Rain water harvesting: barrier, potency and projections. 
Case study: Keputih, Kejawan and Gebang Putih Surabaya

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Abstract. The rainwater harvesting locally collects and stores rainfall through different technologies, for future use to meet the demands of human consumption or human activities. However, rainwater harvesting has much wider perspectives, in particular, if it is considered in relation to its role in supporting ecosystem goods and services. There are challenges and different implications in rain water harvesting practices in Urban and sub urban area, especially when it applied in the low income community area. The case study are Kampongs in near campus area, which are the low-middle income community that expected to be relatively “educated” compare to the other low income community in the others part of Surabaya. The results shows that the study area has a unique characteristic of spatial contour and demographic background which allow this area to adopt a rainwater harvesting technic both in urban and rural practice. Therefore, the rainwater harvesting implementation in the study area will resulting many benefits to the community. Furthermore, the surveillance from the context of water needs reveal that the community in general is appertain to the water scarcity. On the other hand, the settlement environment is enable to be applied by the rainwater harvesting practice.

1. Introduction

Rainwater harvesting is one of the techniques in application of Integrated Urban Water Resources Management (IUWRM) concept. Rainwater harvesting is a multipurpose way of supplying usable water to consumers during a crisis period, recharging the groundwater and finally reducing the runoff and water logging during the season of heavy rainfall. Traditional knowledge, skills, and materials can be used for this system. During the rainy season, an individual can collect water on his rooftop and manage it on his own. Reserved rainwater on rooftops can be used for self-purposes or domestic use. Water from different rooftops of a lane can also be collected through a piped network and stored for some time. This water can be then channeled to deep wells to recharge groundwater.

Rainwater harvesting offers an environmental solution aimed at addressing issues which are related to the water management approach [1]. Maryono and Santoso, mentioned that in the international world today, the effort of rainwater harvesting has become an important part in the global environmental water resources management agenda in order to overcome the water inundation in the rainy and dry season, lack of clean water supply for world population, and also for flood and drought mitigation [2].
Rainwater harvesting application techniques are increasingly being considered in line with the high rate of urban population growth, where the provision of clean water sources is no longer an easy task as the realities on the ground often indicate that some urban areas are experiencing scarcity of clean water [3]. Kim continued that rainwater harvesting is one of the best methods to meet the need for clean water sourced from the natural hydrological cycle which provides an opportunity for urban development to continue, yet also ensures sustainability [4]. Furthermore, Olorotunde and Orgontnde find the fact that rainwater harvesting provides an alternative to water supply in the event of a drought that causes water scarcity [5].

In Indonesia, the source of clean water in urban areas is still based on ground water. The amount of ground water is getting smaller and less difficult to obtain as a result of the fewer recharge areas. While the use of groundwater is quite high, especially in Java, causing the water supply of land that is getting thinner and decreasing the level of ground level. A study by UNEP shows that groundwater is becoming more scarce in large urban areas due to reduced water infiltration [6]. The decrease of groundwater recharge in the cities is directly proportional to the increase in the pavement and roof area. In addition, high population density is has brought about high groundwater consumption.

However, data also noted that more than 33 million Indonesians lack access of safe water [7], means involved large number of Indonesian population. In fact, the huge number of people not only comes from urban areas, but suburban and rural areas remains facing this serious challenge. From here we see an obvious strong community demand for water that satisfies the public in terms of quantity - and quality tends to increase. Conversely, because the quantity of available water is relatively, new methods or techniques must be developed as a solution which provide society to water resources.

In responding to that water provision issue, In the early 2010, Indonesian government introduced a regulation requiring that all buildings have an infiltration well [8]. The regulation applies to two-thirds of the territory, including the Special Province of Yogyakarta, the Capital Special Province of Jakarta, West Java and Central Java Province. It is estimated that if each house in Java and Madura had its own infiltration well, the water deficit of 53% by the year of 2000 would be reduced to 37%, which translates into a net savings of 16% through conservation. But another innovation still needed in order to resolve water supply issue both in urban or suburban area in Indonesia. Theoretically, rainwater harvesting is obviously applicable, yet relevant to overcome that issue.

