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Integrated Vulnerability Assessment: A Decision Tool for Water Scarcity in Small Islands

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Abstract

Water scarcity especially in the small islands in Indonesia had caused troubles for society in maintaining their water needs. There are a lot of instruments developed to measure community vulnerability index, however the majority are partially designed so that they do not reflect the overall condition. Therefore, this research will formulate a vulnerability index of water fulfillment in small islands using a comprehensive method so that the result can be used as a reference in policy making. This research applied a deductive-positivist approach of the quantitative method. It started of with the dimensions of vulnerability, that are: exposure, adaptive capacity, and sensitivity, which then operationalized into indicator/parameter of indexes to measure a vulnerable condition. The result shows that this vulnerability index can be utilized as a basis for policy decision making by considering the attributes that had been proved sustainable. Other than that, to reduce vulnerability in small islands, there is a need for a policy that considers community capacity and their adaptive patterns that could improve their social and economic capital.

Keywords: vulnerability index; small islands; fresh water; adaptation; social capital; sustainability.

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1. Introduction

Recent debates regarding climate change and water scarcity in small islands are gaining scientific as well as political attention. This is mainly because, based on the newest climate change scenario, of the escalating nature of their vulnerability [2, 13, 17].

Because of the relatively small size of the islands, water became a very scarce goods. Ground water is usually not fit for consumption [5, 28]. It is different with the mainland region, the societies that live in small islands are experiencing difficulty in fulfilling water needs. Sufficient water availability in terms of quantity and quality are the requirements in achieving MDGs target [26]. Such problems are affected by the characteristics of hydrology, topography, type of soil, and climate. Besides that, human behavior in utilizing water also affects water resource conditions in small islands [3, 11, 19]. Past studies has proven that small islands in Indonesia were experiencing water resource vulnerability, marked by the difficulty in obtaining fresh water. Poor water condition and limited water volume are common phenomenon in small islands [3, 8, 10, 23]. To get a better understanding on water vulnerability level in small islands, development of various vulnerability indexes has been carried out. However, most of said indexes tend to only be partially done and focused on one specific aspect or dimension, such as environment, or only social aspect [6, 15, 18, 22, 23]. To date, there have been no research that able to come up with comprehensive vulnerability index by combining the three dimensions in one single index formulation. Therefore, it is very interesting to study and develop a concept of vulnerability index on water resource, especially the fulfillment of water in small islands. This is certainly very important because of: (a) Indonesia is an archipelago consists of approximately 17 thousand of islands and some 13 thousand of them are small islands [11]; (b) the existence of development program especially on the fulfillment of water in small islands, thus there is a need of an instrument to measure vulnerability level to support the program. Based on that, the research problems are: (a) How to formulate a vulnerability index to fulfill water needs in small islands?; (b) How is the adaptive pattern of the community in small islands in dealing with water crisis?; and (c) How is the policy alternative in sustainably fulfilling water needs in small islands?

1.1. Water Scarcity

Generally, water scarcity symbolizes the unbalance between water supply and the demand of a certain social-ecological system. Water scarcity signifies problem in fulfilling human and or environmental needs sufficiently in a given time. This concept has been challenged, and the nature of scarcity is now undergone change from which it was initially oriented only on the physical aspect and technical solution, shifting to social, economical, cultural, and political aspect [2, 16, 29]. Physical scarcity or commonly known as water scarcity refers to the limited amount of water on a certain period. Attempts to determine water scarcity tends to use percapita and yearly water availability [1,4]. Other than that, a more comprehensive indicator aims to include economic and social factors [2, 23], but with limited empirical implementation so far. However, the most important thing to remember is that water scarcity is more than just physical problem, but a relative social construct affected by biophysical condition and human behavior and the relationship between those two [14].

1.2. Research Framework

Vulnerability is something that characterized small islands such as poverty, isolation, disaster prone, inadequacy of infrastructure, and also fresh water scarcity.

