The Influence of Groundwater Basin Existence Towards The Urban Development In Java

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Abstract. Groundwater is one of natural water resource that most commonly used to support the human activity. It plays an important role in shaping both physical and non-physical urban development aspect. The different availability of groundwater supply could lead into the different development rates of each area, especially in Java. The correlation between the existence of groundwater basin (CAT) and its influence to urban development could be used as base consideration to propose the development typology. Defining development typologies and what variable could distinct the developments in CAT and non-CAT area using discriminant analysis and remote sensing approach. Furthermore, there are three stages need to observe, i.e.: identify urban-rural area delineation change, defines development rates, and the last is defining discriminate variable which have significantly different means across the urban development in CAT and Non-CAT area. The observation reveals that in order to find the correlation between CAT existence and development rate, the eight-development typology has been establish. The typology is conduct regard to the development rate that categorizes in zero growth, slow growth, moderate growth, and fast growth both in CAT and Non-CAT. While, according to the result of discriminant analysis there are six variables that could distinct the urban developments in CAT and non-CAT, i.e.: proportion of dry land farm, status area, wet-land farm, built up area, agricultural household, and road density.

Keywords: Groundwater basin, Urban development, Discriminant analysis

1. Introduction

Groundwater is considered as the most widely used water source in common for private domestic and industrial use. It is relatively low cost, highest on its availability, easy to exploited, more convenient and less vulnerable to pollution than surface water [1]. Therefore, it is become the primary choice for clean water supply alternative due to the large storage capacity and providing sufficient water supply for public needs [2]. The availability of groundwater in Indonesia provides the largest source of usable water storage. It could be seen on its availability that spread on various islands with each different quantity and quality [3]. The potential of groundwater depends on the area and hydrogeological conditions in each island. From the existence of 421 CAT that spread in whole Indonesia, 80 of it exist in Java.

The area of Java is approximately 13.2 million ha or 4.2 percent from total area in Indonesia, which consists of six provinces, 34 municipalities, and 84 regions. As the island which has the highest population density in Indonesia, Java accommodates 136,610,590 people or 57 percent of Indonesia's population in 2010 [4]. While potential of groundwater basin availability is less than 8 percent from the total groundwater potential in all around Indonesia.

An increasing number of urban population densities and change of community behavior become driving force factors that generate the urban development process [5]-[7]. This urban development process lead to increasing urban activity in which automatically need enormous amount of clean water supply. It is closely related to the trend of groundwater consumption to fulfill public water supply and support production process [8], or in other word, the urban development has a close relation with the existence of CAT area.
As mentioned by [9] the development of an urban area that located above unconfined aquifer system (CAT area) tends to develop rapidly rather than it is not. The interaction between availability and exploitation of the aquifer system in order to fulfill clean water needs with the exact technology utilization could affect the urban development level and pattern certainly. The different availability of CAT could lead into the different development rates of each area. As happen in Java, most of big cities such as Jakarta, Bandung, Bogor, Surabaya is located above CAT area [10]. These large cities tend to develop rapidly due to the support of adequate water resource availability. But, how about the development in the area located in non-CAT area? Through this research, researcher try to find the correlation between the development in CAT and non-CAT area by establish the development typology. It aims to classify the development of the area in Java in sub-district level as the deepest analysis unit toward the existence of CAT. Furthermore, this research also tries to find the discriminate variable which has significantly different means across the urban development in CAT and Non-CAT area.

In order to measure the development rate in Java there are seven variable that categorize into physical and non-physical criteria. The physical criteria are consists of built up area development; agricultural land proportion which divide into wetland and dry-land farm; and road density. While the non-physical criteria are consists of population density changes; classification zone based on ward/village potency (PODES); and agricultural households.

2. Method
This research is using quantitative approach that based on scientific principles, concrete, empirical study, measurable, rational and systematic. This is establishing some variable taken from the literatures and the data collection stage is done quantitatively using measured data. The data actually dominated by tabular format and connected with administrative maps (sub-district as the deepest unit analysis) to view their spatial aspect. The object of this research is focuses on spatial aspects that observe each urban development aspect based on CAT existence in whole Java Island. The research object is observed both from satellite imagery and PODES in time series data year 1990 to 2011 as an input for analysis. The data itself has played an important role in determining the quality, validity and reliability of the analysis result because it used from input, analysis, and output.

