of the city.

This study aims to investigate the changes of groundwater level in Yogyakarta City throughout 30 years from 1985 to 2015, including the magnitude, distribution and causes, and thus to gain an understanding of the relation of land use changes, sanitation, urbanization and annual rainfall variation to the changes of groundwater level in Yogyakarta City.

2 STUDY AREA

According to BPS-statistics of Yogyakarta City (2009), City of Yogyakarta lies between 110°24′19"–110°28′53" east longitude and between 07°49′26"–07°15′24" south latitude, covering area a total area of 32.5 km². The city expands from north to south from the slopes of the Merapi Volcano towards the Indian Ocean with an average elevation of 113 m and 0–2 % inclination. The regional climate is tropical with an annual mean temperature of 27.3°C. The average annual rainfall of 2450 mm/year mainly occurs during the wet season months from November to April (Putra *et al.*, 2013). As shown in Figure 1, there are three rivers flowing through the city from north to south, which are Gadjah Wong river in the east, Code river in the middle, and Winongo river in the west.

In the term of regional geology, Yogyakarta City is mainly composed by quarternary fluvial-volcanoclastic sediments such as tuff, ash, breccia, agglomerate, and lava flows which are named Young Merapi Volcanic Deposits (Rahardjo *et al.*, 1995). MacDonald & Partners (1984) differentiated Young Merapi Volcanic Deposits into two formations; Sleman Formation and Yogyakarta Formation. Sleman Formation is designated as the lower part of Young Merapi Volcanic Deposits. It extends from the upper slope of Merapi Volcano to the southern of Bantul Regency and features mostly sands, gravels with interspersed boulders and derivations from volcanic ejecta with a varying thickness of 38 to 120 m. Yogyakarta Formation acts as top layer covering most of lowland area of Yogyakarta Basin. It is dominated by sands, gravels, silts, clays with a thickness up to 45 m lying unconformably upon the Sleman Formation. Those quarternary fluvial-volcanoclastic sediments form an aquifer system, the Merapi Aquifer System (MacDonald & Partners, 1984).

The City of Yogyakarta is located in the central part of the Yogyakarta-Sleman Groundwater Basin. The Yogyakarta and Sleman Formation are both major groundwater aquifers. Yogyakarta Formation has a hydraulic conductivity of 7.8 m/day, storativity values between 0.03 and 0.20 and an average specific yield of 20 % (Putra *et al.*, 2013). The base of the northern part of the aquifer system are Old Merapi Volcanic Deposits, while the base of the aquifer system in the central and the south of Yogyakarta City consists of limestone, marl, and tuff frm the Sentolo Formation (MacDonald & Partners, 1984). Those rocks act as aquicludes (Putra *et al.*, 2013). Based on data from 1990 until 2002, Putra (2003) estimated Yogyakarta's groundwater recharge using the water balance and groundwater fluctuation equations and came to the result of 442.98 × 106 m³/year groundwater recharge. In contrast, the value for groundwater storage of 3530 × 106 m³/year exceeds the recharge value by far. The dynamic of groundwater quantity is calculated from the transmissivity, hydraulic gradient and aquifer extension and equals to approximately 205.5 × 106 m³/year. Putra (2003) consider a safe yield for abstraction of 6.5 × 106 m³/year. Between 1984 and 2002 groundwater level fluctuations of 0 to 5 m had been observed. A relative decrease of infiltration of 9.25 % due to the city's development was detected (Putra, 2003).

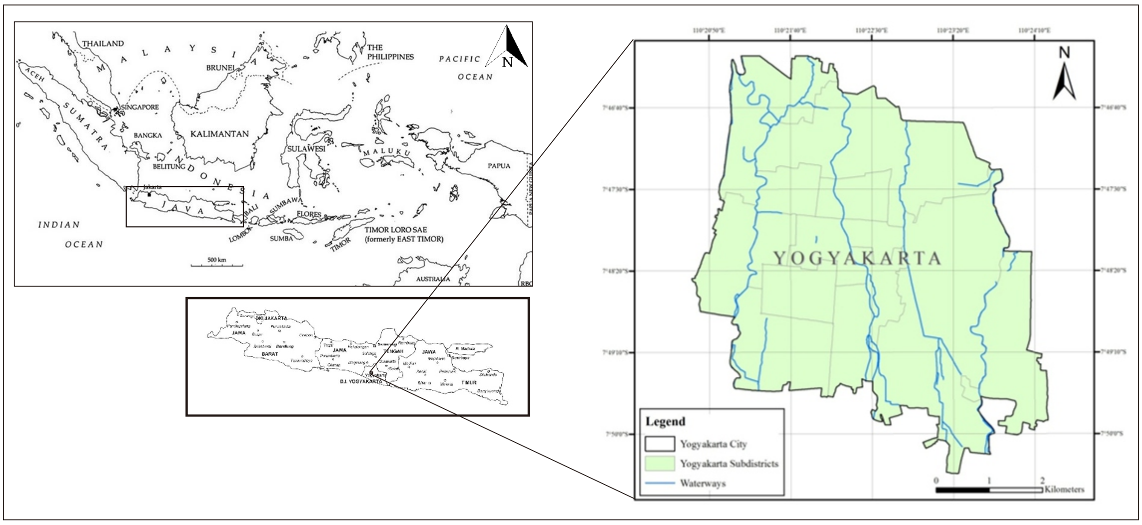

Figure 1: Study area in Yogyakarta City, Indonesia.