One of the obstacles on the development of small islands is the limited availability of water resource [3, 8, 10, 23, 24]. Inadequacy of water resource, because of topographical, morphological, and soil condition in small islands, affecting water crisis condition in small islands, so that the development of small islands needs to be done by looking at the current problem and the water capacity existed in the small islands. The vulnerability of small islands community is shown on social, economic, or environment. The natural condition of small islands which is prone to crisis has raised the importance of finding a solution to the problem. The concept of vulnerability developed by Turner indicates that to reduce small islands vulnerability there is the need to improve their adaptive capacity through various capital resources possessed by a community [25]. Adaptive capacity of small islands can be strengthened by giving intervention or policy, either through improving their existing adaptive capacity or by a well-planned infrastructure development based on their potential capabilities. With that, there will be a declining level of vulnerability in water scarce-small islands through natural adaptation pattern as well as from the participation of the community. This condition will impact on the increasing welfare and sustainability. The research framework is as illustrated in the Figure 1 below:

Water Fulfillment in Small Islands

Basically vulnerability is a tendency of how easy an entity suffers disruption and damage, affected by external and internal factors. Specifically, vulnerability concept consists of three dimensions: (1) exposure, (2) sensitivity, (3) adaptive capacity. In this research, the parameters for exposure are (a) yearly rainfall, (b) population density, (c) disaster occurrence, (d) forest cover. Meanwhile, sensitivity parameters entail (a) water resource diversity, (b) estimated time to obtain water, (c) water usage. Lastly, adaptive capacity entails (a) number of family member, (b) income, (c) education, (d) willingness to pay, (e) perception of climate change, (f) women role in water management, and (g) social capital.

2. Materials and Method

This research applied a deductive-positivist approach which makes it a quantitative study. However, it is also a type of explanatory confirmatory research. The formulation of vulnerability index for water fulfillment in small islands is carried out through literature review, functional relation of a selected dimension and parameter, as well as measuring vulnerability. After vulnerability index is obtained, next is Rapid Appraisal Water (RAP-Water) analysis to determine the sustainability of water fulfillment in small islands. The data used for the analysis of vulnerability index and their sustainability consisted of primary and secondary data. For the primary data, the unit of analysis is the community, and the unit of observation is head of household. Using multi-stage random sampling technique, 257 samples were drawn.

The secondary data are obtained from related institutions, such as data on rain fall, water availability, disaster occurrence, population density, poverty, land coverage, and so on.