In the analysis process, this research uses tabular analysis which is done in Ms. Excel, weighted overlay done in ArcGIS and uses descriptive quantitative method. This research also uses statistical appraisal done by SPPS with discriminant analysis to examine the distinction variable between urban developments in CAT and non-CAT area. Detail of analysis process is explained in the figure 1 below.

Referring to the framework in Figure 1, the discussion about analytical techniques in this research will be explained in five main stages:
1. Administrative boundary changes analysis. This analysis focus on the municipality/regency that experienced regional divisions from year 1990 to 2011, and the relation between municipality/regency administrative boundary change from year 1990 to 2011 and the influence of groundwater basin that exist in the research area.
2. Urban-rural delineation change analysis. This analysis is used to identify the development to the change of urban area status distribution around the major city from year 1990 to 2011. This stage is developed based on physical and non-physical aspect which is converted from tabular analysis into spatial information in GIS.
3. Urban development analysis. This analysis is used to elaborate development rate that measured by urban-rural area delineation change analysis and its correlation to the existence of CAT in each area (sub-district as the deepest analysis unit). The development rate in this analysis is classified into four categories: zero growth, slow growth, moderate growth, and fast growth.
4. Urban development typology analysis. This analysis will be classified based on criteria of urban development rate and the CAT existence. The determination process divided into two major classifications, these are urban development typology in CAT area and urban development typology in non-CAT area.
5. Discriminant analysis. The discriminant analysis is used to performs a multivariate test of differences between urban development in CAT and non-CAT groups based on multiple
variables of physical and non-physical aspect; and testing significance to see which variables have significantly different means across the groups.

**Figure 1. Analytical Framework**

3. Analysis And Result

3.1 Identification of Administrative Boundary Change

The number of population gives broad impact in social, economic and also environmental aspect, so rapid growth of population will directly affect the urbanization process. Java is known as an island which has the highest population density in Indonesia. The high population growth rates, massive urbanization, limited urban space, the enormous amount of land transformation due to rapid development cause Java take option to deal with the uncontrolled development on the suburbs area. To accommodate and keep the negative effects of urban development are under local government control, the Ministry of Home Affair decided to do regional division *(pemekaran wilayah)*. In the regional division, the area of several regency *(kabupaten)* and municipality *(kota)* is divided into new municipality and regions which has smaller area than main city/region.

In 1990, Java divided into five provinces; these are DKI Jakarta, West Java, Central Java, East Java, and DI Yogyakarta Province, with 1783 sub-district which spread in 24 municipalities and 82 regencies. While Banten Province formerly part of West Java Province. Then refer to Law
No.23 year 2000, Banten was declared as a separate province. Finally in 2011 Java has 6 provinces, it consist of 35 municipalities and 84 regencies, and divided into 2,056 sub-districts. Referring to the data, during 1990-2011 the regional division has occurred in most areas of West Java and Banten Province. 7 regencies in both provinces have been divided into 11 new municipality and regencies.

According to the location, these two provinces are adjacent to DKI Jakarta Province where the Indonesian state capital was located. The development of supporting infrastructure and other supporting facilities are prioritized in DKI Jakarta due to the existence of central government. Increasing number of population in West Java and Banten Province has indicated the tendency that people prefer to live in that area. Furthermore, the CAT has covered almost 64% area of West Java and 53% area of Banten Province. It means that in both provinces has high water availability that would influence the urban area to develop rapidly.

3.2 Analysis of Urban Development toward The Existence of Groundwater Basin

The urban development can be identified from the change of urban-rural area delineation and the influence of the CAT existence to the changing of urban area status during 1990-2011. The process of delineating urban and rural area is done by collecting initial data in each sub-district of Java. The criteria to identify urban and rural delineation change are presented into 2 criteria, physical and non-physical criteria. By those physical and non-physical criteria, changing of urban-rural area delineation could be identify by weighting and scoring process. The weighting method is developed by combine the data statistic calculation of every criterion in tabular format and spatial analysis technique (map base analysis). It seems to view the data and to show the relationship between spatial and tabular data.