In 2013, the optimum yield of 125,000 m^3/day was determined with an estimated groundwater withdrawal of 45,000 m^3/day. Natural groundwater recharge of 400 mm/year was determined for 2013 (Putra *et al.*, 2013).

Putra (2007) estimated potential wastewater in Yogyakarta City of 24.51×106 m^3/a, while potential wastewater recharge of 1.86 mm/day. Furthermore, the sewer system discharges 2.43×106 m^3/a f wastewater. Approximately 14.5 % of the the total sewage flow are assumed as losses due to sewage. Therefore, estimated sewage leakage in Yogyakarta City of 0.35×106 m^3/a (Putra, 2007).

3 RESEARCH METHODS

Four main sections are defined in order to obtain the objectives of this research; (1) understanding of the groundwater level in 1985 and 2015, (2) understanding of the growth of land use, population density, and underground sewers system, and (3) understanding the variation of annual rainfall within 30 years' time period from 1985 to 2015. Finally, data is evaluated including all named factors to understand the changes of groundwater level and the relation of urban growth and annual rainfall variation to the changes of groundwater level in Yogyakarta City for the past 30 years.

The analysis of the changes of groundwater level is conducted by obtaining groundwater level data in 1985, and through groundwater level observations conducted in July 2015. As shown in Figure 2, Sudarmadji (1991) collected 258 groundwater level measurement points in 1985. Moreover in 2015, 139 groundwater level measurement points were observed.

The evaluation of land use data requires satellite images. Land use data of Yogyakarta City in 2004 is classified into six categories: settlement, building, freshwater, irrigated rice fields, thicket/bush, garden, grass and moor. Unfortunately there is no land use data available for the long time period from 1985 until 2003. Thus, the first 20 years of observation remain uninterpreted in relation to the groundwater level changes. However, data for 2015 is obtained from Google Earth in order to make conclusions for at least the time period of eleven years. The raw image data from June 2015 was implemented in ArcGIS and area were manually attributed to the already existing individual categories of 2004. Population density is calculated based on the population of villages which are divided by the area of each village. Data of population and area of the villages are taken from various statistics reports. Sewer system data is taken form previous research by Putra (2007), which includs sewer system map. The sewer system is overlaid with the population density map.

As shown in Table 1, rainfall data was collected from 1984, as well as 1990 until 2015. Rainfall data between 1985 to 1989 is not available. Obviously, the available data does not meet the required study period of 30 years from 1985 to 2015. Nonetheless, it still can be assumed and determined based on the trend of annual rainfall.

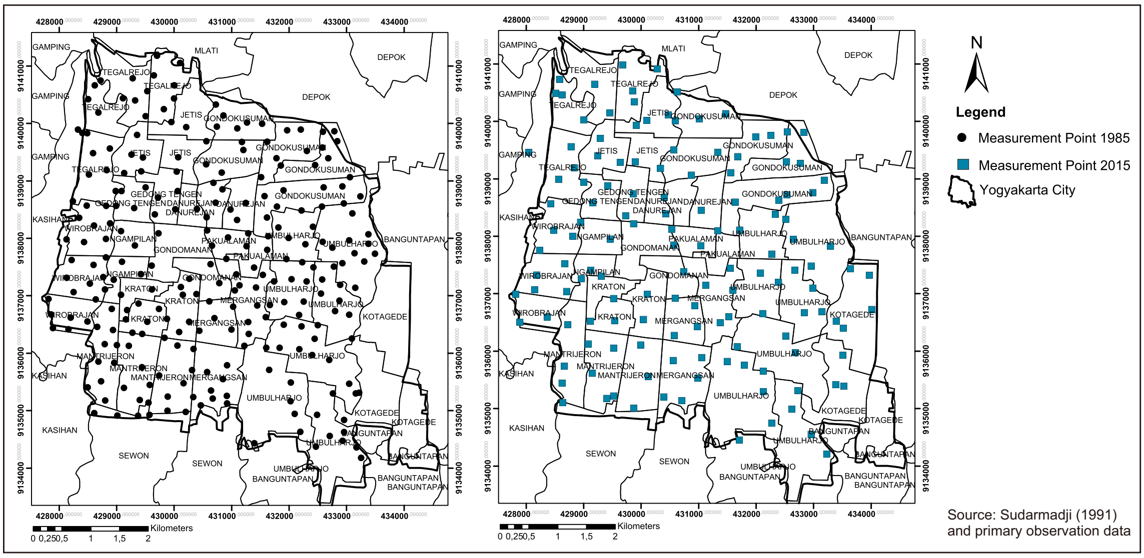

Figure 2: Data measurement points (black dot: 1985, blue square: 2015).

4 RESULTS AND DISCUSSION

The graphic comparison of the two maps of land use in Yogyakarta city for 2004 and 2015 are presented in Figure 3. It reveals an increase of settlement area throughout eleven years. Densification of settlement area occured moderately in eastern and southeastern part of Yorgyakarta City. Settlement area increased slightly in the southwestern and norhtwestern part of the city. In contrary to the main city, the suburban region outside of the city boarders experienced an enormous transformation from open land and agricultural land towards settlement area between 2004 and 2015.