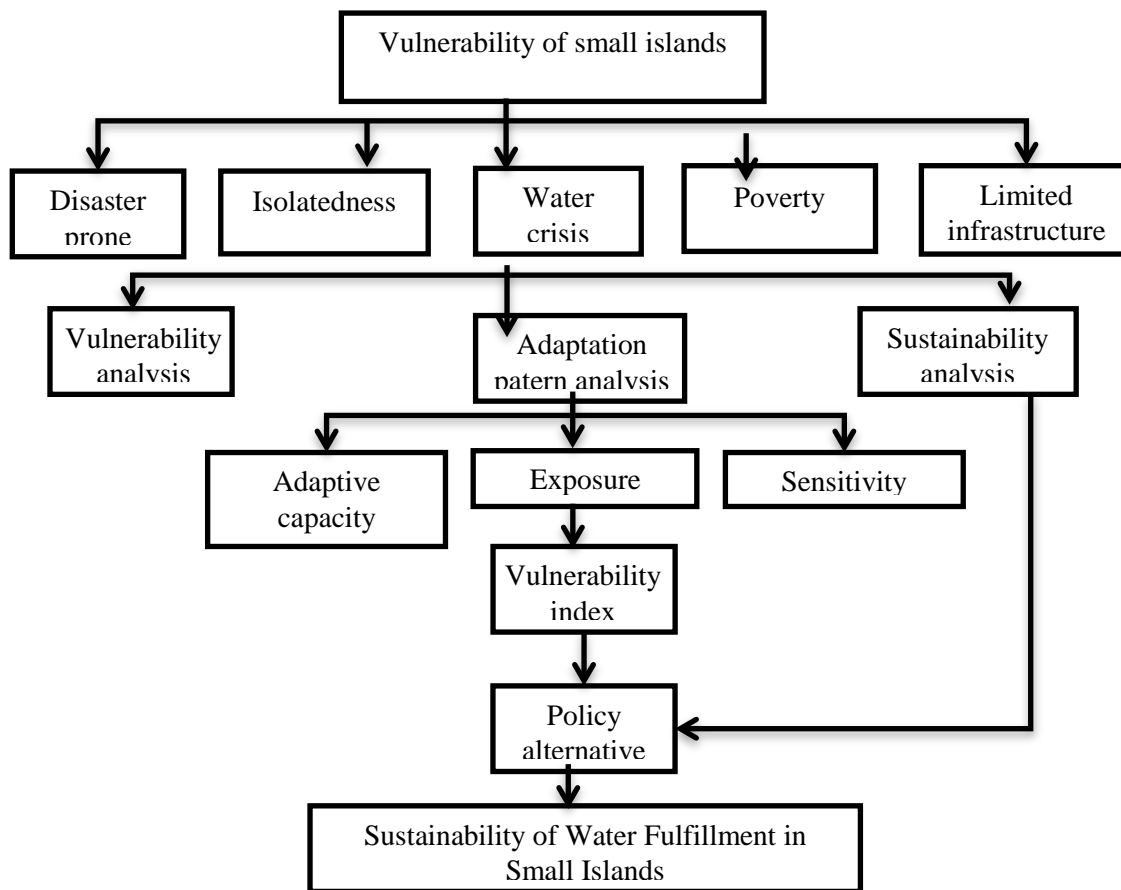


Figure 1: Research Framework for the Formulation of Vulnerability Index to Support

This research is located in the Province of East Nusa Tenggara, Indonesia. This province is selected because of its natural dry climate with limited availability of water. This province belongs to the Nusa Tenggara archipelago, which records low water availability compared to other islands in Indonesia. As a sample of location, three islands were selected, which are: Ende Island, Solor Island, and Semau Island. The image of the research location is shown in Figure 2 below.



Figure 2: Research Location

3. Results and Discussion

3.1. Formulation of Vulnerability Index

Based on the field result from the three islands (Solor, Semau, and Ende), it can be derived that from three dimension (adaptive capacity, sensitivity, and exposure) there are thirteen subdimensions which are important to be used to formulate vulnerability index. After data input and normalisation is performed, followed by data weighted using composite index [12], as well as measuring the standard deviation, the result is shown in table 1.

Table 1: Dimensions and Vulnerability Variables with Score

Dimension	Code	Variable	Ende Island	Solor Island	Semau Island
	KA1	Number of household members	0.073	0.018	0.000
	KA2	Income	0.024	0.074	0.000
	KA3	Education	0.050	0.074	0.000
	KA4	WTP (IDR/lt)	0.055	0.073	0.000
	KA5	Perception towards climat change	0.000	0.067	0.065
	KA6	Woman role on water management	0.009	0.000	0.070
	KA7	Social capital	0.074	0.000	0.022
Sensitivity	S1	Diversity of water resource (type)	0.000	0.066	0.066
	S2	Travel time to water source	0.000	0.075	0.048
	S3	Water usage	0.000	0.008	0.069
Exposure	K1	Yearly rainfall	0.014	0.071	0.000
	K2	Population density	0.016	0.072	0.000
	K3	Number of disaster occurence, Anticipation for disaster	0.066	0.000	0.000
	K4	Forest cover	0.075	0.000	0.047

(Source: Authors, 2015)

It can be seen on table 1 that the scores after weighted are between 0 and 0.075 value. The table explains vulnerability index on each dimensions with 0-1 score. Score closer to 1 means higher vulnerability. Then, vulnerability index of water crisis for each island and dimension can be arranged as shown in table 2.

Table 2 shows us that when we take a look comprehesively, Solor island is the most vulnerable one agains water crisis, followed by Ende island and Semau island. Nonetheless, not all dimension in Solor island suffers from high vulnerability compared to the other two. In Solor island, the most vulnerable dimension is the adaptive capacity. While in Ende island the most vulnerable one is exposure. In Semau island, it is sensitivity.

The formulation of said index, can be used as instrument to calculate the vulnerability index in small islands.

The proof is that statistically all dimensions and subdimensions is significant enough to be used as a differentiator among various variables in those dimensions and subdimensions.

Table 2: Water Vulnerability Index in Small Islands Per Dimension

Region/ Island	Vulnerability Dimensions			Vulnerability Index	Rank
	Adaptive capacity	Sensitivity	Exposure		
Ende Island	0.564	0.000	0.599	0.46	2
Solor Island	0.608	0.709	0.505	0.60	1
Semau Island	0.310	0.871	0.165	0.39	3

(Source: Authors, 2015)

3.2. Adaptive Pattern of the Community in Small Islands in Dealing with Water Crisis: The Power of Resilience

One of the attempts to reduce community's vulnerability in fulfilling water needs is by giving technological aid in the form of Rain Water Storage (RWS) tank. But due to the difference in management pattern, the result is also different. The following are the examples in Ende and Solor island in the RWS management based on social capital in relation with the adaptive pattern of the community.

Based on survey, Solor Island has larger social capital than Ende Island with communal assistance pattern. The differences are in the pattern of assistance delivery and management pattern. The government through PNPM Mandiri program (a community-driven development program) had given assistance in the form of 40 RWS tanks to village residence since 2011. One RWS tank is designed to be used communally for 2-5 household in Labelen village. RWS tank is built in one villager's house, with water distribution is agreed among the residence. Head of neighborhood unit (*Ketua RT*) manages the demand of water from the residents, analyze and decided whether to distribute the RWS or to be sold for IDR. 2,000 per 5 buckets.

