# INDIGENOUS WATER MANAGEMENT: WATER CONSERVATION STRATEGIES IN ROTE ISLAND, NUSA TENGGARA TIMUR (NTT)

## *(Manajemen Air Pola Mamar: Strategi Konservasi Air di Pulau Rote, Propinsi Nusa Tenggara Timur (NTT))*

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### Abstract

Indigenous knowledge described as part of social and cultural structure of a community is one of tangible conservation components of water resources. Water management called Mamar System in Rote Island – NTT is a water conservation effort in an island characterized by karst landscape. Hydrogeologically and socially, this system is threatened by several factors such as population growth, land use modification and global climate change. The objective of this article is to present the result of the study concerning factors affecting Mamar System and provide comprehension of recommendation which are conservation strategies based on sustainable water management principles. This paper evaluates potential factors that reduce Mamar System's capacity in supplying water to the whole communities in Rote Island. As a conclusion several conservation measures are recommended based on sustainable water management principles.

Keywords: Indigenous knowledge, water conservation, sustainable water management

### *Abstrak*

*Kearifan lokal yang adalah bagian dari struktur sosial dan budaya sebuah masyarakat merupakan salah satu komponen konservasi yang ampuh untuk perlindungan sumber daya air. Manajemen air dengan nama Sistem Mamar di Pulau Rote, NTT adalah bentuk usaha konservasi mata air di pulau yang didominasi oleh geologi karst. Sistem ini secara hidrogeologi dan sosial terancam keberadaannya oleh karena beberapa faktor seperti laju pertambahan penduduk, perubahan tata guna lahan dan perubahan iklim global. Tulisan ini memaparkan faktor-faktor yang berpotensi mengurangi kapasitas Sistem Mamar di Pulau Rote. Di akhir tulisan ini didesain rekomendasi berupa strategi konservasi bertolak dari prinsip manajemen air berkelanjutan.*

*Kata kunci: kearifan lokal, konservasi sumber daya air, manajemen air berkelanjutan*

## INTRODUCTION

Water issues are considered as the primary and indispensable problem in East Nusa Tenggara Province (NTT). Each year society suffers from water-related disaster such as frequent drought. The alarming disaster occurs in the dry-hot period of the year ranging from June until November. Characterised by minimum rainfall, drought crests on October resulting in some major detrimental consequences such as water shortage, harvest failure, and environmental destruction. The regional planning and development in NTT is always impeded by this indisputable fact.

However, in some areas in Rote Island people practises local water management rules called "MAMAR". Mamar is a small pocket of forest around natural springs. It also occurs along permanent streams and rivers or on land irrigated by these water sources. Mamar is the hub of the village community. This indigenous institution perhaps was the embrio of community engagement, which would advance into territory authorisation since traditionally people developed their social relationship around water resources. This unique customary is ran for centuries in the way supplying water needs for daily consumption, agriculture, livestock, food, medicine, material for weaving and manufacture of households utensils and others. Regarded as the main source of livelihood, the Mamar develops society's behaviour towards sustainable water conservation as well as environment-friendly agriculture and livestock practices.

The main characteristics of Mamar springs is karst (Klaas & Mudd, 2008) which describes the important geological component of Rote Island. According to Ford & Williams (2007), karst is a form of landscape which consists mainly of soluble carbonate rocks such as limestone, marble, gypsum and dolomite. The springs provide water for communities living surround it throughout the year. However it is indicated that there are several factors threatening the main functions of the springs, such as population growth, land-use change, global climate change and abandonment of local knowledge. The main consequence is food insecurity due to potential water depletion. Therefore it is recommended to analyse the problems before building recommendations towards sustainable water management in Rote Island.

The objective of this article is to present the result of the study concerning factors affecting Mamar System and provide comprehension of recommendation which are conservation strategies based on sustainable water management principles.

## METHODOLOGY

Methods used in this study were literature review, interview, discussion, questionnaire and water gauging in Mamar springs in Rote Island, NTT.

## LITERATURE REVIEW

### Water Balance

In general concept of hydrologic cycle, particle of water continuously moves from one place to another in different events. As depicted in Figure 1, those hydrologic events that generally occur in karst systems are precipitation, evaporation, transpiration and runoff.