The population density in Yogyakarta City is classified into low to high categories based on Indonesia's national standard of urban housing planning procedures (Badan Standardisasi Nasional, 2004). As shown in Figure 4, high population density areas are located in the center of Yogyakarta City, while moderate population density area suround those. The eastern part of Yogyakarta City mostly represents low population density areas. Sewer systems are installed in the center of Yogyakarta City, extending from north to south. Sewer systems are mainly installed where moderate to high population density exists. It is undestood that higher population density tends to produce higher wastewater discharge volumes.

The graph in Figure 5 illustrates the variation of precipitation data in 1984 and 1990 to 2015. The annual rainfall from 1984 to 2015 shos strong fluctuative. However, using trend line, it can be concluded that the precipitation overall decreased from 1984 to 2015.

The comparison of groundwater level maps allows the assessment of groundwater level changes. Figure 6 shows two maps of groundwater level for the years of 1985 and 2015. It is clearly seen that groundwater level change throughout 30 years from 1985 to 2015. A distinct difference is apparent in the northern part and southeastern part of Yogyakarta City.

Figure 7 illustrates the direct temporal changes of groundwater levels between 1985 and 2015. Groundwater level rises in magnitude of 0–12 m appear in many area which are marked in blue color. The northern part of Yogyakarta City encounters the highest groundwater level rise of 3–12 m compared to the condition in 1985. Groundwater level mainly rises for about 0–3 m. Whilst in the eastern part of Yogyakarta City a declining of the groundwater level of 0–9 m occurs, the northern part of Kotagede subdistrick experience 0–9 m lower groundwater levels. However in some area in the western part of the city, groundwater levels declines happens locally.

Considering the development of settlement and the declining trend of precipitation amount, is expected to lead to the declining of groundwater across the Yogyakarta City. Indeed in the southeastern part of the city where settlement increased, groundwater levels declines. Nevertheless, in fact in the most area of the city reveal the opposite. To understand

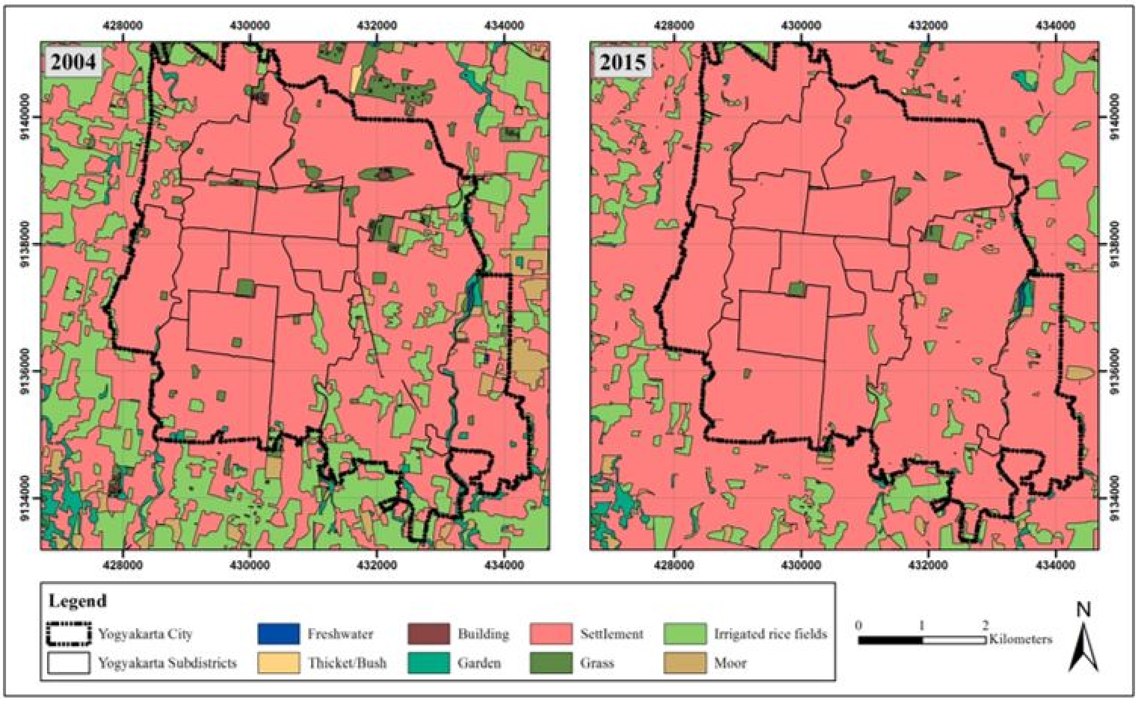

Figure 3: Land use of Yogyakarta City in 2004 and 2015.

the causes for various changes of groundwater level across Yogyakarta City, the changes of groundwater level were attributed to sewer system lines and population density. As presented in Figure 8, areas experiencing a rise of groundwater levels are located in low to high population density parts where sewers system have been installed. On the contrary, in low population density area with no existing sewer system experience the lowering of groundwater levels. Therefore, population density and sewers system are expected to possess a bigger impact to the changes of groundwater level.

Estimation of wastewater discharge from urban population of 2.43 × 106 m^3/a in Yogyakarta City (Putra, 2007) is considered as urban recharge to the groundwater. In addition an estimated sewage leakage of 0.35 × 106 m^3/a in Yogyakarta City (Putra, 2007) contributes to urban recharge which cause the rising of groundwater level. Therefore, combination of urban recharge and sewage leakage lead to the rising of groundwater level in higher population density area in Yogyakarta City. Furthermore, these results are consistent with Putra (2007) groundwater quality analysis which detected high concentration of nitrate and coliform bacteria in shallow groundwater in the middle and western part of Yogyakarta City. There, nitrate concentration of 50 to more than 100 mg/L and coliform bacteria contents of 100 to more than 2000 MPN/100 ml are investigated (Putra, 2007). Nonetheless, local changes of groundwater level still can be considered as an impact of local pumping due to dewatering.