Every criterion of urban-rural area delineation change analysis is then divided into 4 categories (classes), each of which is then given the score based on its hierarchy. Scoring is done with value of 1 to 4 where the higher means the higher level of urbanity of an area. After defining the score of each category, then determining the weight assumption of every criterion, then overlaid based on each weight using spatial weighted overlay done in ArcGIS. The weighted is done to show the various level of influence on each variable, so it gives different proportion on the weight. It is expressed in percent (%) where the total amount is 100%. The output of weighting process is urban-rural delineation area with different score, then simplify into four area classification. (The Figure 2 shows the detail weight and score of urban and rural delineation criteria).

Through the process above, the urban-rural area delineation year 1990 and 2011 has been establish. The area delineation is divides into three big areas classification, i.e.: urban area; peri-urban area which is consists of urban-rural and rural-urban area; and rural area. In order to examine the correlation between changing of urban-rural area delineation and the existence of groundwater basin in Java, the cartographic generalization method need to be done. It uses administrative boundary in year 2011 and ignores the regional division that happen during 1990-2011. In the other way, the groundwater basin existence is represents by the classification area toward the existence of CAT which determined based on administrative boundary in sub-district level. To get the ideal ratio between CAT and non-CAT proportion in classification, the area will be classified as CAT area if the total CAT coverage area is 50% or more. The areas with CAT coverage below 50% are claimed as non-CAT area. The result of this analysis, spatially represent on the Table 1.
Source: Summarized from Yunus (2008), Indonesian Urban-Rural Classification (Head of National Statistical Bureau Regulation, No 37 year 2010), BPS with modification (2014)

Figure 2. Urban-Rural Area Delineation Process

The Table 1 is represents the proportion of sub-district distribution in CAT and non-CAT area. Most of sub-district in java, which reaches to 77.28%, is located in CAT area, and the rest 22.72% was located in non-CAT area. During 1990-2011, the sub-district which located in groundwater basin area has highest experience on shifting of urban rural-area delineation. It could be identify from the number of rural area in 1990 is extremely decrease in 2011, while the other categories of this area tends to increase. Changing of urban-rural area delineation also occur the Non CAT area, but it is not happen as high as in CAT area. This condition is indicates that the development was occur rapidly in the area which has supported by the water availability.
Table 1 Spatial Representation of Sub-district Distribution in Each Area Delineation Classification Year 1990 and 2011

| Groundwater Basin Area (CAT)                      |
|---------------------------------------------------|
| **Year 1990**                                     |
| ![Map Legend](image1)                             |
| ![Map Legend](image2)                             |
| **Year 2011**                                     |
| ![Map Legend](image3)                             |
| ![Map Legend](image4)                             |

| Year     | Urban Area | Urban-Rural Area | Rural-Urban Area | Rural Area | Total |
|----------|------------|------------------|------------------|------------|-------|
| 1990     | 99         | 133              | 177              | 1180       | 1589  |
| 2011     | 204        | 212              | 349              | 824        | 1589  |

Non Groundwater Basin Area (Non-CAT)
Most of urbanize area (which can be identify through shifting of urban rural-area delineation in 1990 and 2011) was located in area underline by groundwater system, while in area which has no groundwater system tend to dominate by rural area. Although in Non-CAT area dominated by rural area, during 1990 to 2011 some of sub-district which located in Cilacap,
Central Java that considered as industrial center located in Non-CAT area could develop into urbanized area. This condition is indicates that the existence of supporting sector, industry or tourism for instances, could significantly affect the development process in that area.

### 3.3 The Influence of Groundwater Basin Existence on Urban Development Rates

After identify the urban-rural area delineation change in the previous analysis, the development rates of each area can be determined. In order to measure the development rate, it is assumed that the changing of urban-rural area delineation is represents the rate of development. According to the total score of weighted overlay process in urban-rural area delineation change in 1990 and 2011, in this research the development rates then classified into 4 classifications; zero growth, slow growth, moderate growth, and fast growth. Each of which has classified based on its score that can be detailed inform in the Table 2.