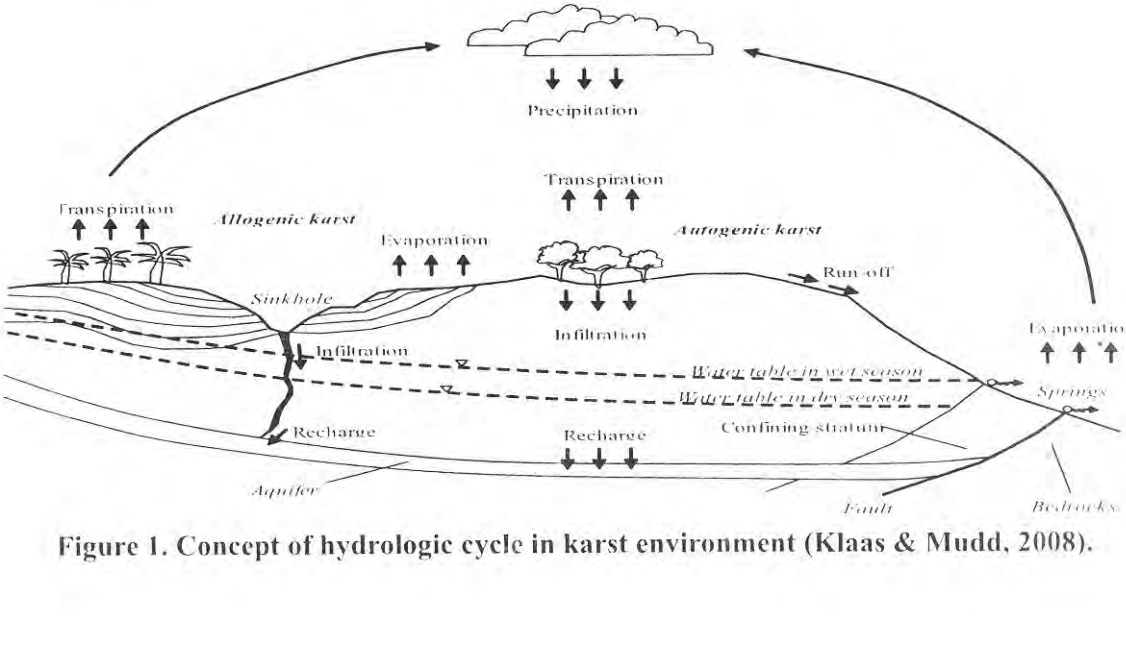



**Figure 1. Concept of hydrologic cycle in karst environment (Klaas & Mudd, 2008).**

Water coming from the earth is precipitated mainly in the form of rain. Part of it is intercepted and evaporates back to the atmosphere while the rest falls on soil and flows on the ground as runoff or infiltrate into the ground through secondary porosity, such as sinkhole or diffusive karst drainage system. Water that infiltrates flows as subsurface water which may feed surface stream or groundwater in which water is stored in karst aquifer and emerges as both gravity and artesian springs at places where groundwater aquifer meets ground surface. (White, 2003). Together with surface water, water emerged at springs then evaporates back to the atmosphere. The events above resume with water being precipitated to the earth.

**Change in groundwater**

Excess infiltration which reaches groundwater is called recharge and is a fundamental factor in groundwater flow. Once recharge process initiates, water is stored in porous media of soil called as groundwater storage. Therefore recharge process determines groundwater storage by which it replenishes quantity of water in groundwater storage. The recharge process taken place in karst environment is conceptually described in Figure 2.

Recharge process is determined by several factors. According to Nolan et al. (2007) recharge in several places can be different significantly due to heterogeneity of catchments' characteristics such as topography, sediment and climate

In karst area recharge process takes place as diffuse or point-based type or combination of the two. The area, categorised as autogenic and allogenic, where the rain falls determines the subsequent flow type of water through the complex drainage system of karst (Ford & Williams, 2007). Parts of water evaporate during infiltration process, while in point recharge water goes directly to groundwater aquifer through secondary porosities such as fissures and sinkholes.

On the other hand, controlled by diffuse recharge other parts of water remain in soil in a condition governed by atmospheric variables, such as humidity and temperature, and soil condition such as type of soil and soil moisture that influences the capacity of soil layers in storing water. (Bauer, et al, 2003). Modification of any of these geohydrogeological and climatological variables could result in change in groundwater storage.