5 CONCLUSIONS

The comparison of groundwater levels in 1985 and 2015 shows various spatial changes. Groundwater levels in Yogyakarta City, Indonesia mostly rose at 0–3 m. In the northern part of the city encounter highest groundwater level rise of 3–12 m. Whilst groundwater levels in the eastern part of Yogyakarta City generally declined by 0–3 m. The maximum of groundwater level decline occured in the southeastern part of the city at magnitude of 6–9 m. In some areas, groundwater level declines occured on local scale.

Settlements mainly developed in the southeastern part of the city and declining trend of precipitation are expected to result in the decline of groundwater levels in the eastern part of Yogyakarta City. Wastewate discharge which is estimated of 2.43 × 106 m^3/a and sewage leakage which is estimated of 0.35 × 106 m^3/a (Putra, 2007) are considered as urban recharge. It is expected to be responsible for the rising of groundwater levels in the middle and western part of Yogyakarta City. Areas experiencing the

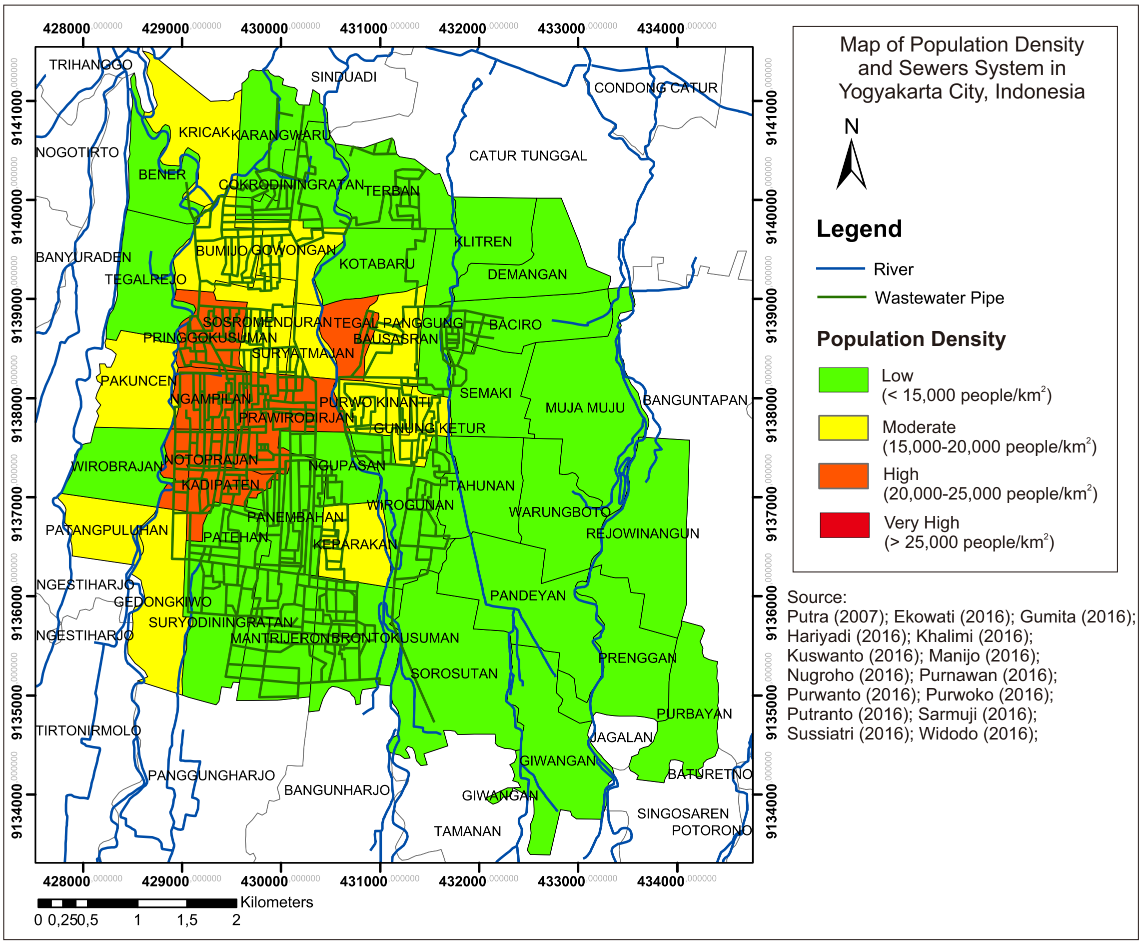

Figure 4: Population density and sewers system (wastewater pipe network) in Yogyakarta City (data from Ekowati, 2016; Gumita, 2016; Hariyadi, 2016; Khalimi, 2016; Kuswanto, 2016; Manijo, 2016; Nugroho, 2016; Purnawan, 2016; Purwanto, 2016; Purwoko, 2016; Putra, 2007; Putranto, 2016; Sarmuji, 2016; Sussiatri, 2016; Widodo, 2016).