| Delta Score of Urban-Rural Area Delineation in 1990 and 2011 | Classification       |
|-------------------------------------------------------------|----------------------|
| < 0.1                                                       | Zero Growth          |
| 0.10 – 0.50                                                 | Slow Growth          |
| 0.51 – 1.00                                                 | Moderate Growth      |
| 1.01 – 2.30                                                 | Fast Growth          |

Source: Own Analysis, 2014

The following stage is analyzing the correlation between changing of urban-rural area delineation during 1990-2011 through development rate measurement toward the existence of CAT area in Java. As previously stated, the development rate is measured from delta score of urban-rural area delineation year 1990 to 2011. The next step is established the sub-district classification in regard to the assumption for the existence of groundwater basin area. Finally, the correlation between urban development rates toward the existence of groundwater basin area can be identified.

According to the development rate classifications above, the result of classification area based on CAT existence shows that 42.17% is dominated by slow growth category of development rates. The fast growth rate is dominated 5.15% in the area underlain by groundwater system, while in non-CAT area is just 0.24%. The fast growth development rates are represents the areas which have the highest classification of delta score in urban-rural area delineation change in 1990 and 2011. This condition is indicates that the level of urban development in groundwater basin area quite rapid rather that in non-groundwater basin area.

The area which classified as fast growing area in CAT mostly located in the area surrounding the most urbanize area, capital of state or province for instance. The existence of most urbanize area tend to give significant effect to the development level surrounding its area. The area surrounding DKI Jakarta, Bogor, Bandung, Semarang, and Surabaya municipality mostly have fast growth development rate. While the areas far from these municipalities, the development rate tend to be classified as slow or even zero growth. For more detail about spatial pattern of this analysis result can be seen in in the Table 3.
Table 3 Development Rates Distribution in CAT and Non-CAT Area in Java

**Groundwater Basin Area (CAT)**

| Development Rate | Zero Growth | Slow Growth | Moderate Growth | Fast Growth | Total |
|------------------|-------------|-------------|-----------------|-------------|-------|
|                  | 486         | 671         | 326             | 106         | 1589  |

**Non Groundwater Basin Area (Non-CAT)**

| Development Rate | Zero Growth | Slow Growth | Moderate Growth | Fast Growth | Total |
|------------------|-------------|-------------|-----------------|-------------|-------|
|                  | 232         | 196         | 34              | 5           | 467   |

Source: Own Analysis, 2014

Furthermore, in non-CAT area that located in the south part of Java tend to dominate by the area which classify as slow and zero growth. While the areas that located surrounding urbanizes area are still could affect by the development of urbanize area although as not
significant as the area which underline by groundwater system. This condition can be seen in the area surrounding Bogor, Bandung and Malang municipality.

After examine the distribution of development rates in each sub-district, the next step is define the development typology. In order to define the type of development found within area which classified based on CAT existence, the development typology classifies into eight typologies. The aim of defining the typology is to provide detail description of these two distinct types of area regard to the existence of CAT. The typology is established regards to the composition of each urban-rural area delineation change criterion, development level and its correlation to the CAT area classification. Here the following eight typologies which can describe the development characteristic:

1. **Typology 1** for area that located in CAT and has zero growth rates.
   - It could occur in all delineation area, but in different characteristic. It is typically happens in the area far from the most urbanize area and tend to dominate by rural area.

2. **Typology 2** for area that located in CAT and has slow growth rates.
   - It commonly occurs in the area which classifies as rural and small town which has specific function for preservation area, especially in agricultural sector. This typology is belongs to area which mostly located in Central and East Java Province.

3. **Typology 3** for area that located in CAT and has moderate growth rates.
   - It typically occurs on the area which has functions as PKW (Pusat Kegiatan Wilayah) that support main city and previously classify as urban area. It commonly occurs on the developed area which consider being the most urbanize area. This typology is belongs to area which mostly located in West Java Province.

4. **Typology 4** for area that located in CAT and has fast growth rates.
   - It commonly occurs on the developed area which consider being the most urbanize area. This is belongs to area which mostly located adjacent with capital state or province. It typically happens in the rural area which categorize as under developing area that adjacent to the developed urban area. This typology is belongs to area which mostly located in West Java Province which the development supported by DKI Jakarta as capital state of Indonesia.

