Preliminary study of the human activities and perception on the groundwater conservation in lowlands of Semarang

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Abstract. This paper aims at investigating the human activities and perception of the residents in lowland areas of Semarang city regarding the groundwater conservation. As the first step, classifying and rating land use in the study area is conducted as the interpretation of human activities. A map of human perception using the adapted Protocol Perception Monitoring is then configured to evaluate the deviation between the expected and observed behavior of the community in an integrated ecosystem. The result of preliminary study shows that about 68% areas in lowland have score 8 (built-up area, irrigated field crops), 25% has score 7 (industries and reservoirs), 1% has score 5 (plantation), 3% has score 2 (non-irrigated field crops) and about 3% has score 1 (forest, park and open areas). It means that more than 90% lowland areas in Semarang city have been intervened by the human activities. Based on the result of the perception mapping, it is found that there is a high deviation (about 40-90%) between expected and observed behavior in critical areas, including the understanding of area situation, utilization of groundwater and water resources (wells/PDAM) as well as the community comprehension of government regulation on groundwater conservation.

1 Introduction

Groundwater as natural resources and the representation of valuable drinking water resources has been affected particularly by the increasing population in urban cities [1,2,3,4,5,6,7]. An enormous stress has been established on this resources caused by the increasing water demand from urban and industrial development both in quantity and quality aspects.

Semarang is an urban city in the central north of Java Island which is facing a rapidly increasing population as well. This phenomenon leads to the increasing water demand from groundwater for domestic and industrial purposes. The groundwater exploitation affects some environmental problems. Therefore, to solve the problems and achieve a sustainable ecosystem, there are some steps that should be considered. They are a mapping of the conservation area in Semarang as technical aspect assessment as well as mapping of human activities and perceptions regarding groundwater conservation as human factors evaluation.

A preliminary study of groundwater quality in Semarang coastal areas [8] showed that there were four groundwater conservation zones in Semarang based on the Electrical Conductivity (eC) value assessment. The area classifications were secure (1.1%), vulnerable (24.5%), critical (43.6%) and damage (30.9%) as seen in Figure 1, while based on lowering groundwater level, there were 68,8% secure zone, 28.5% vulnerable zone, 1.1% critical zone and 1.6% damage zone in lowland area of Semarang city. This study is focused on the critical class as the largest area in conservation classification.

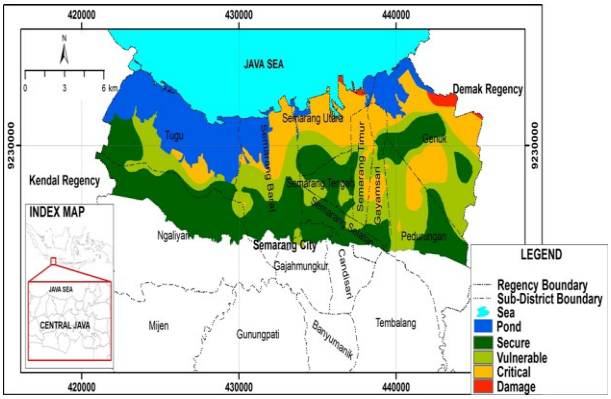

Fig. 1. Map of groundwater conservation zones in lowland areas of Semarang city based on electrical conductivity value [8]

Based on these results, preliminary results of human factor can be taken into account. The evaluation of human factor cover a land use map that explains the impact of human activities on groundwater state [9]. Besides, the assessment of human perception using adapted Protocol Perception Monitoring [10] for each classification also taken into account. Water resources

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and their management are critical to human security and are essential for achieving sustainable development [11].

Recent global analyses have revealed that almost no area of the world is untouched by human impacts [12]. Thus, an understanding of the location and intensity of human impacts on the ecosystems is an essential component of informed and successful coastal management. Mapping of human activities and behaviour allows an assessment of human activities impacts on the health of these ecosystems [13].

A recent study of the human factor in groundwater management is conducted by [14]. They design an ergo-hydrogeology system to model groundwater based on zonation method. However, this study only considers technical system in groundwater management including mapping of the groundwater utilisation and zonation. Ergonomic aspect only adopted on the concept of the study using SHIP (Systemic, Holistic, Interdisciplinary, and Participatory) approach.

Therefore, this study aims at exploring the human factor in the groundwater management to achieve a balance and an integrated design of groundwater system both on the technical and human aspects.