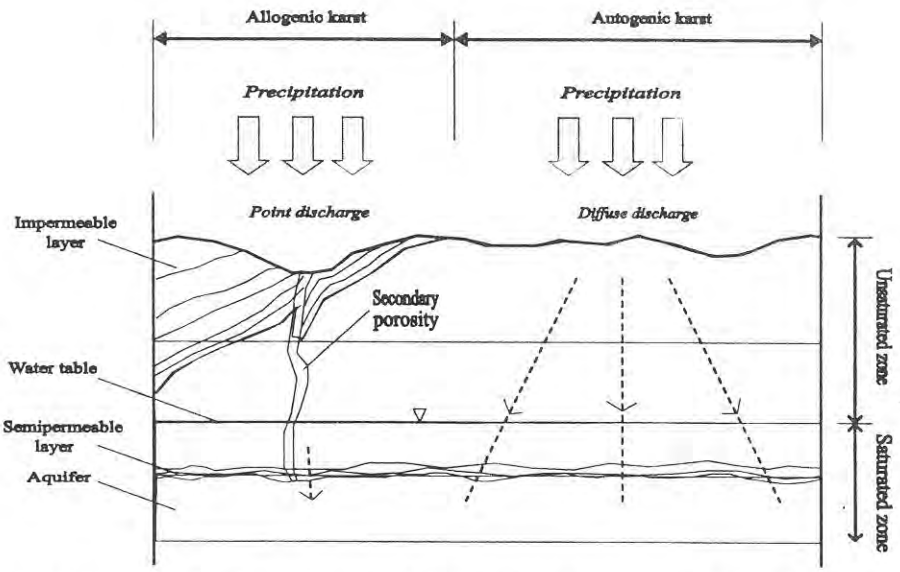



**Figure 2. Conceptual recharge process in karst environment (Klaas & Mudd, 2008).**

**Concept of sustainable water management**

The concept of sustainable water management refers to the term of sustainability in Bruntland Commission's Report on in which sustainable development was principally characterised as human's effort to meet the needs of the present generation without compromising the needs of future generations (WCED, 1987). When it is related to water as primary source of living for all people, this definition implies an impartial distribution of water over time which takes into account the same quantity and quality of water for users at any time, and over space which aim at reaching all locations.

Meanwhile, the ability to manage water as a crucial natural resource entails a comprehensive set of concerns to administer water in a way that accommodate ecological, economical, technical and societal acceptance of a broader society (Bernhardi et al., 2000). Therefore the basic principles of sustainable water management can be summarised as a way or process to manage available water with proper ecological, economical, technical and societal concerns by giving recognition of future generation's right to utilise the same quantity and quality of water.

**Result**

**Location of Study**

Geographically, Rote Island is located between 10°25' and 11 °00' South Latitude and between 121°49' and 123 °26' East Longitude (Gambar 3). The total area of this island is approximately 978.5 km$^2$ with elevation ranges mainly between 0 and 150 m above sea level (68.6%). Topography of this island is dominated with a highly undulated landscape that forms a very complex drainage system. Distribution of slope surface is varied where flatter areas are primarily found in both west and east ranging from 0.20 to 0.35 %. The slopes then substantially become stepper (11 – 28%) towards the middle north of the island.

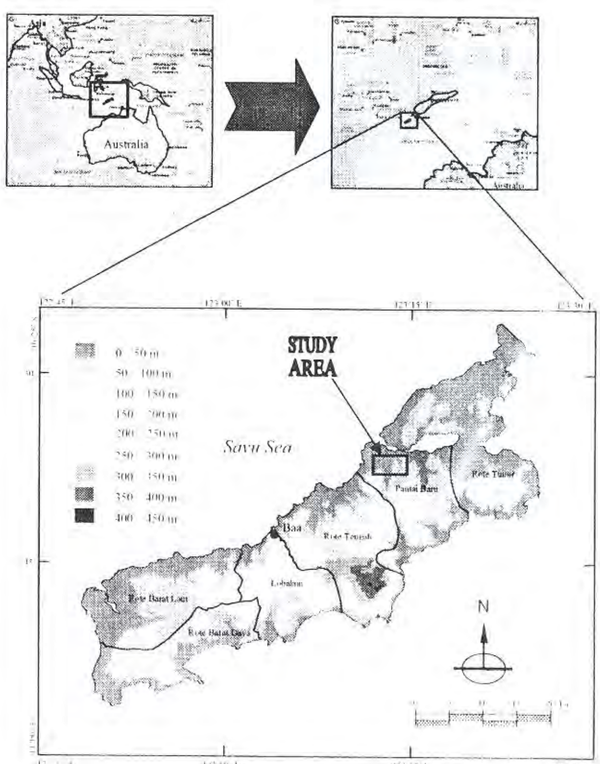



**Figure 3. Study Area**

Administratively Rote Island consists of six sub-districts. The total population of this island based on 2004 census were about 110,000 people. In general, from census data (BPS, 2004) collected in 2002 and 2004 population in Rote Island annually tends to increase by approximately 2.33%. The most notable rise appears in Lobalain Sub-district situated in the middle of the island where the growth reaches 13.56%.