Meanwhile the pattern of assistance in Ende island is having lesser social capital value compared to Solor island. This condition can be explained based on field evidence in Rendoraterua and Rorurangga villages. In between 2007 and 2008, the inhabitant of Ende island received aid from UNICEF in the form of RWS tanks as the source for fresh water. Through this assistance, each household in the island already has RWS tank to be used during dry season. Residents in Rorurangga village uses the water only for consumption. For daily needs they uses brackish water from the well. This is because there are no other water sources in the village. When water supply runs out, the residents must draw water from the neighboring Numba village, about 6 km from theirs. Beforehand, there was the attempt to distill salt water in Rorurangga village, but failed due to constantly diminishing fresh water production, and also that the running cost was not affordable to the community.

The condition explains that the lower the social capital in a certain location or community, the more vulnerable the community is. Solor island with communal assistance pattern has higher social capital because of its social

network. The strong bonds of the community is built through inter-society interactions. Conversely, in Ende island with individual assistance pattern has lower social capital score because of the individual characteristic of the assistance affected the low chance of inter-society interaction. This implies a low chance of possibility of interaction between inhabitants.

Improving adaptive capacity highly determines community resilience in dealing against water crisis which is frequent to them. The following is an illustration of community resilience by looking at the effect of two capitals (economic and social capitals) in Solor and Semaui island.

It is certain that generally the community in Solor island relies on social capital as the resilience against water crisis. As confirmed through field survey, in Solor there are unwritten values and norms regarding the management of public well that it can only be used during dry season which shows reflections of social capital as the resilience of social norm. It was reinforced by the local rituals in Solor island which is usually done once a year before entering the fasting month of Ramadhan; cleaning and taking care of the public wells. The ritual is performed by many people in Solor island and a means of social interaction for people in Solor island as well as activities that serve to reinforce the values and social norms related to the unwritten rules regarding water usage. Then form of resilience of the people in Solor island is reflected by the availability of RWS management on neighborhood level where the RWS tank also given to the Solor community to every 2 to 5 households that has shared rules in the management of RWS. Resilience of the water crisis on the social network dimension was reflected in the lack of cooperation towards development of clean water by residents although this was not many in number, as residents tend to help each other in getting fresh water and establish networking in purchasing water in Adonara through the help of fishermen at IDR. 2,000 for every jerry can. Lastly, reflection of confidence in the dimensions of the community in Solor island that the author has assumed is affected by “social norm” strengthened by “social network” in the community in Solor island. From field evidence, there were no indication of misappropriation of fresh water usage by water manager in neighborhood level.

From the explanation of social capital as a form of resilience in Solor island, it was loaded with social interaction that made them lacking interaction with outsiders in Solor in dealing with water crisis because they are just a “water buyer” depends on their economic capital. So that they will be less aware of how values and social norms that exist in society related to the water usage, and due to the lack of interaction with others makes them less able to establish network in the community and that their network may be smaller compared to those who has social capital because of the lack of economic capital as a form of resilience of the water crisis.

Then, due to the lack of social interaction with the other party, it is likely that they are less familiar and less aware of the other party that contributes to low trust and enormous suspicions towards the other party.

It can be able to explain because the main resilience of the community in Semaui island depend highly on the economic capital that determines how big is their access to water resource in order to meet needs and that they have to “interact” to other party which having the access to water resource to establish social network with said party.

Semau Island which generally relies on the strength of the economic capital for example on their self-help installation of RWS tank using less than IDR. 15 million rupiahs that can be utilized for a small number of households. From the use of this communal RWS each member of the family also have values and rules of water usage. The example is a reflection of the positive relationship between economic capital with social networks and social norms in some communities in Semau. Then the adhered values and rules on the usage of RWS leads to the formation of "trust" on one another in addition the kinship based trust. However, the economic capital used by people in Semau island is highly dependent on environmental conditions such as "seaweed farmers " that is highly dependent on sea conditions, so that under the occurrence of environmental disturbance on marine ecosystems is causing harvesting failure of "seaweed" in Semau will cause the lost of the resilience ability of the society in Semau during water crisis conditions .

