

Rain harvesting patterns for a dynamic secondary city: a case study of Semarang City

Y Prihanto^{1,4}, R H Koestoer^{1,4}, D Sutjiningsih^{2,4} and L Darmajanti^{3,4}

¹ School of Environmental Science

² Department of Civil Engineering, Faculty of Engineering

³ Department of Sociology, Faculty of Social and Political Science

⁴ Universitas Indonesia, Depok 16424, Indonesia

Email: putranusa212@yahoo.com

Abstract. Semarang is considered as a secondary city in a country like Indonesia. Beside its unique characteristics due to its location in northern coast of Central Java, it also faces increasing water demand. Semarang implements rain harvesting technology but has not yet achieved desired standard level. This study aims to identify community acceptance pattern of rain harvesting in settlement area through a combined method of landscape physiography units and urban observation of non-parametric statistical questionnaires. Both are supported by geographic information system. Variables measured were knowledge, perception, and attitude. Findings resulted in spatial distribution of rain harvesting pattern.

Keywords: *Acceptance, community, pattern, rain harvesting, urban.*

1. Introduction

Many countries are aware of increasingly critical condition of water resources. UNESCO has set a shared vision of water management to achieve a sustainable world's water resources in 2050. That vision seeks to achieve water management conditions related with resources that can support human well-being and ecosystem integrity in a strong economic situation. It is expected that water can be available sufficiently in quality and quantity to meet basic needs of everyone. Development of human settlements is expected to be aligned with natural water cycles and ecosystems in order to reduce vulnerability and to increase resilience in facing water caused natural disaster [1].

In line with UNESCO's vision, many countries in the world, such as America, Australia, Japan, China, Korea, India, South Africa and Jordan, have reviewed and applied various methods of rain harvesting as alternative source of water and water saving facilities [2, 3, 4, 5, 6, 7]. Rain harvesting methods are not new in managing and fulfilling clean water needs. Rain harvesting recently has become an increasingly popular alternative source of effective water collecting with reasonable cost and easy maintenance [8].

There is a huge potential of rain harvesting in Indonesia in reference to average rainfall in Indonesia that reaches 2,347 mm per year, except in East Nusa Tenggara that is about 1,200 mm per year. The quantity of potential water availability in Indonesia is 3,221 billion m³ per year or equivalent to 16,800 m³ per capita per year [9]. This condition is contrary to the fact that parts of Indonesia have faced water security threat due to water deficit [10].



Water resistance threat especially in Java Island is mainly caused by population growth, beside other government, development and economy activities. This condition causes water concentration needs in Java. The population of Indonesia has reached 237,641,300 people in 2010 and was projected to reach 252,164,800 by 2014. Among those population, 57.44% or equivalent to 136.5 million are living in Java Island. Java Island covers only 6.77% of total area of Indonesian territory [11]. The inhabitants of Java Island are generally concentrated in coastal cities in north of Java Island such as Jakarta, Cirebon, Semarang, and Surabaya. Based on Working Group on Water Supply and Environmental Sanitation of Indonesia report, Java water availability in 2000 is only 1,750 m³ per capita per year. This number continues to decrease to 1,200 m³ per capita per year in 2020, whereas minimum water adequacy standard is 2,000 m³ per capita per year [9].

Semarang City Government has run socialization program and provision of rain harvesting facilities. This program is implemented on awareness of urban water resilience due to population growth, landscape physiographic and climate change impacts. Unfortunately, this program shows diminutive results. The community continues to meet their water needs by using groundwater and/or buying bottled water. People's interest for rain harvesting does not increase very significant. Although some studies have stated that utilization of rain harvest is relatively efficient economically [12, 13]. The reason might be due to implementation of rain harvesting programs that tends to be technical. Some evident can be seen in Worm & Hattum study [14]. They argue that if the rain harvest system will be built and developed in a specific location, it is necessary to conduct five systematic steps. These steps are: determining the total amount of water requirements, designing rain catching areas, designing rain delivery systems, determining the size of water storage required, and selecting suitable water storage designs. This systematic step does not seem to put the elements of society as the subject of a comprehensive system. The community is only consigned as object of the program.