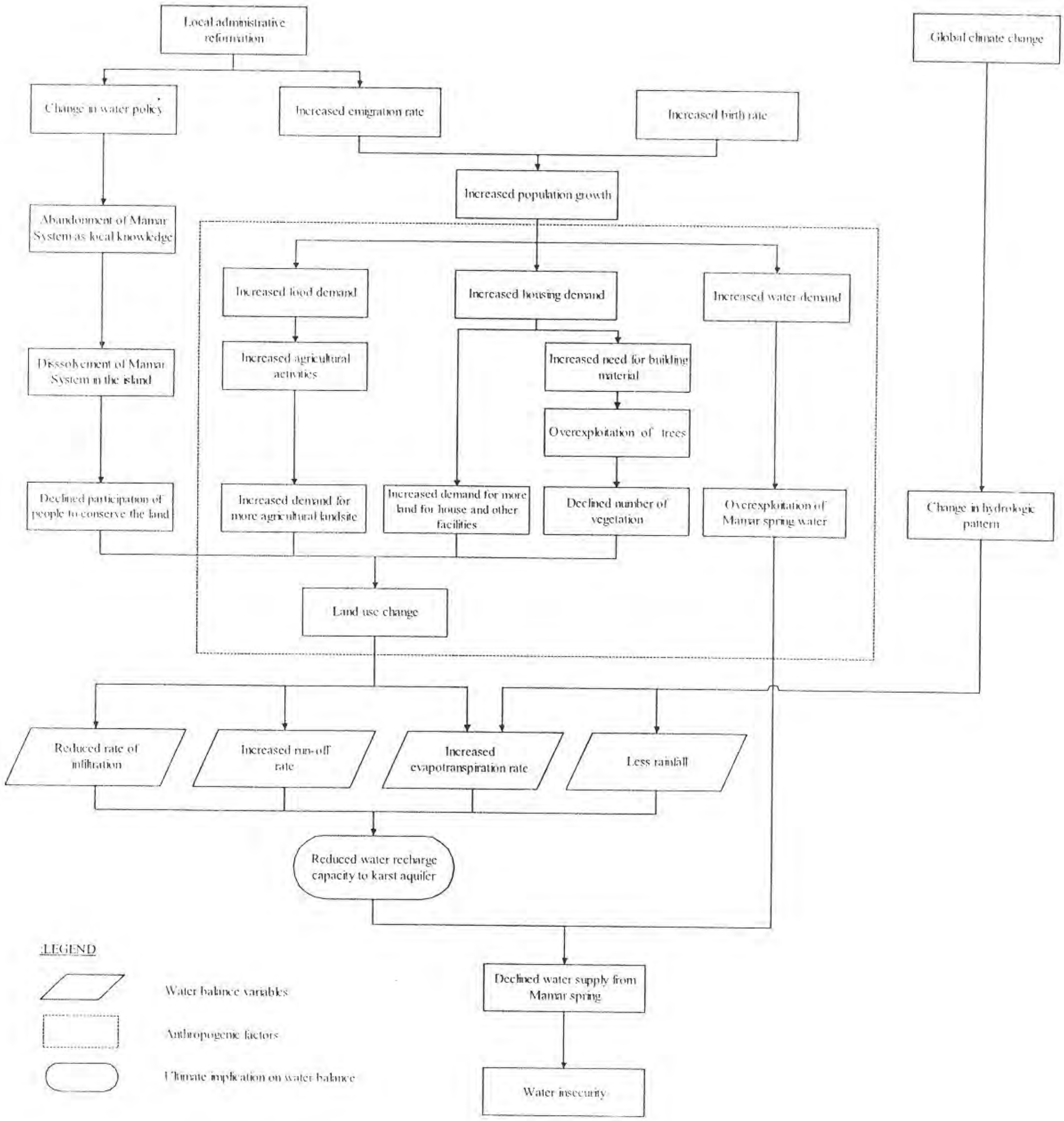
The major change in demography in Lobalain Sub-district reflects population boom due to migration right after the shift of level of government from sub-district to regency. In the new administrative category, Rote Island has its own local government and legislative body. It also receives more allocation of funds from the central government in Jakarta. Therefore there was a significant demand for both infrastructures and human resources which already drove people to migrate to this island. Nevertheless, the distribution of migration is uneven. Migrants mostly resides in the capital (Baa) which is situated in Lobalain Sub-district in where people may enjoy quantitatively more and better facilities such as telecommunication, education and entertainment. Most of the people in Rote Island rely on agriculture sector, from which 47% of the economic revenue comes (BPS, 2004) while other sectors such as service and trade play minor role in building the economy of this island.