5. **Typology 5** for area that located in Non-CAT and has zero growth rates.
   - It typically happens in the rural area which consider as under developing area. Without groundwater system support, these areas tend to hard develop and stay constant during 1990-2011 periods. This typology is belongs to area which mostly located in West and East Java Province.

6. **Typology 6** for area that located in Non-CAT and has slow growth rates.
   - It typically happens in under developing urban area which consider as rural area and located far from the developed urban area. This typology is belongs to area which mostly located in West and Central Java Province.

7. **Typology 7** for area that located in Non-CAT and has moderate growth rates.
   - It typically happen in developing area which recognizes as small town that has potency to develop and located surrounds the developed urban area. This typology is belongs to area located which mostly in the West Java Province.

8. **Typology 8** for area that located in Non-CAT and has fast growth rates.
   - It typically happens in area surrounding urbanized area that has potency to develop. Most of area which classifies in this typology located adjacent with the developed urban area. This typology is belongs to area located which mostly in the West Java Province.

### 3.4 Analysis of Distinguishes Development Criteria Toward the Existence of Groundwater Basin

The discriminant analysis is aim to analyze the difference of categorical data, whether different or not. If they are, it is necessary to look for variables that cause these differences. In addition, the discriminant analysis is used to classifying objects or data included more than two categories. In this analysis, the discriminant analysis is used to determine what distinguishes criteria between each area which classified based on groundwater basin (CAT) existence. This analysis is also testing the significance to see which variables have significantly different means across the groups. This analysis is conducted by using discriminant analysis in SPSS.
According to the result of discriminant analysis, the level validity of the processing data reaches 100% for 2056 sub-district as an object data. This is used to predict a group membership, so firstly it need to examine whether there are any significant differences between groups on each of the independent variables using group means and ANOVA results data. The Table 4 Group Statistics and Tests of Equality of Group Means below provide this information. If there are no significant group differences it is not worthwhile proceeding any further with the analysis. A rough idea of variables that may be important can be obtained by inspecting the group means and standard deviations. In the result of discriminant analysis, mean differences between each criterion scores. For instances built-up area and population densities depicted in below suggest that these may be good discriminators as the separations are large.

| Tests of Equality of Group Means | Wilks’ Lambda | F     | df1 | df2 | Sig.  |
|----------------------------------|---------------|-------|-----|-----|-------|
| Built Up Area                    | .935          | 143.956 | 1   | 2054 | .000  |
| Wet Land Farm                    | .962          | 80.862  | 1   | 2054 | .000  |
| Dry Land Farm                    | .895          | 240.562 | 1   | 2054 | .000  |
| Road Density                     | .952          | 102.898 | 1   | 2054 | .000  |
| Population Density               | .955          | 97.520  | 1   | 2054 | .000  |
| Status Area                      | .907          | 209.701 | 1   | 2054 | .000  |
| Agricultural Household           | .922          | 174.240 | 1   | 2054 | .000  |

Source: Own Analysis, 2014

Wilks’ lambda indicates the significance of the discriminant function. Value of Wilks Lambda is ranging from 0.895 to 0.955, this condition indicate that the all variable is different due to its value close to 0. The validation criteria for Wilks Lambda value seen from Sig. value which categorizes as:

- If Sig. value > 0.05 means that there is no difference between tested variable.
- If Sig. value < 0.05 means that the differences between tested variable is exist.

For instance, Sig. value of built up area is 0.000, it is means that less than 0.05. This condition is indicates that there is difference of built up intensity between municipality/regency located in CAT and Non CAT area. It probably shows that built up intensity located in group CAT area tend to be denser than other group area. While on this discriminant analysis, all variable entered has Sig. value 0.000. It means that there is difference of all variable entered between areas which classify based on the CAT existence.

The entered / removed table shows the variable which define from all criteria that could be included into the discriminant equation. In this analysis, these criteria must have Sig. values below 0.05. Thus of the seven criteria included, only population density as a variable has been removed. While the other six variables are include as significant variables. The proportion of dry land farm, status area, wet-land farm, built up area, agricultural household, and road density could affect the classification of CAT and Non CAT. Through the variable in the analysis, population density is the only criteria to removed due to this variable has Sig. of enter is 0.375 which is more than 0.05. While the other 6 (six) variable area include on the discriminant model due to this criteria have the lowest Sig. of F to Remove value which is ranging between 0.000 to 0.019 (far below 0.05).