This research has two fundamental questions that want to be answered related to condition in Semarang City. The first question is whether there is a different pattern of community acceptance on different physiographic landscapes. The second question is how the relationship and the influence level of knowledge variables and perceptions affecting individual attitudes in determining the level of acceptance in application of rain harvesting. The aims of this research are to recognize patterns of public acceptance on physiographic landscape and to assess how much people's knowledge and perception contribute to people's attitudes in their determination toward rain harvesting.

2. Methodology

2.1. Study area

This research is conducted in Semarang City administration area that is considered to represent many cities on the north coast of Java Island. Semarang City is also considered to represent plurality of urban and peri-urban cultures. In landscape physiography, Semarang City has an absolute uniqueness because the region of Semarang can be divided into 3 regions, lower Semarang, center Semarang, and upper Semarang. The administrative city of Semarang is divided into 16 sub-districts and 177 urban villages.

2.2. Secondary data (*land use data, landscape physiography, and statistical data on population*)

This research uses land use data obtained from BIG (Geospatial Information Agency of Indonesia). The data is in the form of visual interpretation of high-resolution satellite image recorded in 2012. That interpretation of imagery result has been validated through field work activity in 2013 and 2016. Land use unit that become priority of observation is settlement and non-settlement area.

This research uses supporting data in the form of maps, namely: topography, geology, slope, and imagery data SRTM (Satellite Radar Topographic Mission) 30m resolution to obtain physiographic picture. Topographic maps using digital maps from BIG of 2013 production. Geological and slope maps using digital maps from spatial planning document of Semarang City 2005-2030 product of Regional Development Planning Agency of Semarang City.

Population data uses BPS (Central Bureau of Statistics) Semarang City, 2012 and 2015 data. Population data used is population and number of head of households and area of district administration.

2.3. Sampling method

The sample of respondents was determined by stratified purposive random sampling method. The number of samples is determined purposively by considering distribution of sub-district area and number of head of household. The population of this research is the entire head of family, or members of the family, or self-sufficient individuals who are able to make choices and determine the decisions of the type of water source that is utilized to meet the needs of individual families or individuals. The sample of respondents can be male or female and randomly determined.

This research calculates the minimum sample size based on number of urban household heads in 2015 in comparison with sub-district administration area. The minimum sample size to meet 95% accuracy is 400 respondent samples. The city administration area is grouped into 3 units of observation area based on landscape physiography unit. Each unit of landscape physiography should be represented in the minimum sample size calculation.

2.4. Variables

This study has 3 variables. Variables are calculated using questionnaires. There are two independent variables and one dependent variable. The independent variables measured are knowledge (11 questions) and perceptions (8 questions), while the dependent variable measured was attitude (8 questions). These three variables are expected to describe community acceptance patterns of rainwater harvesting in settlement areas, both in urban centers and peri-urban areas. In this case, Likert scale is used to facilitate quantification of variables that are generally qualitative in nature.

Table 1. Questions on knowledge variable.

No.	Questions on knowledge variable
A1	Do you know what is rain harvesting meant?
A2	Do you know that rain water can be used for household purposes such as washing, watering, and bathing?
A3	Did you know that collecting rainwater in the tank is one of rainwater harvesting activities?
A4	Do you know that absorbing rainwater into soil through absorption wells is on rain harvesting activities?
A5	Do you know how to create and the benefit of absorption wells?
A6	Do you know that absorbing rainwater into soil through biopore hole is one of rain harvesting activities?
A7	Do you know how to create and the benefit of biopore holes?
A8	Do you know that harvesting and absorbing rainwater can reduce the risk of flooding in rainy season?
A9	Do you know that harvesting and absorbing rainwater can reduce the risk of drought in dry season?
A10	Do you know that by rain harvesting we can reduce the cost of daily water needs?
A11	Do you know that pumping and excessive use of groundwater can cause decreasing ground surface?