**Potential trade-offs**

Mamar spring is the main source of water in Rote Island. The typical karst characteristics of the land that covers over 60% of Rote Island as well as a short period of wet season that is only last for about four months which are December to March preclude the availability of surface water such as river and lake. Therefore, together with other one-quarter of the world's population that are fed by or live in karst groundwater areas (Ford and Williams, 1989), people living in this island heavily rely on the perennial supply of groundwater that emerges as mamar springs.

However, there are some factors that pose threats to the capability of mamar spring to supply adequate water for the whole communities in Rote Island. An increase in population in the form of augmented immigration and birth rate could trigger a rise in basic demands i.e. food, water and housing. This increase could consequently put an immense pressure on natural resources that are already limited in this island. Higher demand of natural resources may subsequently trigger land use change that converts natural recharge area of for groundwater to agriculture and settlement areas. Meanwhile, amplified demand on water as a coherent consequence of increased population may exacerbate the problem, as water might be overused beyond its physical capacity that is directly linked with recharge performance of the land.

The relationships of the potential factors that pose threat to Mamar are presented in Figure 4. In this flowchart, the connections among each factor are described in arrows by which it is explained that one problem occurs as a result of preceding factor. It is shown that all factors have direct and indirect implication to the state of water balance variables that govern hydrologic process in this karstic island. Anthropogenic factors have direct correlation with water balance parameters, i.e. rainfall, infiltration, run-off and evapotranspiration. Furthermore, a potential of hydrologic impact of global warming may contribute to the change in water balance of Rote Island. Any changes occurs in the state of water balance of the karstic groundwater may result in a reduced water recharge capacity to karst aquifer, by which water is stored and conveyed to mamar springs. As a result, the capacity of spring to supply water for the community is degraded as groundwater supply from karst aquifer is depleted.




**Gambar 4. Potential trade-offs over water provision from Mamar springs**

This condition may also to some extent has potential to reduce the functions of Mamar System which is developed as water institution that manages the mamar karstic springs. And ultimately, as water supply from mamar springs declines water scarcity may be intensified and ends in water insecurity in the communities of Rote Island.

**Population growth**

Increase of population gives additional burden to natural resources such as water. Total water requirement in term of quantity is magnified as population grows. Therefore, demand for bigger water consumption soars as population growth rate rises. A projection by Gardner-Outlaw & Engelman (1997) shows that a direct correlation is present between population and water withdrawals. In their report, within the last sixty years world population tripled while rate of water abstraction follows the same trend. The United Nations has predicted the acuteness of threat on water as by 2050 there will be 7 billion people in sixty countries suffering water shortage (UN, 2003).

Urbanization might be the potential threat to the availability of water in Rote Island. The recent census between 2002 and 2004 shows of that population grew significantly due to immigration in Lobalain Sub-district in where the capital of the regency is situated. Unlike other five sub-districts, Lobalain experienced this irregular growth rate since a transfer of the governance status of Rote Island took place in 2002. In that year, Rote Island gained a new authority as regency replacing the previous status which was sub-disctrict. The shift in governance level in this island brought direct changes in economic and administration settings.

Nevertheless, its new "governmental cloth" has attracted more people to immigrate from other island. Migrants mainly come and settle in Rote Island as public servants and traders. Contributing to an increase in total annual population growth rate from 1.50% to 2.33% between 2002 and 2004 respectively, this trans-island migration brings a heavy strain as settlement areas expands and so does water demands in Rote Island. This situation can be clearly seen in the capital of the regency where water problems that were previously severe have become even more acute, especially when it deals with drinking water service provided by the local Water Agency.