This paper will explain further about rainwater harvesting methods and techniques, which suitable to apply in urban or suburban area and also the potency, barrier and projection in The Surabaya city cases. Rainwater harvesting already known as method which is flexible and adaptable to a very wide variety of conditions, It is used in the richest and the poorest societies, as well as in the wettest and the driest regions on our planet [9]. Therefore, the method has a big opportunity to well executed in many parts of Indonesia region including the three cases area.

2. Methods
This research is using positivist approach and quantitative kind of research to investigating what are the barrier, potency and projection of rain water harvesting techniques application in Surabaya City. This is applied research kind of study which targetting the settlements around campus ITS to reach its sustainability which one of the issues is water supply. This research is also a program for Campus Social Responsibility that choose the case study in three area: Keputih, Kejawan Putih Tambak dan Gebang Puth. To have an optimum sampling SRS, we use the formula as Sevilla describe to determine the bound of error (B) [10]:

$$ n = \frac{N}{1+NB^2} $$

There are several scenarios in order to determine bound of error which are: 5%, 10%, dan 25%. Since this is small grant research, the researcher choose the B = 25%.
Figure 1. The Rain Water Harvesting Sampling

Source: [11]

3. Result and Discussions

3.1. Comparison on Techniques for Rainwater Harvesting Application: Urban and Suburban Practices

Water is an important natural resource and is the very basis of our life. In urban areas, water used for drinking, irrigation, industry, transport and for the production of hydro-electricity. Water is a cyclic resource which can be used again and again after cleaning. The best way to conserve water is its judicious use. Meanwhile, suburban area used water for somewhat different use. A large quantity of water is used for irrigation and there is an urgent need for proper water management in irrigation sector. Section below will explain what are the rainwater harvesting techniques that commonly used, and practically has already proven to be well functioned, taken from study case in all over the world.

3.1.1. Urban Areas

In urban areas, rain water available from roof tops of buildings, paved and unpaved areas goes waste. This water can be recharged to aquifer and can be utilized gainfully at the time of need. The rain water harvesting system needs to be designed in a way that it does not occupy large space for collection and recharge system. Roof top rain water harvesting can be a very effective tool to fight the problem of water shortage particularly in urban areas. Roof top rain water harvesting depends upon the amount of rainfall and the roof top area. More the amount of rainfall more is the harvested water from roof top. Similarly, larger amount of roof top rain water is harvested from roofs with large area.

Table 1. The Rain Water Harvesting Techniques in Urban Area

| Kelurahan          | N    | n   | B=5% | B=10% | B=25% |
|--------------------|------|-----|------|-------|-------|
| Keputih            | 16157| 390 | 99   | 16    |       |
| Kejawan Putih Tambak | 7737 | 380 | 99   | 16    |       |
| Gebang Putih       | 6297 | 376 | 98   | 16    |       |
| Total              | 30191| 1147| 296  | 48    |       |