The scoring method on each question group under each variable uses Likert scale with variation of score 1-5. Score 1 represents the worst condition whereas score 5 represents the best condition. Variable knowledge has 3 choices of answers i.e. know (score 5), hesitate (score 3) and do not know (score 1). Variable perception has 5 choices of answer i.e. very imprecise (score 1), imprecise (score 2), quite precise (v 3), exact (score 4), and very precise (score 5). The attitude variable has 5 choices

of answer, i.e. strongly disagree (score 1), disagree (score 2), simply agree (score 3), agree (score 4), and strongly agree (score 5). The final value of each variable is the sum of total sum of answers obtained. Variable knowledge will have a minimum value of 11 and a maximum value of 55. Variable perceptions and attitudes will have a minimum score of 8 and maximum value of 40.

2.5. Questionnaire

Questions in the questionnaire are organized and grouped into number of variables assessed. Each question in variable group considers environmental, social and economic management values for sustainable condition. If the variables score value is higher, it is estimated that the community acceptance will also be higher. High community acceptance is expected to ensure sustainability of rain harvesting. The questions on the questionnaires are presented in Table 1, Table 2, and Table 3.

Table 2. Questions on perception variable.

No.	Questions on perception variable
B1	According to you, is it appropriate/suitable if we use rainwater from the roof for domestic purposes such as washing clothes, washing vehicles, watering plants, bath and sanitary?
B2	According to you, is it appropriate/suitable if we use rainwater from the roof using a tub or tank for drinking water?
B3	According to you, is it appropriate/suitable if there are efforts to absorb rainwater using absorption wells to increase ground water availability and reducing impact of drought?
B4	According to you, is it appropriate/suitable if there are efforts to absorb rainwater using biopore to increase ground water availability and reducing impact of drought?
B5	According to you, is it appropriate/suitable if there are efforts to absorb rainwater using absorption and biopore wells to reduce the risk of flooding in urban areas?
B6	According to you, is it appropriate/suitable if there are efforts to collect rainwater in your home or neighborhood to be applied as an alternative water source than ground water and tap water?
B7	According to you, is it appropriate/suitable if there are efforts to accommodate and to absorb rainwater to apply in urban areas to resolve the flooding problem?
B8	According to you, is it appropriate/suitable if there are efforts to accommodate and to absorb rainwater to be implemented in urban areas to resolve drought and water shortages?

The distribution of questionnaire to the respondents is conducted in two ways. The first way is to interact directly with the respondents. This is done in areas considered to be peri-urban areas or areas with lower social strata. The second way is by distributing questionnaires through community leaders or environmental officials. The second way is done in urban areas that are considered to have higher social strata. The higher social strata can be expressed in higher levels of income and higher education levels.

Table 3. Questions on attitude variable.

No.	Questions on attitude variable
C1	Do you agree, if the central/regional government promotes rain harvesting in your area by developing a reservoir/tank to meet sufficiency water needs?
C2	Do you agree, if the government promotes rain harvesting in your area through development of absorption wells and/or biopores to absorb water and reducing flooding risk?
C3	Do you agree, if you are asked to get involved in rain harvesting activities by preparing your own tanks/tubs to collect rainwater in your home?
C4	Do you agree, if you are asked to be involved in rain harvesting activities by making your own absorption well and/or biopores to absorb rainwater in the vicinity of your residential area?
C5	Do you agree, if the government provides equipment and community assistance to provide

No.	Questions on attitude variable
	means and infrastructure of rain harvesting, such as tank, well, and drill?
C6	Do you agree, if the government provides incentives in the form of tax deductions or exemptions on earth and buildings if you apply rain harvesting through applying absorption wells, biopore and/or rainwater reservoirs in your residence?
C7	Do you agree if - harvesting or collecting rainwater activities in a tub/water tank for sufficient water needs should be managed through community or urban village activities?
C8	Do you agree, if the activities to create and to maintain absorption wells and/or biopore to absorb water, to reduce flooding and drought risks should become routine joint activities managed by community or urban village?

2.6. Data analysis method

The result of the questionnaire is processed using statistics method and being analyzed using descriptive and path analysis. Descriptive analysis is used to determine distribution of knowledge, perceptions and attitudes values spatially in each administrative unit and landscape physiography region. Path analysis is used to find out the most influent variables and how each variable influences each other.

3. Result and Discussion

This section will present results of each stage performed and reviewed the relationship between one part with another. This section will also look at the community phenomenon in relation with the implementation of rain harvesting in Semarang City.