2 Literature reviews

2.1 Human activities

Human activities can affect the groundwater quality and increase its pollution risk. Using the land use/cover map of the study area, a classification of human activities can be mapped and analysed. Classification of the land use covers six classes: urban, agriculture, natural vegetation, water, evaporation pond and bare land [9] and the rating for each class will be referred to the categorization of land use by Secunda *et al.* [15].

Considering human as an integrated part of the ecosystem and a role holder of environment stresses regarding urbanisation and industrial development, human activities that may impact the condition of groundwater should be taken into account. Data of human activities will be obtained based on different land use or cover map. Industrial activities, traffic, septic tanks and sewer systems within urban areas and fertilisers, used in agriculture, are considered as 'hazards' [16] and categorised under the human activities parameter. These hazards can affect the groundwater quality and increase its pollution risk.

Therefore, there will be a classification of land use/cover including urban, agriculture, natural vegetation, water, evaporation pond, and bare land. The detailed ratings for each class are given in **Error! Reference source not found.**.

2.2 Perception monitoring

There are many studies about perception monitoring in environmental topic, i.e., Protocol Perception Monitoring [17,18,19] applied in Marine Protected Areas in Indonesia. These studies aimed at highlighting the trends in the measured perceptions, and look at differences in these perceptions between the different villages that took part in the surveys. Perception monitoring protocol includes the structured questionnaire, the interviewer selection procedure, sampling procedure and interview procedure, is an adaptation of the MPA monitoring standard developed by Bunce and Pomeroy [20].

This study adapted perception monitoring protocol to obtain perception data of the communities around the lowland areas of Semarang city. Deviation of the human perception is defined as the gap between expected and observed behaviour. Therefore, this study designed the questionnaire based on the necessity of perceived data of the communities to be compared with the actual data.

Table 1. Land Use [15].

Land Use Category	Rating
Site-specific Land Usage	
Toxic-waste disposal	9
Oil spillage	8
Industries	7
Solid-waste disposal (regional)	6
Domestic-waste disposal (local)	5
Effluent irrigated fields	4
Effluent reservoir	3
Extensive Land Usage	
Cotton	10
Built-up area	8
Irrigated field crops	8
Greenhouses/tomatoes	8
Reservoirs	7
Citrus orchards	7
Orchards of other fruits	6
Pasture or other land unsuitable for agriculture use	5
Uncultivated land	5
Temporary uncultivated land	5
Vineyards	5
Olives	5
Quarries	5
Non-irrigated field crops	4
Avocados	2
Forests	1
Natural areas or reserves	1
Dune sands – open areas	1

3 Research methods

Methods in this research were applying into two stages including land use analysis and human perception analysis. Land use analysis was focused on lowlands of Semarang city and mapped during collecting water samples in a preliminary study 7.

The human perception was analysed using the deviation between expected and observed behaviour of the residents. The respondent was selected based on the location of residence. It also considered the proportion of the population compared with the area study [21]. As the preliminary study, there were in total 94 respondents in lowlands of Semarang city. These respondents were distributed based on the area of each zone of conservation as seen in Table 2.

Table 2. Distribution of respondents

No	Conservation zone of the area	Number of respondents
1	Secure	37
2	Vulnerable	28
3	Critical	21
4	Damage	8

This stage was using a questionnaire to obtain human perception data regarding the groundwater conservation. The questionnaire contained the understanding of area situation (V1) (6 points), utilisation of groundwater (V2) (7 points) and water resources (well (V3) with 12 points and/or PDAM (V4) with 5 points) as well as the community comprehension of government regulation on groundwater conservation (V5) (7 points).

Actual human perception data (Observed Value/OV) was compared with ideal condition (expected value = EV) of human perception regarding groundwater conservation. The formula can be seen in Equation (1). Expected value was obtained based on the multiplication of the maximum points and number of respondents for each variable, while the observed value was generated from the total right point for each variable.

$$\text{Deviation (D)} = \frac{\text{EV}-\text{OV}}{\text{EV}} \text{x} 100\% \quad (1)$$

An analysis was then conducted to evaluate the human perception in lowland areas of Semarang city.

4 Result and discussion

4.1 Land use

The result of the study showed that the largest area of Semarang city lowland was covered by the built-up areas and irrigated field crops (96.9 km^2 or 68% of total area). Besides, industry and reservoir were placed in a second largest area (35.8 km^2 or 25.1%). Detail of the study result can be seen in Table 3 and Figure 2.