Table 1. The Rain Water Harvesting Techniques in Urban Area

| Techniques | Description | Illustration |
|------------|-------------|--------------|
| 1. Recharge Pit | a. In alluvial areas where permeable rocks are exposed on the land surface or at very shallow depth, roof top rain water harvesting can be done through recharge pits; b. The technique is suitable for buildings having a roof area of 100 sq m and is constructed for recharging the shallow aquifers; c. Recharge Pits may be of any shape and size and are generally constructed 1 to 2 m wide and 2 to 3 m deep which are back filled with boulders (5-20 cm), gravels (5-10 mm) and coarse sand (1.5-2 mm) in graded form— Boulders at the bottom, gravels in between the coarse sand at the top so that the silt content that will come with runoff will be deposited. Roof top rain water harvesting through recharge pit the top of the coarse sand layer and can easily be removed. For smaller roof area, | Recharge Pit for Rainwater Harvesting Practice | Source: [12] |
| Techniques | Description | Illustration |
|------------|-------------|-------------|
|            | pit may be filled with broken bricks/cobbles; |             |
| d.        | A mesh should be provided at the roof so that leaves or any other solid waste/debris is prevented from entering the pit and a desalting/collection chamber may also be provided at the ground to arrest the flow of finer particles to the recharge pit; |             |
| e.        | The top layer of sand should be cleaned periodically to maintain the recharge rate; |             |
| f.        | By-pass arrangement is provided before the collection chamber to reject the first showers. |             |
| a.        | Recharge trenches are suitable for buildings having roof area of 200-300 sq m and where permeable strata are available at shallow depths; | Recharge Trench for Rainwater Harvesting Practice Source: [13] |
| b.        | Trench may be 0.5 to 1 m wide, 1 to 1.5 m deep and 10 to 20 m long depending upon availability of water to be recharged; |             |
| c.        | These are back filled with boulders (5-20 cm), gravels (5-10 mm) and coarse sand (1.5-2 mm) in graded form—boulders at the bottom, gravel in between and coarse sand at the top so that the silt content that will come with runoff will be deposited on the top of the sand layer and can easily be removed; |             |
| d.        | A mesh should be provided at the roof so that leaves or any other solid waste/debris is prevented from entering the trench and a desilting/collection chamber may also be provided on ground to arrest the flow of finer particles to the trench; |             |
| e.        | By-pass arrangement is provided before the collection chamber to reject the first showers; |             |
| f.        | The top layer of sand should be cleaned periodically to maintain the recharge rate. |             |

Source: [11]

### 3.1.2. Sub-urban Areas

In suburban areas, rain water harvesting is taken up considering watershed as a unit. Surface spreading techniques are common since space for such systems is available in plenty and quantity of recharged water is also large. Following techniques may be adopted to save water going waste through slopes, rivers, rivulets and nalas (dry riverbed or ravine).
Table 2. The Rain Water Harvesting Techniques in Sub-urban Area

| Techniques                        | Description                                                                                                                                                                                                                                                                                                                                 |
|-----------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1. Gully Plug & Contour Bund      | **Gully Plug**  
a. Gully plugs are built using local stones, clay and bushes across small gullies and streams running down the hill slopes carrying drainage to tiny catchments during rainy season;  
b. Gully plugs help in conservation of soil and moisture;  
c. The sites for gully plugs may be chosen whenever there is a local break in slope to permit accumulation of adequate water behind the bunds.  
**Contour Bund**  
a. Contour bunds are effective method to conserve soil moisture in watershed for long duration;  
b. These are suitable in low rain fall areas where monsoon run off can be impounded by constructing bunds on the sloping ground all along the contour of equal elevation;  
c. Flowing water is intercepted before it attains the erosive velocity by keeping suitable spacing between bunds;  
d. Spacing between two contour bunds depends on the slope of the area and the permeability of the soil. Lesser the permeability of soil, the close should be spacing of bunds;  
e. Contour bunding is suitable on lands with moderate slopes without involving terracing. |
| 2. Check Dams/Cement Plugs/Nala Bunds | **Check Dams**  
a. Check dams are constructed across small streams having gentle slope. The site selected should have sufficient thickness of permeable bed or weathered formation to facilitate recharge of stored water within short span of time;  
b. The water stored in these structures is mostly confined to stream course and the height is normally less than 2 m and excess water is allowed to flow over the wall. In order to avoid scouring from excess run off, water cushions are provided at downstream side;  
c. To harness the maximum run off in
Techniques
the stream, series of such check dams can be constructed to have recharge on regional scale;
d. Clay filled cement bags arranged as a wall is also being successfully used as a barrier across small nalas (dry riverbed or ravine). At places, shallow trench is excavated across the nala and asbestos sheets are put on two sides. The space between the rows of asbestos sheets across the nala is backfilled with clay. Thus a low cost check dam is created. On the upstream side clay filled cement bags can be stacked in a slope to provide stability to the structure.