Based on the above explanation, it can be seen that there are differences in the form of community resilience between Solor and Semau islands. The tendency, based on the available data, is that there are unwritten rules, villagers obedience towards unwritten rules, the availability of water resource management, the existence of community joint effort in managing and treating public well and the strong trust between the society in using water in Solor island shows that their resilience are leaning to a sustainable social capital.

Although it can not be denied that there are also forms of resilience based on economic capital in Solor it is less likely tp be committed by Solor inhabitants where those with high social capital tend to come from the lower economic capital. It also happened in Semau but slightly different from what happened in Solor.

In Semau the data obtained are in the efforts to overcome the water crisis through the purchase of water to parties having the access to clean water, so that Semau inhabitants possesses economic capital resilience from experiencing water crisis. The low social capital in Semau may be affected by poor infrastructure in the island, making it difficult for the community to interact with each other, so that the public depended on individual economy or at the group level on the basis of kinship.

3.3. The Sustainable Fulfillment of Water Needs in Small Islands

There are five dimensions which being used to determine the value of sustainability, that are ecological dimension with 7 attributes (diversity water source, quality of raw water, geographic proximation over water resources, forest cover, rainfall, reservoir conditions, balance of annual water resources); the economic dimension with four attributes (price of raw water, WTP, water purchasing power of the community, and poverty); social dimension with four attributes (traditional wisdom in obtaining clean water, togetherness in water management, conflict of status on water resources utilization, the role of CSR in the provision of clean water); institutional dimension with 5 attributes (community water management institution, regulations of water management, government assistance in the provision of clean water, planning of raw water management, local budget allocation for the conservation of raw water); and dimensions of technology/infrastructure with three attributes (infrastructure providing raw water, water treatment technology, water resource infrastructure).

Based on the Rap-Water analysis score results, the data as in Table 3 below is obtained:

Table 3: Rap-Water Analysis Score

Island	Ecology	Economy	Social	Institution	Infrastructure and Technology	Average
Ende	46.03	34.95	69.20	45.76	33.88	46.49
Solor	33.14	34.95	87.61	43.39	33.88	47.12
Semau	37.87	66.88	37.33	42.45	33.88	44.20

(Source: Author, 2015)

The data above shows that Solor island has the highest sustainability value with average score at 47.12; followed by Ende island at 46.49; and Semau island with total score 44.20. If we refer to sustainability range criteria, where score between 0 and 25 is considered not sustainable, 26 to 50 as less sustainable, 51 to 75 as averagely sustainable and 76 to 100 as highly sustainable, then the sustainability of the three islands are considered bad. This means that raw water availability and sustainability in these islands are low. This is in line with the vulnerability index analysis which also show vulnerable condition of the society in terms of raw water availability.

To see the variables that are sensitive to the sustainability of water supplies in small islands, the leveraging result for each analyzed dimensions shows that for ecological dimension, as shown in Figure 3, generally can be seen that the catchment area/forest cover, geographical proximation on water resources and rainfall became the most sensitive variable towards the sustainability of water in small islands. This is in line with the real conditions in which the raw water is a function of the catchment area. In this case, the larger the total area of forest cover in small islands, the most likely water resources will be maintained. While the distances in obtaining water in small island has been a big problem for people in small islands, as it creates high costs, which most poor can not afford. This condition causes the sustainability of the raw water supply becomes very sensitive. Rainfall is another important variable in the procurement of raw water, but during field research it is extremely difficult to obtain, with the composition of the rainy season of only 3 months every year, causing rainfall variable became very sensitive to the sustainability of raw water.

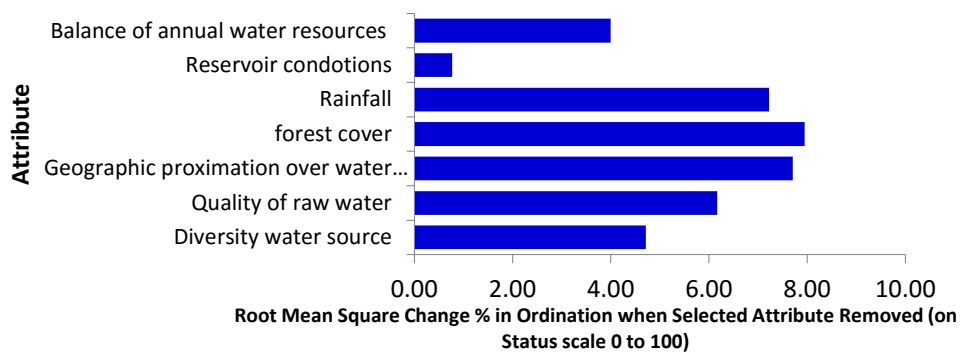


Figure 3: Leverage of Ecological

For the economic dimension as shown in Figure 4, the price of raw water becomes the most sensitive variable towards the sustainability of raw water in small islands. In line with the ecological dimension, where the water is difficult to obtain due to ecological characteristics such as few vegetation covers, occasional rainfall and also geographical distance over water resources, causing the price of water to be very high. Poverty exacerbates this condition because of their ability to pay, although high, cannot catch up with price increase. Community's WTP and poverty are the variables that are also sensitive to the sustainability of water supplies in small islands .