3.1. Landscape physiography and land use in Semarang City

Figure 1 illustrates height and shape of Semarang surface area. Figure 2 shows spatial distribution of settlement areas in Semarang City. Both of these images provide an overview of linkage between landscape physiography and land use specifically the settlement areas.

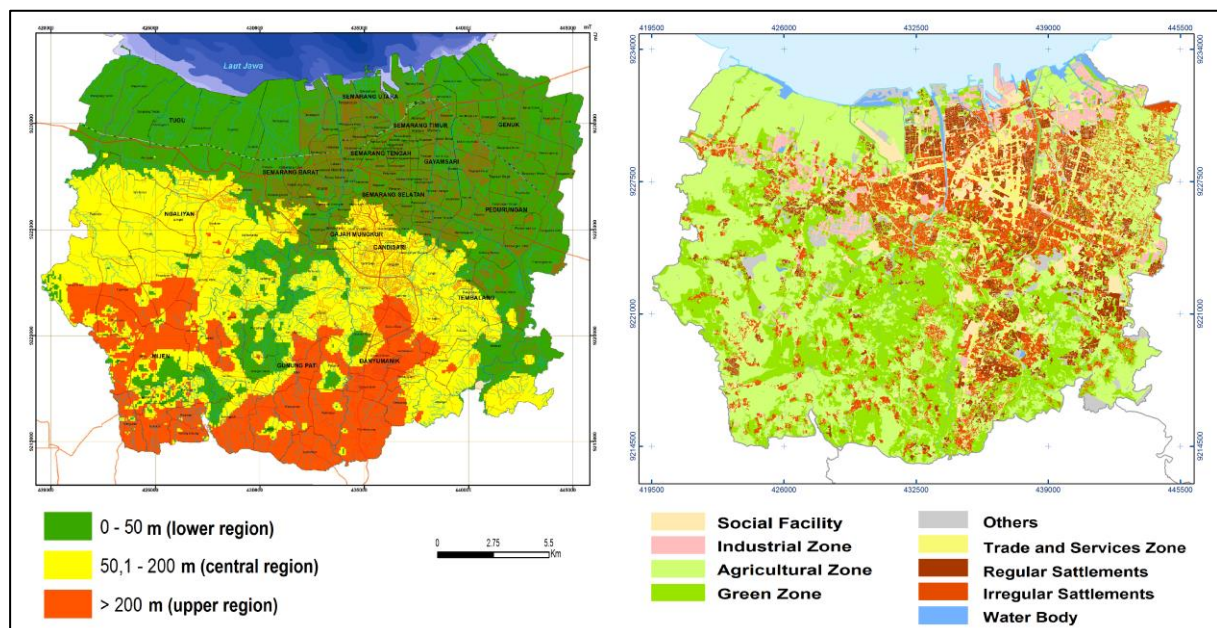


Figure 1. Landscape physiography of Semarang City.

Figure 2. Land use of Semarang City.

3.2. Value distribution of knowledge, perception, and attitude in sub-districts

The sample data collected in this study came from 588 respondents. Based on results of analysis in Table 4, it is seen that sub-districts with low average score of low knowledge are Gayamsari (17.13), Genuk (25.06), and Candisari (27.84) sub-districts. For high level of knowledge are East Semarang (43.40), Ngaliyan (43.17), and Banyumanik (42.88) sub-districts. Sub-districts with lower average score of perception score are Gayamsari (22.14), Genuk (22.34), and Candisari (23.58) sub-districts. For high perception level is East Semarang (29.05), Ngaliyan (28.93), and Banyumanik (28.21) sub-districts. Sub-districts with a total score of low average attitude were Gayamsari (14.91), Genuk (16.31), and Candisari (26.37) sub-districts. The high level of attitude sub-districts is Tembalang (30.51), Banyumanik (30.50), and East Semarang (30.35) sub-districts. Referring to data results, it appears that knowledge and perception variables have similar value distribution patterns. Based on value variations, perceptual and attitude variables have similarity patterns of distribution.

Table 4. Value distribution of knowledge, perception, and attitude on sub-districts.