Source: [11]

3.2. Barrier of Application Rain Water Harvesting in the Area
3.2.1. Mixed Spatial and Demographic Characteristics of Urban and Sub Urban Within the Study Area
Rainwater harvesting both in urban and suburban area basically applicable in terms of material and technology procurement. The technology is flexible and adaptable to a very wide variety of conditions. It is used in the richest and the poorest societies, as well as in the wettest and the driest regions on our planet. Collected rainwater can supplement other water sources when they become scarce or are of low quality like brackish groundwater or polluted surface water in the rainy season. It also provides a good alternative and replacement in times of drought or when the water table drops and wells go dry.

While in the urban areas rainwater harvesting is practiced for drinking, domestic, gardening, and ground water recharge purposes, in suburban areas it is undertaken more extensively for irrigation, dryland agriculture, horticulture, ground water recharge, domestic, livestock, inland fisheries, duck rearing and for multifarious other similar purposes. Each form of storage has its specific merits and uses, although from the efficiency point of view, underground storage is the best as evaporation and other losses are eliminated.

The typology of the area are located in the estuary area that most likely consist of swamp and also there are scatter area which is are still remain an open spaces and can be use for the rain water harvesting in typically sub – urban area like Gully Plug & Contour Bund. The consideration of conducting a rainwater harvesting practice in this area confronted with many issues pertaining to water in the location like:
1. Lack of full water from traditional sources and therefore rainwater as a supplementary source;
2. Urban flooding therefore rainwater harvesting as a flood mitigation measure;
3. Depletion of groundwater aquifers and therefore rainwater harvesting as a method of artificial recharge;

The characteristics of the area are the combination between urban and sub-urban. Almost 9% of the community still work in the primary sector like fisherman and farmers. The other 50% is blue collar that working in many sectors in ther urban and 28% are working in the white collar and the rest of 13% as an unemployed person. This low income community are mostly finished the high school (48% of the population) and the 18% was attended University. This can be shown in Figure-2 below.
The demographic data shown that there are some needs for usage water as a primary sources for the primary sectors that usually is not urban concerns like:

1. Community water for washing, bathing and for animals, this usually supplied by ponds, ground catchment rock-cisterns, riverbed-cisterns, shallow wells, etc in the sub urban areas but lack of supplies in the case study area;

2. Water for agriculture, this usually supplied by sub-surface impoundments, supplemental irrigation, road catchments for irrigation of fruit trees, use of furrows for storing rainwater in situ, inter-row water harvesting, etc in the sub urban areas but lack of supplies in the case study area.

The mixed characteristic between sub urban and urban life style and the scale of priorities put the conflict prone zone to the water resources, especially there are also still land ownership issues in that area.

3.2.2. Material Barrier of Rain Water Harvesting

Rain water harvesting is one of the safest method to obtain water since the quality of the water from the rain is drinkable in every part of the world. The problem arise when the rain hits the roof it is subject to contamination by pollutants that were deposited on the roof by wind, animals, insects, or by the leaching and dissolving of the material that the roof is made of.

The material that mostly safe for the rain water harvesting is asbestos, galvalum and the unsecure including leads. Woods is mostly safe but the debris of the woods will limit the water use and need more purification techniques.

Figure 3 shown that most material are from asbestos 39% and woods 39%, others are: 1). galvalum 9%, 2). leads layering 5% and 3).combination leads and woods 4% and 5).combination of asbestos and woods is also 4%. The barrier started if the material divided into safe and non safe material for rain water harvesting. Assume the woods and leads is not feasible for rain water
harvesting than total there are 52% house that not feasible for rain water harvesting and there are 48 that relatively safe for rain water harvesting. The conditions caused by the Social Economy Status (SES) of the community that lives in the area. The consequences of the barrier is: 1) Limitation of rain water harvesting utilization, 2) Arising the purification techniques and 3) Increasing number of flushing and cleaning the roof (high maintenance).