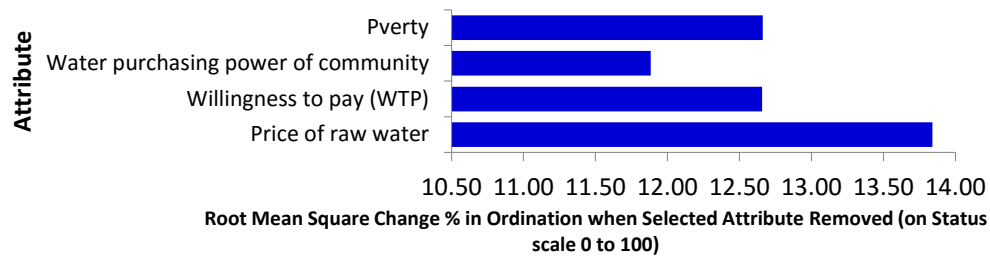


Figure 4: Leverage of Economic

For the social dimension as shown in Figure 5, the sustainability of water supplies in small island turned out to be very sensitive to water resource conflicts. Eventhough Solor and the two other islands have local wisdom, and also a good kinship in water management (social sustainability value are relatively moderate (between 50-60 %), but occasional conflicts is the most sensitive in determining the sustainability of water supplies in small islands.

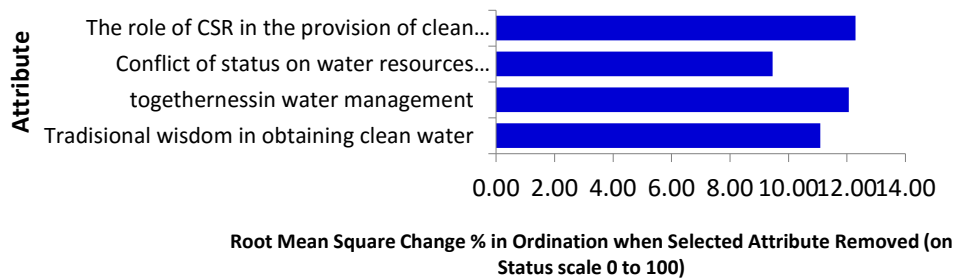


Figure 5: Leverage of Social

For institutional dimensions as shown in Figure 6, the most sensitive attributes are the water management planning and its governance. Conditions research field indicated that there has been no systematic efforts in the form of local or central planning to deal with water scarcity in relatively isolated small islands. Based on interviews with local government, the budget allocation for the provision of clean water is very limited. Eventhough, as shown in the social analysis results, the CSR aid programs were very important and sensitive towards the procurement of raw water in small islands. Regulations is also an attribute that is sensitive to the dimensions of institution. The conflict that sensitive to the social dimension is a reflection of the importance of management of water in small islands. Until now, water governance has not been regulated in the research

fields. The community has not yet obtained their right to water which is a basic human needs. In this case the local government has the resources of small islands located in remote areas, need to be encouraged to planning and good governance and optimal for the procurement of raw water. This governance can refer to the results of the analysis of Rap-Water on other dimensions that are considered sensitive.

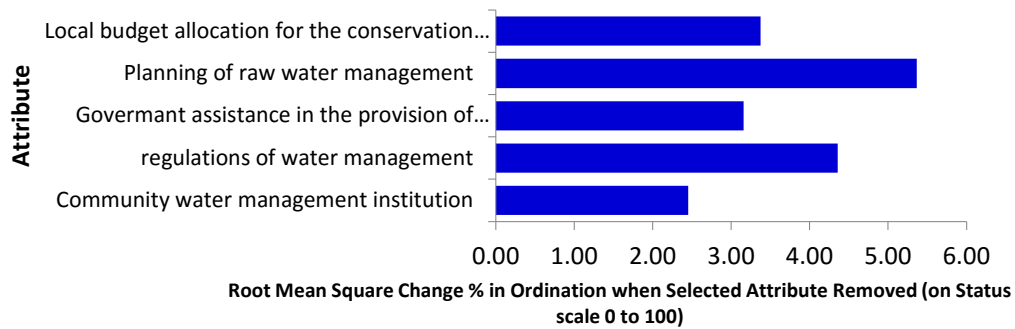


Figure 6: Leverage of Institutional

Analysis of infrastructure and technology leverage as shown in Figure 7, indicates that the most sensitive attributes is water treatment technology in the form of reuse, recycling, or the processing of seawater into fresh water. Until now there has been a lot of technology as it is introduced in the area of small islands in the research area.