Sub-district	Region	Sample amount	Average Value of Total Score		
			Knowledge	Perception	Attitude
Semarang Barat	Lower region	46	37.48	26.17	29.67
Tugu	Lower region	8	32.13	27.88	30.13
Gayamsari	Lower region	18	17.13	22.14	14.91
Semarang Utara	Lower region	30	35.67	28.20	29.47
Semarang Timur	Lower region	20	43.40	29.05	30.35
Semarang Tengah	Lower region	30	32.83	27.93	28.23
Semarang Selatan	Lower region	24	42.50	26.79	28.04
Genuk	Lower region	23	25.06	22.34	16.31
Pedurungan	Lower region	77	38.01	26.60	29.04
Ngaliyan	Central region	41	43.17	28.93	30.15
Gajahmungkur	Central region	24	37.08	26.83	29.33
Candisari	Central region	19	27.84	23.58	26.37
Tembalang	Central region	69	38.72	27.68	30.51
Mijen	Upper region	31	31.81	26.61	28.81
Gunung Pati	Upper region	70	36.69	28.11	29.43
Banyumanik	Upper region	58	42.88	28.21	30.50

3.3. Value distribution of knowledge, perception, and attitude on landscape physiography unit

The same sample data is further processed and analyzed by landscape analysis unit of physiography. The results of this analysis show several things that can be observed based on average score of total score presented in Table 5, Figure 3, 4, and 5. Generally, average score of the highest score on knowledge and attitude is found in the central region of unit analysis. The second rate of average score on total knowledge and attitude scores is found in the upper region of unit analysis. The average value of highest perception score on the highest position is found in the upper region of unit analysis. People in the lower region of unit analysis generally have the lowest average score of total value, in exception for the perception value that has the same value with those in the central region of unit analysis.

Table 5. Value distribution of knowledge, perception, and attitude on landscape physiography unit.

Region of Semarang City	Sample amount	Average Value of Total Score		
		Knowledge	Perception	Attitude
Lower region	276	36.65	27.37	29.27
Central region	153	38.31	27.37	29.71
Upper region	159	37.99	27.86	29.70

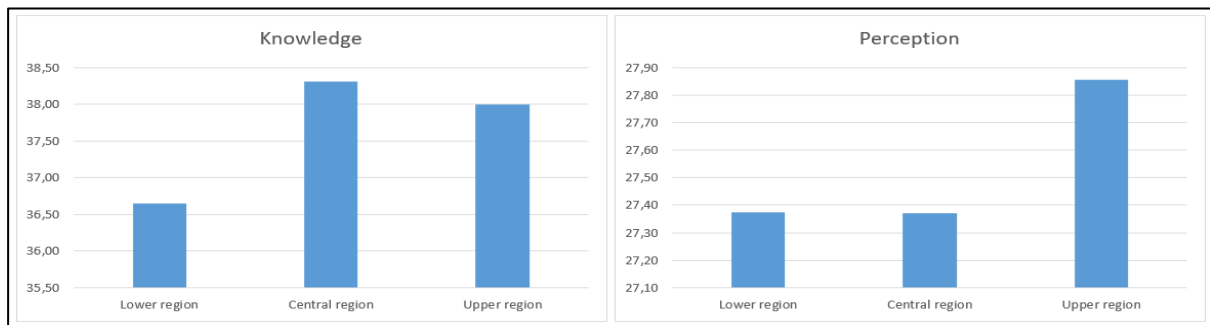


Figure 3. Average value of total score knowledge in the region.

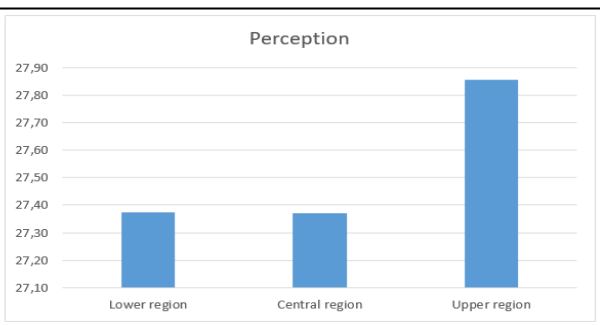


Figure 4. Average value of total score perception in the region.