**Land-use change**

According to Turner, et al (1993) land use change is categorised as land cover conversion and land cover modification. The difference between the two categories is that the earlier denotes total replacement of land cover with another type while the change in land use in the latter category does not transform the main type of land use. However, despite the level of change described in the two categories, land use change contributes to the modification of hydrologic characteristics of a particular area.

Any changes to soil-atmospheric behaviour may lead to environmental problems. Ford & Williams (1989) suggested that compared to other type of landscape, karst areas are more vulnerable to numerous types of environmental problems, especially those that relate with water. Unlike non-karst aquifers that are generally covered by overlying or less-permeable rock formations or soils, those in karst terrain are often exposed directly to surface without a low permeability cover (Kaçaroğlu, 1999). Therefore, the only protective coverage of the karst surface is vegetation. Consequently, any conversion or modification on land use that lead to removal of covering vegetation in a karst area may result in the surface being uncovered and as a result the overall karst system may be prone to water loss due to run-off (Gillieson, 1996). As vegetated areas being anthropogenically transformed to impermeable areas such as settlement, roads and buildings, land capacity to let water infiltrates decreases. Consequently, there is little supply to karst aquifer from both allogenic and autogenic areas through recharge process. Thereby, karstic springs may experience water shortage throughout the year.

**Global climate change**

According to the climate projection by Intergovernmental Panel on Climate Change (IPCC, 2007a) that employs seven scenarios the global average sea surface temperature will increase by 0.6 to 4.0$^{o}$C between 2090 and 2099 relative to temperature in 1999. Locally, Rote Island is projected to experience a 1.5 to 2$^{o}$C temperature increase in the same time framework (IPCC, 2007c). It is also expected that mean rainfall in Rote Island between December and March will increase by 0.2 mm/day however during dry period it decreases by 0.1 mm/day (IPCC, 2007b).

The change in climate condition in Rote Island apparently will change the recharge pattern with regards to karst environment. The increased temperature leads to an increase of evapotranspiration, thus reducing the recharge rate on a watershed scale. Although there is an increase in rainfall in wet season it is argued that without any conservative precaution on land coverage in recharge area most water may become runoff rather than infiltrate into karst. It is also possible that the increase in precipitation is presented as intense and extreme rainfalls that suggests an increased chance of flash flooding rather than as steady rain which helps maximise infiltration (IPCC, 2007b).

**Abandonment of local knowledge**

Incorporation of indigenous knowledge on managing natural resources such as groundwater is crucial for building a strong foundation that in the long-term serves as a basis for conservation. As noted by Burke & Moench (2000), the step to acknowledge local context is an efficient way to better manage groundwater resources. A case study from the Andean Region of Ecuador (Cremers et al., 2005) shows that when policy makers fail to recognise and embrace the significant value of local water rights and knowledge access to water by all users is endangered. Bridgewater & Arico (2002) underlines that preservation of biodiversity requires a cultural control that shares its manifestation in the form of indigenous knowledge.

**Conservation strategies**

Water insecurity in many places of the world has become a problem that without any cure could trigger other problems such as health, sanitation, poverty and food insecurity problems. It is predicted that 25% of world population live in countries that are affected by lack of freshwater (Gardner-Outlaw and Engleman, 1997). People living in karst area are more likely to be susceptible from water shortage due to physical characteristics of carbonate rocks in which water stored in its porous media may evaporate quicker than that of impermeable soils. Other factors such as rapid economic growth and increased population rate could put tremendous pressure on karstic water sources to supply enough water to the society. Consequently, without appropriate conservation strategies the provision of water from karst landscape that covers 7-12% of the earth terrain (Drew, 1999) is at stake.

In order to protect karstic groundwater in the framework of sustainable water management in Rote Island several proposed measures are recommended. These measures that are presented in Figure 5 are designed to encourage an integrated approach in watershed scale in order to facilitate sustainability in the area. The formulation of proposed measures takes into account characteristics of karst areas in Rote Island, existing indigenous practice of natural resource management called Mamar System and potential trade-offs. Each measure correlates with others to an extent that one supports others, thus all components of the proposed measures are linked in an integrated relationship as described below.