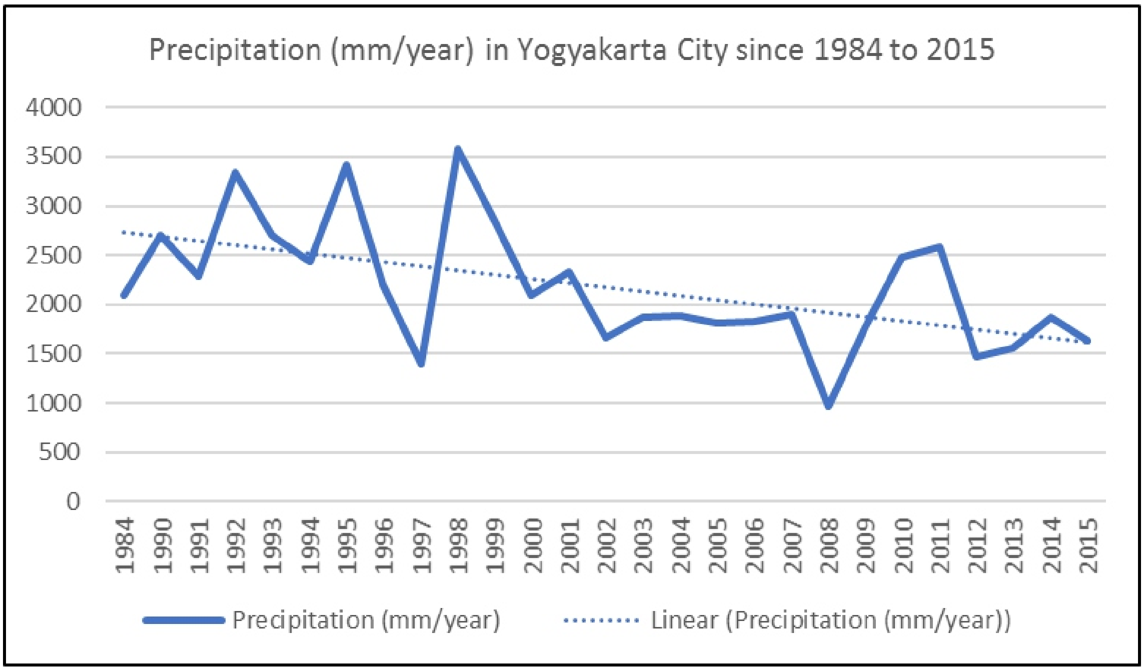

Figure 5: Annual precipitaion in Yogyakarta.

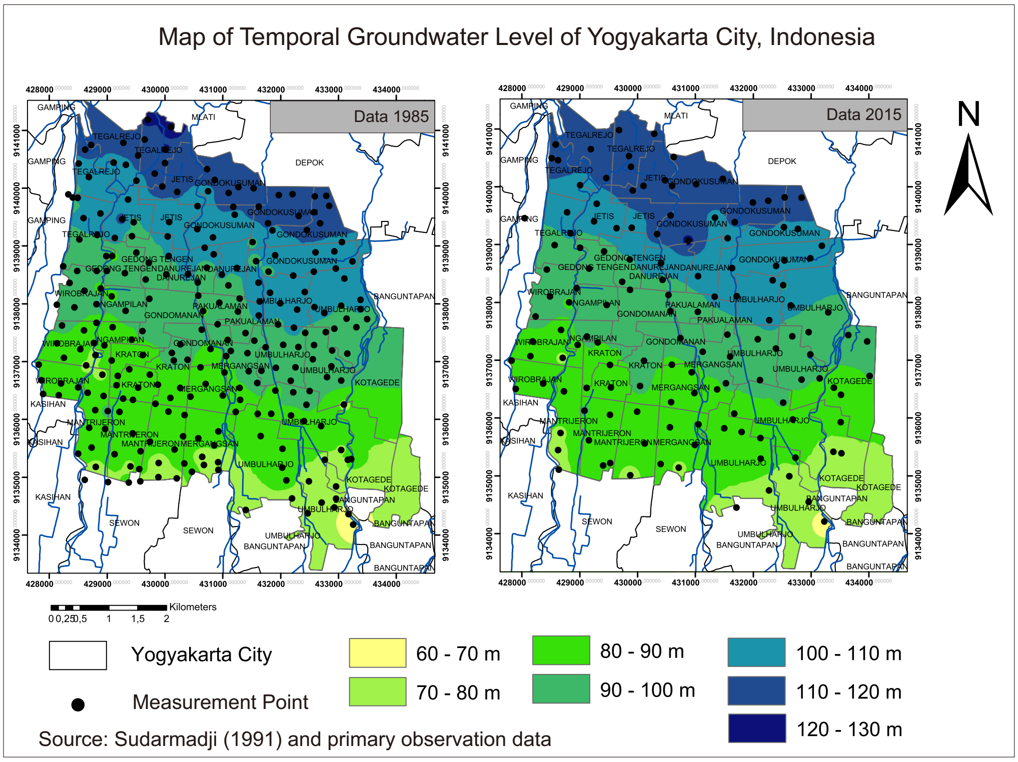

Figure 6: Groundwater level of Yogyakarta City in 1985 and 2015 (Sudarmadji, 1991 and observation data).