The prior probabilities for groups table shows the composition of 2056 sub-district using discriminant model resulted 467 sub-district located in Non-CAT area and 1589 sub-district located in CAT area. While the regression equation that formulate in standardized function of this discriminant analysis can be seen in the equation bellow:

\[ Z\text{SCORE} = 0.321 \times \text{Built Up Area} + 0.601 \times \text{Wet Land Farm} - 0.159 \times \text{Dry Land Farm} + 0.157 \times \text{Road Density} + 0.337 \times \text{Status Area} - 0.210 \times \text{Agricultural Household} \]

The result of discriminant analysis could be seen in the table classification result (see Table 5). In order to examine the accuracy level of discriminant model it can be measured from
Table 5. In original data, the sub-district which classified as Non CAT and in further classification using discriminant function still classified in the same classification is 370 and CAT is 1068. Therefore, the prediction of accuracy level this discriminant model is:

\[
\text{Accuracy level} = \frac{370 + 1068}{2056} = 0.699 \text{ or } 69.9\%
\]

Table 5 Level of discriminant model

| Zone Classification | Predicted Group Membership | Total |
|---------------------|---------------------------|-------|
| Non CAT             | CAT                       |       |
| Original            |                           | 467   |
| Count               |                           |       |
| Non CAT             | 370                       | 97    |
| CAT                 | 521                       | 1068  |
| %                   |                           | 100.0 |
| Non CAT             | 79.2                      | 20.8  |
| CAT                 | 32.8                      | 67.2  |
| Cross-validated*    |                           | 1589  |
| Count               |                           |       |
| Non CAT             | 369                       | 98    |
| CAT                 | 523                       | 1066  |
| %                   |                           | 100.0 |
| Non CAT             | 79.0                      | 21.0  |
| CAT                 | 32.9                      | 67.1  |

a. Cross validation is done only for those cases in the analysis. In cross validation, each case is classified by the functions derived from all cases other than that case.
b. 69.9% of original grouped cases correctly classified.
c. 69.8% of cross-validated grouped cases correctly classified.

The accuracy level of this discriminant model is 69.9%. It is more than 50%, so it could be classified as high enough. Based on the analysis, the models can be used to classify a case in determining the area which classifies based on groundwater basin existence, such as the area which is include as CAT, or Non CAT area.

4. Conclusion

The existence of CAT area could affect the development rate of an area. The development in area which underlain by CAT system is quite different with development in Non-CAT area. The correlation between the development in CAT and non-CAT area could be represent by establishing eight typologies of urban development. The typology is established regards to the composition of each urban-rural area delineation change criterion, development rate and its correlation to the existence of CAT area. It is conduct regard to the development rate that categorizes in zero growth, slow growth, moderate growth, and fast growth both in CAT and Non-CAT. Through these eight development typologies above, it could be used as basic consideration to arrange the regulation spatial plan according to the existence of CAT area. Refer to these typologies, it also could be uses to determine the development area priority in order to support which area should be develop in further years.

Furthermore, based on the result of discriminant analysis there are six variables that could distinct the sub-district classification into each area which classified based on the existence of groundwater basin, i.e.: proportion of dry land farm, status area, wet-land farm, built up area, agricultural household, and road density. The accuracy level of this discriminant model is 69.9%. It is more than 50%, so it could be classifies as high enough. Based on the analysis, the models can be used to classify a case in determining the area which classifies based on groundwater basin existence.

This research also has the limitation regarding to the result of development rate distribution. This research is only measure the horizontal development and ignores the possibility of vertical development. As happen in the development of DKI Jakarta for instance, the capital state of Indonesia. The development level of DKI Jakarta is just dominated by low developed. If it compared into reality, DKI Jakarta might be the most developed area due to increasing number
of high rise building with enormous amount of GDP Value. Based on those limitations, the future researchers are challenge to create research related to urban development and its relation to the existence of CAT area including aspect of vertical development to define the typology of urban development in CAT and Non-CAT area.

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