**Determination of Protective Karst Area (PKA)**

Establishment of protection zones is the first option undertaken in several cases in karst areas in the world (Escolero et al., 2002, Afrasiabian, 2007). The concept of protective karst areas, that is often called vulnerability and risks map (Nguyet and Goldscheider, 2006), has been widely used to become a foundation of policy formulation of karst protection in several European countries (Goldscheider, 2005, Andreo et al., 2006, Gogu et al., 2001). In the context of Rote Island, PKA is determined using the concept described above towards which hydrogeological characteristics of the karst landscape is used. Here, it is concluded that the karst system is governed by a mixture of autogenic and allogenic karst. Therefore, the area where both types of karst that initiate infiltration occur is described as PKA (Figure 6).

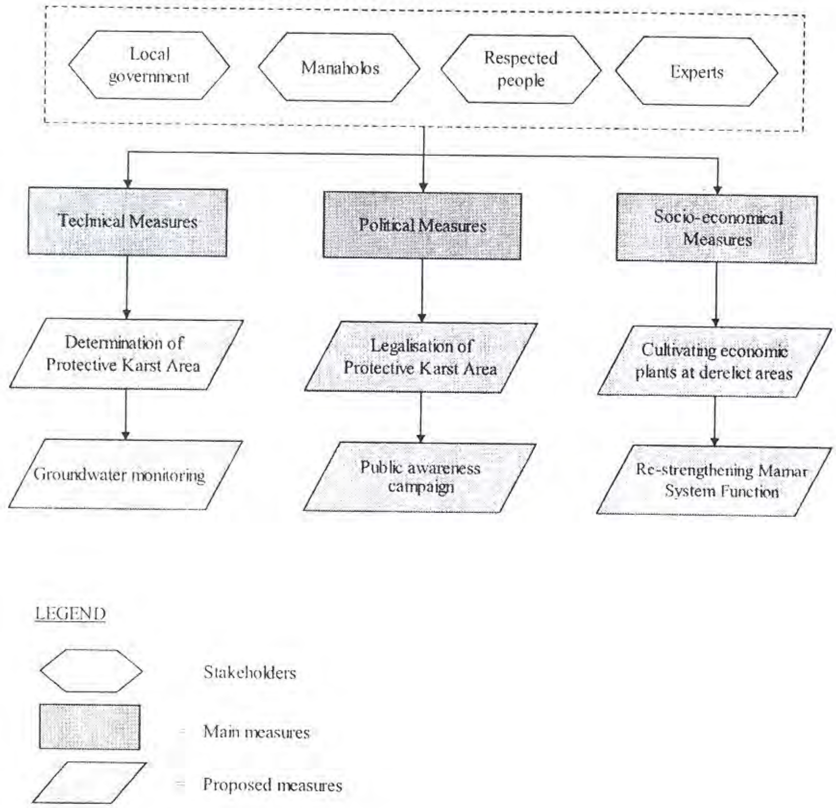



Figure 5. Proposed measures for sustainable water management in Rote Island

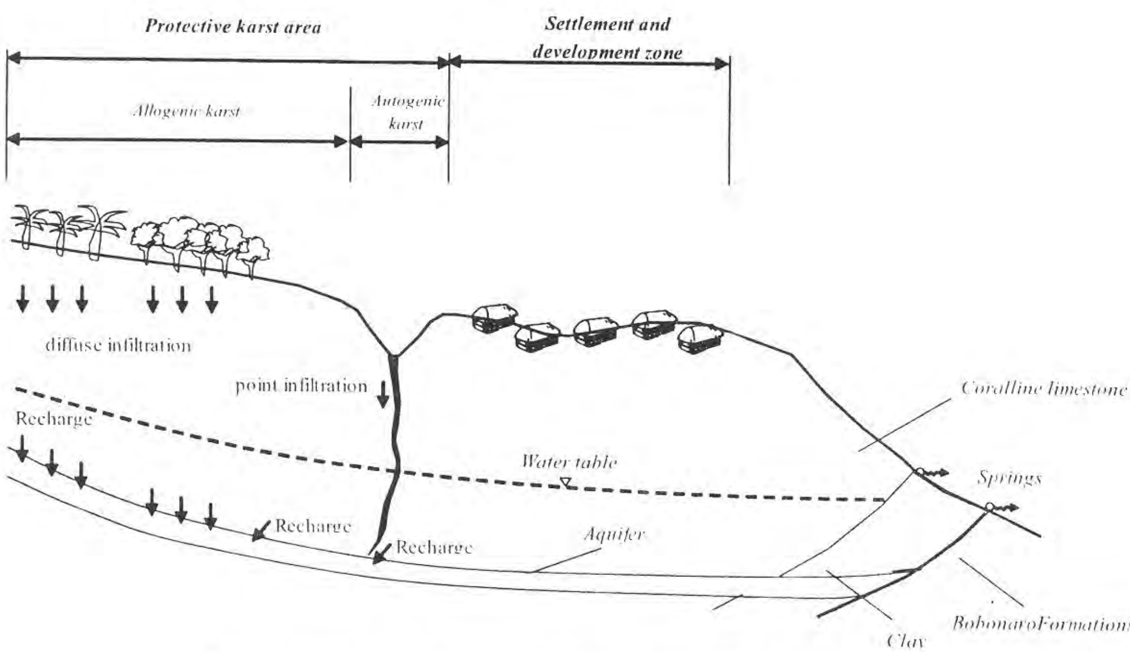



Figure 6. Concept of protective karst area (PKA) in Rote Island

**Groundwater monitoring at Mamar springs**

Knowledge of hydrogeological system of a specific area is a precondition for appropriate conservation strategies (Nguyet and Goldscheider, 2006). The knowledge is built upon thorough analysis of a set of data available for pertinent area. In karst areas, several places i.e. springs, cave streams, and wells, are the only suitable location to monitor the quality and quantity of groundwater (Quinlan and Koglin, 1989). Data such as springs' water discharge taken from continuous groundwater monitoring is important to determine characteristics of groundwater recharge process.

**Legalisation of protective karst area (PKA)**

After being confirmed by all stakeholders, it is recommended that the final draft of PKA be implemented with legal means. The government, through its Regional BAPPEDA (Regional Development Planning Agency), who mainly works as a coordination agency in regencial platform, can adopt PKA into its regional strategic plan (*Rencana Strategis Daerah*). This plan projects and integrates overall development strategies from all agencies in Rote Island. The plan is then translated in a formal-legal language as Perda (Regional Regulation).

**Cultivating economic plants at diffuse recharge area**

Ecologically, reforestation measure is a method to conserve the land by which it accommodates more water to penetrate the earth, thus entering the aquifer during recharge process. Therefore, the absolute benefit of reforestation in hydrologic cycle is that it accentuates infiltration by increasing the quantity of water percolating down to the water table (Allen and Chapman, 2001 ). The selection of local vegetation needs to take into account the concept that the improvement of inhabitants' livelihood is the most important long-term objective in efforts to enhance natural resources management in developing countries (Merrey et al., 2005), such as coconut (*Cocos nucifera*), Palm (*Borassus flabellifer*), betel palm (*Areca catechu*), banana (*Musaceae*) and mango (*Mangifera*), which in turn can strengthen local's economy.