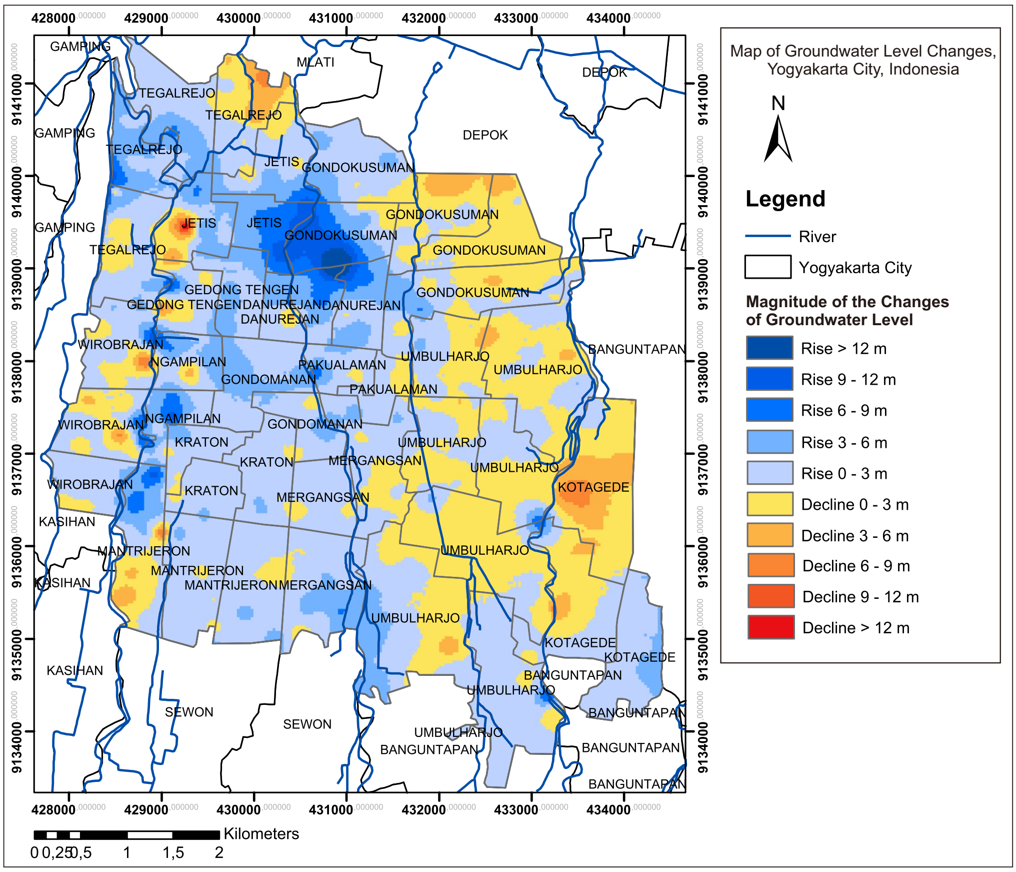

Figure 7: Magnitude of the changes of groundwater level in Yogyakarta City.

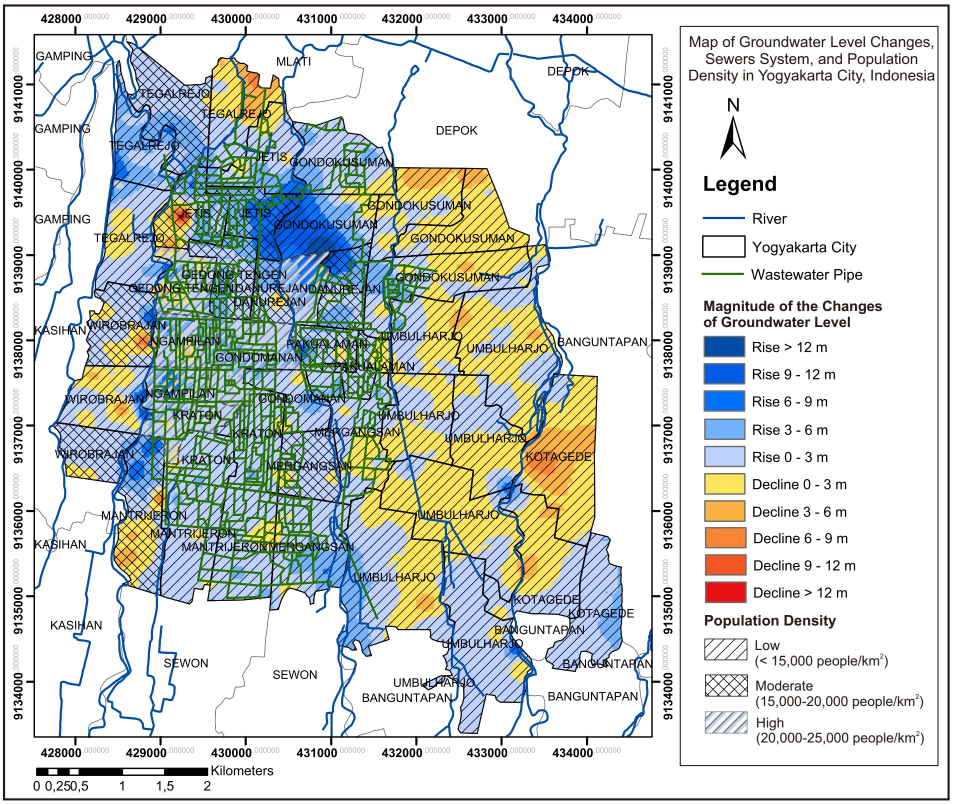

Figure 8: Changes of groundwater level attributed to sewer system and population density in Yogyakarta City, Indonesia.

rising of groundwater levels mostly are located in low to high population density areas where sewer system is installed. Local variation of grondwater level changes still can be ascribed to the impact of local pumping.