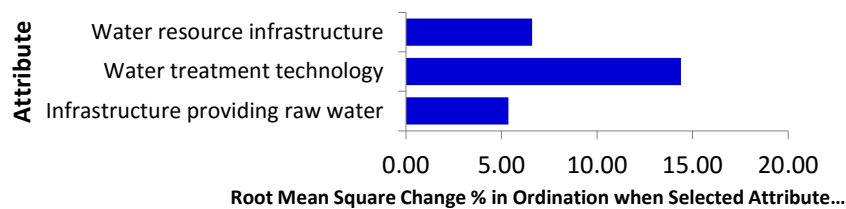


Figure 7: Leverage of Infrastructure and Technology

4. Policy Implications

On the arranged index formulation, based on statistical result shows that the formulation is valid and reliable to be used to calculate the vulnerability index of small islands in dealing with water crisis. Therefore, generally the previous studies are still relevant [9, 20, 21]. However, if we study them further especially on the subdimension part, there are several subdimensions that has not yet occurred before, but statistically significant for the measurement of vulnerability index.

On the adaptive capacity dimension there are subdimensions; the willingness to pay (WTP), perception towards climate change, and social capital. If we refer to the previous works [9, 20, 21, 24], they have yet to express such subdimensions as the important elements in the formulation of vulnerability index so that it can be said that

the subdimensions are a very valuable findings in this research. Meanwhile, on the exposure dimension, the three subdimensions formulated in the index is evidently a new finding. The three subdimensions are just confirming the theory by previous scholars [9, 20, 24], while the view of Preston & Smith [21] apparently is not getting empirical confirmation in this research.

Furthermore, the formulation of the index in portraying empirical condition on the three islands. Based on vulnerability index, it can be said that Solor island is the most vulnerable compared to Ende and Semaun islands. However, when we look further it turns out that not all dimensions have high vulnerability in Solor island. There are variations of vulnerability on the three dimensions in the islands. Data shows that in the adaptive capacity, Solor island is the most vulnerable one. Meanwhile on sensitivity dimension, Semaun island is the most vulnerable. And on exposure, Ende island is the most vulnerable.

It cannot be denied that vulnerability is very related to physical environment, but one of the resource that can be used to overcome the problem is technology. However, using the same technology, but with different management and usage pattern, turns out to influence the growth of social capital within the society, which enable them to reduce the level of vulnerability. Field evidence shows that although using the same technological assistance, although with different management and usage pattern, the resulting social capital is different.

For example, social capital of the community in Solor island is higher compared to Ende island. It is affected by two types/dimensions of social capital. Firstly, structural social capital (outside of individual), which in Solor island there is institutions or joint forum to commonly manage the RWS. moreover, there is a rule that limit resident's access to water by giving them 3-5 buckets of water at the most. Conversely, in Ende island there are no such thing because the management is done by individual in each household. Secondly, cognitive characteristic inherent in the society in doing collective cleaning of the RWS facility, even has been internalized as manifestation of the customs to clean up water source. Conversely, on the island of Ende there is no value as the basis for such action.

The above conditions indicate there is a relationship between the management and utilization patterns of a technology and the continuity in meeting water needs with social capital. The working of the two dimensions of social capital, both structurally and cognitively as proposed by Uphoff (2000) showed that the level of social capital in Solor island can be quite high. This is evidenced by the commitment of citizens to cooperate, sacrificing personal interest, and subject to the common rules. The conditions of social capital is an important aspect to reduce vulnerabilities in fulfilling fresh water needs in small islands.