## CONCLUSION

There are several points concluded in this study. The local knowledge by which the community manage the spring water and its ecosystem is called Mamar System developed and maintains a system which is locally acknowledged as Mamar System which is, in this study, defined as a local knowledge and practice of water management in Rotenese society in Rote Island to conserve karstic groundwater spring in order to primarily provide sufficient water for plantation and drinking water for the community living surrounding it.

It is concluded that all factors that pose threat to Mamar have direct and indirect implication to the state of water balance variables that govern hydrologic process in this karstic island. Any changes occurs in the state of water balance of the karstic groundwater may result in a reduced water recharge capacity to karst aquifer which end at reduction of capacity of spring to supply water, thus creating water insecurity in the communities of Rote Island. Therefore conservation strategies, which in this are drawn in the framework of sustainable water management, need to be designed and implemented in order to overcome the potential tradeoffs.

The finalisation of legal aspect of Protective Karst Area (PKA) is important through appropriate administrative means in Rote Island in order to strengthen the preservation of the recharge area. Wider participation of the community to support the overall measures is suggested to be achieved through dissemination of information that encourage better understanding of the karst characteristics in Rote Island.

Coordination of all Mamar System in Rote Island is recommended through regular meeting that discusses economic, social and technical issues regarding Mamar Spring to strengthen Mamar System's capability to manage the spring and its ecosystem. It is recommended to perform reforestation at recharge area with profitable plants that could improve inhabitants' livelihood in order to gain continuous participation of inhabitants to conserve the mamar ecosystem.

## SUGGESTION

In order to achieve an enhanced understanding of karst characteristics which govern the recharge process to Mamar springs, the following potential studies are considered suitable for further research: a detailed geological study that aims at identifying the actual geological stratum over the Rote Island and water balance analysis of the island.

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