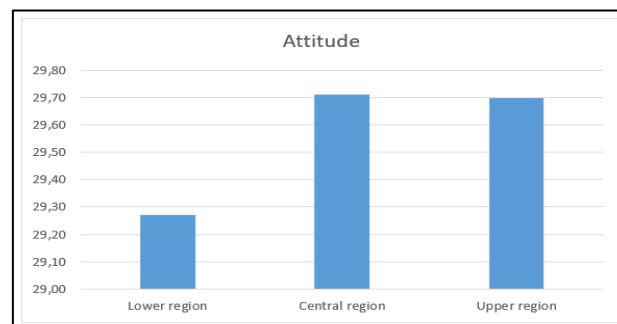


Figure 5. Average value of total score attitude in the region.

3.4. Path analysis of knowledge, perception, and attitude

The result of path analysis test is to show that the relationship between X_1 variable (knowledge variable), X_2 (perception variable), and Y (attitude variable) can be illustrated as Figure 6. Table 6 presents the results of regression calculations showing relationship and magnitude of the effects among variables that are taken into account. Knowledge variable contributes 0,58% as direct effect on attitude variable, whereas, perception variable has 20,34% direct effect on attitude variable. On the other hand, indirect effect of knowledge variable and perception variable to attitude variable is 1,36%. Total effect of knowledge variables only contributes 1,94% on attitude variable, while perception variable on attitude equal is 21,70%. The result of path analysis shows that the perception variable influences more than the knowledge variable, however other internal factors outside those 2 variables calculated in this research have more considerable influences, that is 76.36%.

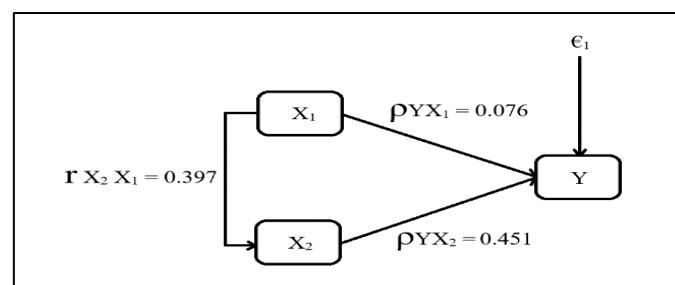


Figure 6. Structure of path analysis.

Table 6. Relationship and influence between variables.

Effect	Relationship	Influence	Influence Value	%
Direct Effect (DE)	$X_1 \rightarrow Y$	$\frac{(\rho_{YX_1} \times \rho_{YX_1})}{(0.076 \times 0.076)}$	0.0058	0.58
	$X_2 \rightarrow Y$	$\frac{(\rho_{YX_2} \times \rho_{YX_2})}{(0.451 \times 0.451)}$	0.2034	20.34
Indirect Effect (IE)	$X_1 \rightarrow X_2 \rightarrow Y$	$\frac{(\rho_{YX_1} \times r_{X_2X_1} \times \rho_{YX_2})}{(0.076 \times 0.397 \times 0.451)}$	0.0136	1.36
Total Effect (TE)	X_1	$\frac{(DEX_1 + IE)}{(0.0058 + 0.0136)}$	0.0194	1.94
	X_2	$\frac{(DEX_2 + IE)}{(0.2034 + 0.0136)}$	0.2170	21.70
	$X_1 \text{ and } X_2$	$\frac{TEX_1 + TEX_2}{(0.0194 + 0.2170)}$	0.2364	23.64
Residue	$\epsilon_1 \rightarrow Y$	$(1 - 0.2364)$	0.7636	76.36

4. Conclusion

In general, the results of this research indicate that there is a relationship of landscape physiography and patterns of public acceptance level in rain harvesting application. The result of descriptive analysis shows that value of knowledge; perception and attitude lead to different patterns on each landscape physiography analysis unit. This pattern also indicates that urban growth pattern is related to population growth distribution.

Path analysis shows that perception variables give more contribution on rain harvesting application than public knowledge related to public attitudes. This condition shows that rain harvesting efforts and programs implementation are insufficiently done if only using dissemination of information. Increased knowledge on rain harvesting is not enough to encourage public attitudes to support successful implementation of rain harvesting.

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