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REFERENCES

Asriningtyas, V., Putra, D.P.E. (2006). Ten Year Groundwater Simulation in Merapi Aquifer, Sleman, DIY, Indonesia. Indonesian Journal of Geography, 38(1), 1–14.

Badan Standardisasi Nasional. Tata Cara Perencanaan Lingkungan Perumahan di Perkotaan, Pub. L. No. SNI 03-1733-2004, 52 (2004). Indonesia.

BPS-statistics of DI Yogyakarta Province (2002) Daerah Istimewa Yogyakarta in Figures 2001. Yogyakarta: BPS-statistics of DI Yogyakarta Province.

BPS-statistics of DI Yogyakarta Province (2003) Daerah Istimewa Yogyakarta in Figures 2002. Yogyakarta: BPS-statistics of DI Yogyakarta Province.

BPS-statistics of DI Yogyakarta Province (2004) Daerah Istimewa Yogyakarta in Figures 2003. Yogyakarta: BPS-statistics of DI Yogyakarta Province.

BPS-statistics of DI Yogyakarta Province (2005) Daerah Istimewa Yogyakarta in Figures 2004. Yogyakarta: BPS-statistics of DI Yogyakarta Province.

BPS-statistics of DI Yogyakarta Province (2006) Daerah Istimewa Yogyakarta in Figures 2005. Yogyakarta: BPS-statistics of DI Yogyakarta Province.

BPS-statistics of DI Yogyakarta Province (2007) Daerah Istimewa Yogyakarta in Figures 2006-2007. Yogyakarta: BPS-statistics of DI Yogyakarta Province.

BPS-statistics of DI Yogyakarta Province (2008) Daerah Istimewa Yogyakarta in Figures 2008. Yogyakarta: BPS-statistics of DI Yogyakarta Province.

BPS-statistics of DI Yogyakarta Province (2009) Daerah Istimewa Yogyakarta in Figures 2009.

Yogyakarta: BPS-statistics of DI Yogyakarta Province.

BPS-statistics of DI Yogyakarta Province (2010) Daerah Istimewa Yogyakarta in Figures 2010. Yogyakarta: BPS-statistics of DI Yogyakarta Province.

BPS-statistics of DI Yogyakarta Province (2011) Daerah Istimewa Yogyakarta in Figures 2011. Yogyakarta: BPS-statistics of DI Yogyakarta Province.

BPS-statistics of DI Yogyakarta Province (2012) Daerah Istimewa Yogyakarta in Figures 2012. Yogyakarta: BPS-statistics of DI Yogyakarta Province.

BPS-statistics of DI Yogyakarta Province (2013) Daerah Istimewa Yogyakarta in Figures 2013. Yogyakarta: BPS-statistics of DI Yogyakarta Province.

BPS-statistics of DI Yogyakarta Province (2014) Daerah Istimewa Yogyakarta in Figures 2014. Yogyakarta: BPS-statistics of DI Yogyakarta Province.

BPS-statistics of DI Yogyakarta Province (2015) Daerah Istimewa Yogyakarta in Figures 2015. Yogyakarta: BPS-statistics of DI Yogyakarta Province.

BPS-statistics of DI Yogyakarta Province (2016) Daerah Istimewa Yogyakarta in Figures 2016. Yogyakarta: BPS-statistics of DI Yogyakarta Province.

BPS-statistics of Yogyakarta City (2009) Yogyakarta City in Figures 2009. Yogyakarta: BPS-statistics of Yogyakarta City.

Ekowati, E.D. (2016) Statistik Daerah Kecamatan Umbulharjo 2016. Yogyakarta: BPS Kota Yogyakarta.

Gumita, H.E. (2016) Statistik Daerah Kecamatan Danurejan 2016. Yogyakarta: BPS Kota Yogyakarta.

Hariyadi (2016) Statistik Daerah Kecamatan Mantrijeron 2016. Yogyakarta: BPS Kota Yogyakarta.

Hendrayana, H., Vicente, V.A.D.S. (2013) Cadangan Air Tanah berdasarkan Geometri dan Konfigurasi Sistem Akuifer Cekungan Air Tanah Yogyakarta-Sleman. In Prosiding Seminar Nasional Kebumian Ke-6 (pp. 356–375). Yogyakarta: Teknik Geologi Universitas Gadjah Mada.

Karamouz, M., Nazif, S., & Falahi, M. (2013). Hydrology and Hydroclimatology: Principles and Applications (vol. 27). https://doi.org/10.1201/b13771

Khalimi, N. (2016) Statistik Daerah Kecamatan Kotagede 2016. Yogyakarta: BPS Kota Yogyakarta.

Kuswanto (2016) Statistik Daerah Kecamatan Wirobrajan 2016. Yogyakarta: BPS Kota Yogyakarta.

MacDonald & Partners (1984) Greater Yogyakarta Groundwater Resources Study, Volume 3: Groundwater. Directorate General of Water Resources Development Project (P2AT), Ministry of Public Works, Government of the Republic Indonesia.

Manijo (2016) Statistik Daerah Kecamatan Jetis 2016. Yogyakarta: BPS Kota Yogyakarta.