3.2.3. Medium – Small Size Catchment Area
The other barrier occur is the medium and small size of the catchment area. The size of the catchment area or roof will determine how much rainwater that can be harvested. The area is based on the “footprint” of the roof, which can be calculated by finding the area of the building and adding the area of the roof’s overhang. From the Figure 4 there are 4 category of observation which are very narrow 9%, narrow 52%, quiet wide 26% and wide 13%. The categorization is not based on the exact counting but by observing the house size. Very narrow is home less than 36 m$^2$, Narrow is between 36-42 m$^2$, quiet wide is in the category of 42-48 m$^2$ and wide is more than 48 m$^2$. It is depends on the rainfall how many can be collected and store in the storage.

3.2.4. Density and Spaces Between The Buildings
The techniques used in suburban area has a very significant difference compared to rainwater harvesting techniques in urban area. In Suburban, where the land relatively wider and remains an expansive vacant land, the techniques also utilizing the existing land. Moreover, the natural resources bring a benefical function the the rainwater harvesting scheme. The existing land surface, contour, and natural dam can be used, makes the technology seems more simple. The problem occurs in the high density area like these is related with the space and dimension for the storage. The Figure 5 shown that the space between buildings are 70% less than 1 m$^2$ and than the other 26% are more than 2 m$^2$ and the other 4% is not willingly to give an answer. With the space available it will be challenges to have a dimension of storage that can store rain water for more than 2 days supply.

3.3. Potency of Application Rain Water Harvesting in the Area
3.3.1. Limited Access to The Water Sources in The Area

Figure 5. The Space Between Buildings
Source: [11]

Figure 6. The Issues of Water Access in The Area
Source: [11]
On the other hand, some of the barriers that happened in the community also being an advantage/potency to applied the rain water harvesting in the area. From Figure 7 although 70% has received services from PDAM (regional water supply instation) but 63% services is only at night services. And the other 13% still have to buy water and 9% is sharing with their neighbor.

3.3.2. Acceptance of The Community in The Area
Perceptions about rain water harvesting is one of the most sensitives case and also key success of the program. Figure 7 describe that at least 55% of the community thinks that it is good to have rain water harvesting in their area. Although 27% is still in doubts and the other 9% prefer government services and there are still 9% of the community is not answering the questions.

3.4. Rain Water Harvesting in The Area: Projection
3.4.1. Secondary Needs Fullfillment for the Area
Figure 8 mostly will answer the question of “how if rain water harvesting is applied in the case study area”. 83% of the community still buying the water in order to fulfill their needs and 4% is building wells. The focus group discussion with the community also reached consensuss, that with the limited fund of the application and also low purifying techniques, the rain water harvesting that will be gathered by the community will not utilize as a primary sources but as secondary sources, such as: 1). Gardening, 2). Laundry, 3). Washing vehicle or kitchen applies, and if plausible 4). Maintenance of animals.

3.4.2. Relevancies and Adaptations with the Needs of The Water in The Area

![Figure 7. Efforts in Lack of Water Supply](source: [11])

![Figure 8. Perceptions in RWH techniques](source: [11])

![Figure 9. The Issues and Relevancies of Water Access in The Area.](source: [11])

Figure 10 shows that there are complex problems (56%) of the area that including little water services, land ownership issue, drainage, high density to solid waste troubles that might be has become priority over the rain water harvesting. Some of the highlight issues are high density and space for the storage. So instead bulging the big constructions that can store water for a weeks or more. The community will use it on the different mode between the rainy and dry seasons as an adaptation. This is due to the low rain water harvesting storage and catchment area. The storage is categorize in small storage about 3.000 litre per home and located in the garden/blank space between the buildings. The constructions is simple made from fiber and directly connected with the catchment area using the pipe. During rainy
season the community will use it for rain water storage and use it for secondary needs of water and during the dry season the will still buy the water and use the RWH storage as a regular water storage.