With these results, it should be further examined whether the communities aware of the situation of the land cover. The utilisation of the groundwater should be considered due to the least area of forest and open areas (only about 2% of total area in lowlands of Semarang city).

Table 3. Land use cover

Land use	Score	Area (km^2)	%
Forests, Park, open areas	1	3.4	2.4
Non-irrigated field crops	2	4.7	3.3
Plantation	5	1.7	1.2
Industries, reservoirs	7	35.8	25.1
Built-up area, irrigated field crops	8	96.9	68.0
	Total	**142.4**	**100**

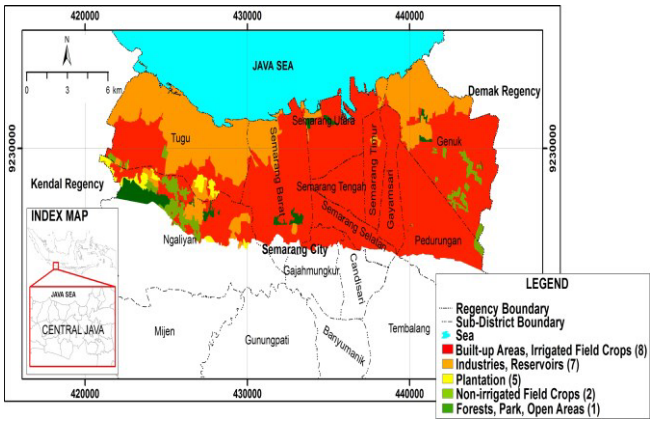

Fig. 2. Map of land uses in lowland areas of Semarang city.

4.2 Human perception monitoring

Based on the questionnaire result, it can be concluded that the communities in lowland areas of Semarang city had a high deviation value considering expected and observed behaviour in groundwater utilisation. The recapitulation of the study results for each classification of conservation zone can be seen in Table 4. Detail deviation for each variable in a different zone of conservation can be seen in Table 5. The deviation value can be different for each variable depended on the number respondents. The number of respondents using the well and/or the PDAM can be varied for a different zone of conservation area.

Table 4. Deviation of human perception.

No	Conservation area	EV	OV	D
1	Secure	210	114.5	45.5%
2	Vulnerable	160	73.3	54.8%
3	Critical	107	54.3	49.9%
4	Damage	47	20.8	53.5%

Table 5. Deviation of human perception for each variable

	Secure			Vulnerable		
	EV	**OV**	**D (%)**	**EV**	**OV**	**D (%)**
V1	222	97	56.3	168	73	56.5
V2	264	152	42.4	204	83	59.3
V3	95	54	43.2	80	36	55
V4	259	155	40.2	196	101	48.5
V5	147	75	49	196	32	83.7
	Critical			**Damage**		
	EV	**OV**	**D (%)**	**EV**	**OV**	**D (%)**
V1	126	62	50.8	48	16	66.7
V2	60	28	53.3	36	26	27.8
V3	95	49	48.4	40	18	55
V4	147	78	46.9	56	35	37.5
V5	147	34	76.9	56	4	92.9

Based on these results, it can be further analysed that community comprehension regarding government regulation obtained the highest deviation in vulnerable (83.7%), critical (76.9%) and damage (92.9%) areas. It means that community in damage areas do not conform and obey the government regulation regarding groundwater system in their areas, whereas they should be aware of the risk and danger of living the vulnerable areas especially related to the utilisation of water and groundwater resources. The result also confirmed that understanding regarding area situation of the residents in damage area was in low level compared with other areas. Therefore, even the damage area only cover less than 2% lowland area, the intervention for the residents should be actively implemented.

5 Conclusions

Based on the result of the research, it can be concluded that more than 90% lowland areas in Semarang city have been intervened by the human activities. It covered by the built-up areas and irrigated field crops (96.9 km^2 or 68% of total area), industry and reservoir (35.8 km^2 or 25.1% of total area), non-irrigated field crops (4.7 km^2 or 3.3 of total area), forests, park, open areas (3.4 km^2 or 2.4% of total area), and plantation (1.7 km^2 or 1.2% of total area). The result of human perception conducted a low level of community understanding regarding government rule and area situation, especially for residents in vulnerable (deviation = 54.8%) and damage areas (deviation = 53.9%). The further studies can be developed research topics into ecological behaviour, the design of intervention for the community as well as mapping the human perception in the groundwater conservation.

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