Another interesting finding in this study is that even though the economic capital of a society is well enough, characterized by high income and expenses, it did not necessarily make their social capital high. People Semaun island that rely more on economic capital such as independently building relatively expensive RWS tank, at a certain level does have a good social capital, but only in the family environment and is based on ties of kinship. However at higher level such as neighborhood it failed to improve. This suggests that high economic capital cannot encourage social capital growth widely. Conversely, in Solor, high social capital was influential to high

economic capital, in terms of financial outlay can press so as to meet other needs. Such social capital condition is still in micro level and not yet related to the social capital in macro level [30]. The low level of social capital in Semaui and Ende islands in micro level, both cognitive and structural dimension, actually can be supported if participation room is opened in macro level. This was demonstrated in the UNICEF RWS tanks aid that were less able to contribute to social capital growth because of the lack of public participation in policy making. Conversely, community driven program (PNPM) using communal RWS assistance has created room for the growth of social capital because it was able to open up community participation in the macro level decision making.

Therefore, the alternative policies that meet the needs of clean water provision in small islands using five dimensions that are tested is very important, let alone all of them showed indications of sustainability. The test results showed that the ecological dimension, the seven attributes, that the most sensitive is the catchment area/land coverage, geographical proximity over water resources, and rainfall. Meanwhile on the economic dimension, the four attributes, the most sensitive is the price of raw water, poverty, and people's WTP raw water. Similarly, the social dimension, among the four attributes, the most sensitive is the conflict utilization of water resources and the role of CSR in raw water provision. Furthermore, the dimensions of the institution, among the four attributes, the most sensitive is the raw water management planning and regulatory management (governance). Whereas on the dimensions of infrastructure/technology, among the three most sensitive attribute is ai management technologies (reuse, recycling, etc.)

Sensitive attributes on the various dimensions of the above indicates that the necessary policies for vulnerability reduction fulfillment of clean water for people in small islands that are based on models that have been developed. Therefore, the model applied is an important policy to consider the five dimensions and their attributes. Model policies aid the individual technologies are only considering several irrelevant aspects. To that end, a comprehensive policy making involving multistakeholders are very urgent to do. For example, reservoir development policy needs to be supported by the movement of reforestation to improve forest cover. Similarly, the development of technologies such as RWS need to be supported by good management institutions and aimed at increasing community's social capital and improving the economic capital of the community. In addition, it should also support the development of other infrastructure such as roads and infrastructure to support the community access to clean water sources. Thus, through these policies, the level of vulnerability of the community will be further reduced in each dimension and its attributes.

5. Conclusions and Recommendations

In the formulation of vulnerability index on water fulfillment it was discovered 14 parameters which belongs to three dimensions; (1) seven parameters on adaptive capacity, (2) three parameters on sensitivity. (3) four parameters on exposure. On the application in the three small islands, it can be found that island with the highest vulnerability is Solor island (0.60), followed by Ende (0.46), and the lowest is Semaui island (0.39). However, not all dimensions experiencing high vulnerability in each island. Adaptive capacity is the most vulnerable dimension in Solor island, while in Semaui island it is sensitivity, and in Ende island it is exposure.

The adaptation pattern of the community in dealing with water crisis is through building or utilizing rain water storage (RWS) tank, either by self-financing or from external source. The finding that is interesting is that the more communal the facility is, the more it is able to strengthen community's social capital in overcoming water crisis, and in contrast individual assistance turns out to weaken social capital. There are two types of community's resilience pattern; resilience based on social capital and based on economic capital. Each of the resilience is having its own superiority as well as drawback. We also found out that social capital based resilience tends to come from those having low economic capital.

The policy alternative for the fulfillment of fresh water needs in small islands sustainably by using five dimensions along with their attributes that are ecology (7 attributes), economy (4 attributes), social (4 attributes), institutional (5 attributes), and technology/infrastructure (3 attributes), turns out effective to be used as the basis for policy making. This shown by the stability of the model. This condition also serve as proof that the system has significant level of confidence and can be used to measure the sustainability of raw water supply in small islands.

Based on above conclusion, the following can be recommended:

Firstly, the formulation of water resource utilization and support policy is based on vulnerability index. The more vulnerable people in the fulfillment of clean water is increasingly urgent to be handled. *Secondly*, there is the need to consider forms of development that are able to increase stock of social capital stock of the community, instead of weakens it. *Thirdly*, promoting assistance in the form of CSR programs to manage the existing water resource and to develop capacity buliding of the community to design their own economy or even to develop infrastructure and technology in order to increase raw water supply. *Lastly*, we need a comperehensive and holistic policy by involving multiple stakeholders. The policy for the development of infrastructure and technology needs to be under one package of plan supported by reboisation effort to increas land coverage. Likewise, it needs the support of a good management institution which pushes for the increasing of social capital of the community as well as improving their economic capital so that small island community's level of vulnerability is getting lowered.

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