3.4.3. Community Willingness to Adept with the System

With the certain issues and adaptations, the questionnaire also ask the community to projects what will happen in the corridors. Figure 10 shows that 65% of the community willingly to adept with system and 26% are objecting to adept with the system and the rest of 9% are still in the doubts.

![Figure 10. The Community Willingness to Adept with The System. Sources: [11]](image)

4. Conclusion

From the study, we can conclude that rainwater harvesting is a method in which, generally take a role in water management. However, this method has a more specific purpose to provide a secondary clean water resources, yet flood and overage runoff also can be resolve. To face nowadays issue regarding the access of cleanwater resources and many phenomena from many regions of lacks of water, rain water harvesting must be considered as one of the solution. Moreover, this method is practically easy to conduct, both in urban and suburban area. Indonesia is now still remains to deal with a water scarcity issue, in most of every region. Rainwater harvesting perhaps could be implemented for future action.

5. References

[1] Julius, J.R. (2013). Rainwater Harvesting (RWH) – A Review. International Journal of Innovative Research & Development. ISSN : 2278-0211/Vol. 2 Issue 5/

[2] Maryono, A and E N Santoso (2006). Metode memanen dan memanfaatkan air hujan untuk penyediaan air bersih, mencegah banjir dan kekeringan. Asdep Deputi Bidang Peningkatan Konservasi Sumber Daya Alam & Pengendalian Kerusakan Lingkungan. KLH Jakarta.

[3] Dwivedi A (2013). Rooftop rain water harvesting for groundwater recharge in an educational complex. The Global Journal of Researchers in Engineering.

[4] Kim, R H S, Lee YM, Kim JH, Lee S K, Kim and S.G Kim (2004). Pollutants in rainwater runoff in Korea; Their impacts on rainwater utilization. Environmental Technology, Vol 26 No 4.

[5] Lade O and Okunlala O (2017). Rainwater Quality in Ibadan (Nigeria): Effect of Short Term Storage in Surface and Underground Tanks. World Journal of Research and Review (WJRR)

[6] UNEP (2002). Rainwater harvesting and Utilisation; an environmentally soundly approach for sustainable urban water; an introductory guide to decision makers. http://www.unep.org/lets/Publications/Urban/UrbanEnv-2/index.asp. Accessed Mar 2010

[7] UNEP (2015) The UNEP Environmental data explorer as compiled from world population prospects, The 2012 Revision (WPP 2012). United Nations Population Devison. United Environment Programme.

[8] UNEP (2002). Rainwater harvesting and Utilisation; an environmentally soundly approach for sustainable urban water; an introductory guide to decision makers. http://www.unep.org/lets/Publications/Urban/UrbanEnv-2/index.asp. Accessed Mar 2010

[9] WHO and UNICE. (2013). Joint Monitoring Programme for Water Supply and Sanitation ; Indonesia data 2010.
[10] Hatum, T.; Worm, J. (2006): Rainwater Harvesting for Domestic USE. Wageningen: Agrosima and CTA.

[11] Sevilla, Consuelo G. et. al (2007). Research Methods. Rex Printing Company. Quezon City

[12] Tucunan., K P. et. al (2017). Kampung Tahan Bencana Ring 1 ITS Surabaya. Unpublished Document.

[13] Body, N. (1968). The Design of Water Supply Services Based on Impervious Catchment Areas. Progress report, Commonwealth Bureau of Metereology, Melbourne.

[14] Body, N. (1968). Design Information for Domestic Water Supply from Roof Runoff. Progress Repost, Commonwealtg Bureau of Meteorology, Melbourne.

[15] Bailey, N.G. (1959). Cisterns for Rural Water Supply in Ohio. Colombus : Department of Natural Resources.

[16] Biswas, A.K. (ed.). (1983). Rain and Stormwater Harvesting in Rural Areas. Water Resources Series, Vol. 5. UNEP, London, UK.

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