Marwasta, D. (2010) Yogyakarta Urban Growth Versus Smart Growth : Towards Yogyakarta Slow City Proposal. In Seminar on "To Solve Problem Through Art and Cultural Activities" (pp. 1–16). Yogyakarta: Urban Research Plaza Yogyakarta Sub-Center.

Morris, B.L., Lawrence, A.R.L., Chilton, P.J.C., Adams, B., Calow, R.C., Klinck, B.A. (2003) Groundwater and its Susceptibility to Degradation: A Global Assessment of the Problem and Options for Management, Early Warning and Assessment Report Series (RS. 03-3). Nairobi: United Nations Environment Programme.

Nugroho, A. G. (2016) Statistik Daerah Kecamatan Gondokusuman 2016. Yogyakarta: BPS Kota Yogyakarta.

Purnawan, I.D. (2016) Statistik Daerah Kecamatan Gedongtengen 2016. Yogyakarta: BPS Kota Yogyakarta.

Purwanto, A. (2016) Statistik Daerah Kecamatan Gondomanan 2016. Yogyakarta: BPS Kota Yogyakarta.

Purwoko, S.Z. (2016) Statistik Daerah Kecamatan Mergangsan 2016. Yogyakarta: BPS Kota Yogyakarta.

Putra, D.P.E. (2003) Integrated Water Resources Management in Merapi-Yogyakarta Basin. Yogyakarta.

Putra, D.P.E. (2007) The Impact of Urbanization on Groundwater Quality A Case Study in Yogyakarta City. RWTH Aachen.

Putra, D.P.E., Iqbal, M., Hendrayana, H., Putranto, T.T. (2013) Assessment of Optimum Yield of Groundwater Withdrawal in the Yogyakarta City, Indonesia. Journal of South East Asian Applied Geology, 5(1), 41–49.

Putranto, M.E. (2016) Statistik Daerah Kecamatan Kraton 2016. Yogyakarta: BPS Kota Yogyakarta.

Rahardjo, W., Sukandarrumidi, Rosidi, H.M.D. (1995) Geological Map of Yogyakarta Quadrangle. Scale 1:100.000. Geological Research and Development Center of Indonesia.

Remondi, F., Burlando, P., Vollmer, D. (2016) Exploring the hydrological impact of increasing urbanisation on a tropical river catchment of the metropolitan Jakarta, Indonesia. Sustainable Cities and Society, 20, 210–221. https://doi.org/10.1016/j.scs.2015.10.001.

Sarmuji (2016) Statistik Daerah Kecamatan Ngampilan 2016. Yogyakarta: BPS Kota Yogyakarta.

Sudarmadji (1991) Agihan geografi sifat kimiawi airtanah bebas di Kotamadya Yogyakarta. Universitas Gadjah Mada.

Sussiatri (2016) Statistik Daerah Kecamatan Tegalrejo 2016. Yogyakarta: BPS Kota Yogyakarta.

Widodo, K. (2016) Statistik Daerah Kecamatan Pakualaman 2016. Yogyakarta: BPS Kota Yogyakarta.

Table 1: Rainfall data in Yogyakarta City in 1984 and 1990 to 2015.

Year	Monthly Rainfall (mm)												Total (mm)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1984	380	320	320	150	120	60	60	20	40	110	220	290	2090
1990	425	284	537	387	108	106	0	40	0	9	416	389	2700
1991	484	519	191	477	5	5	0	0	3	16	341	249	2289
1992	500	328	498	342	225	33	29	203	171	351	386	279	3341
1993	425	284	537	387	108	106	0	40	0	9	416	389	2700
1994	429	469	731	293	69	0	0	0	0	63	163	219	2435
1995	549	559	395	172	151	274	49	0	2	224	763	273	3409
1996	334	306	318	170	43	20	1	54	3	286	521	147	2200
1997	319	249	98	74	61	3	0	0	0	3	75	522	1401
1998	405	656	452	206	55	253	151	15	111	614	342	316	3574
1999	383	326	456	340	162	44	41	5	12	243	414	435	2859
2000	344	352	440	366	238	112	69	0	47	0	0	131	2099
2001	493	271	466	335	46	83	30	0	0	212	201	191	2328
2002	340	135	260	140	68	35	35	24	38	105	220	264	1664
2003	281	278	275	103	113	23	0	0	12	120	281	380	1866
2004	330	343	293	135	124	6	35	0	10	19	225	366	1886
2005	314	318	289	118	67	48	32	19	38	96	216	262	1817
2006	395	304	318	262	195	5	5	0	0	1	33	305	1823
2007	180	320	310	355	35	10	0	0	0	30	122	538	1900
2008	146	211	200	71	42	4	7	0	3	35	101	144	964
2009	171	355	387	246	112	2	0	0	3	257	37	202	1772
2010	470	242	397	125	194	102	6	95	53	156	243	393	2476
2011	654	358	278	377	193	0	0	0	3	36	377	310	2586
2012	242	278	147	119	38	0	0	0	0	63	170	409	1466
2013	368	268	160	155	98	91	42	0	0	18	108	247	1555
2014	330	294	133	282	37	40	63	0	0	0	254	434	1867
2015	312	252	211	216	78	5	0	0	0	0	106	459	1639

Source: data from BPS-statistics of DI Yogyakarta Province (2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016); MacDonald & Partners (1984); Putra (2003).