



**CLIMATE CHALLENGE AND WATER SCARCITY  
ADAPTATION STRATEGIES IN THE AREA OF PACITAN,  
INDONESIA**

**Dissertation**

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**“Say, Have you considered: if your water was to become sunken [into the earth], then who could bring you flowing water?”**

**AL MULK (67): 30**

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## ABSTRACT

Water scarcity is one of the main issues in Pacitan, particularly in the karst areas that are intersected with Gunung Sewu karst areas. There are three *Kecamatan* that are included in karst areas of Gunung Sewu in Pacitan, namely: *Kecamatan* Donorojo, *Kecamatan* Punung, and *Kecamatan* Pringkuku. Due to the porous texture of the karst underground, most of the precipitation trickles immediately down into extensive system of sinkholes and caves. Therefore, surface water rivers or brooks are limited to be found in the area, particularly during dry season where water supplies are depleted. During dry season, the three *Kecamatan* suffer water shortage where some people need to walk up to several kilometres to fetch water for their domestic use. The long period of dry season exacerbates the condition where extreme climate events, i.e. ENSO occur. However, PDAM (Perusahaan Daerah Air Minum) or Piped Water Supply from the Government that had developed since 1992 in Pacitan had contributed in water supply in these areas and it had covered 70% in three *Kecamatan* by building IPA and is currently developing to cover the rest of the area by utilizing perennial water sources. PDAM and The Ministry of Public Work are supporting the water treatment installation (*Instalasi Pengolahan Air*/IPA) especially in these three *Kecamatan*. Furthermore, adaptive capacity has been developing in the local community of karst area in Pacitan, e.g. planting cultivars that resistant to drought (cassava, maize, soybean, and groundnut) or doing multi cropping between those cultivars, and the application of traditional Javanese agriculture calendar that is called pranata mangsa by some communities.

Water governance in Pacitan has been able to cope with the complexity of water management. Since 2004, where PDAM was expanding its service, the local government of Pacitan has been collecting information regarding villages in three *Kecamatan* that suffer severe water issues from the head of village, thus further actions to tackle water shortage in the respected areas are prepared. Nevertheless, the implementations of regulation that attributable to climate variability adaptation from the central government are not well enforced. Although Pokja or working groups from DNPI through Government Regulation has formed greenhouse gas emission reduction strategy and climate change adaptation mainstream policies, but the top-down implementation has not been well implemented. Therefore, the integrated coordination between supported governmental institutions in water and climate sector is significant to be established, as well as the involvement of Public-Private Partnership to support the finance development by taking the role of local communities into consideration.

## ZUSAMMENFASSUNG

Wassermangel ist eines der Hauptprobleme in Pacitan, insbesondere in dem Gebiet, das zum Gunung Sewu-Karst gehört. Zu der Gunung Sewu-Karstregion gehören die drei Bezirke Danurojo, Punung und Pringkuku. Wegen des porösen Karstbodens versickern die meisten Niederschläge sofort in dem weitläufigen System aus Dolinen und Höhlen. Aus diesem Grund gibt es nur wenige Oberflächengewässer, wie Flüsse oder Bäche. Das gilt insbesondere für die Trockenzeit, in der die Wasservorkommen schnell erschöpft sind. Während der Trockenzeit leiden die drei Bezirke unter Wassermangel und manche Menschen müssen mehrere Kilometer laufen, um Wasser für ihre Haushalte zu holen. In der lange andauernden Trockenzeit wird die Situation durch extreme Klimaereignisse, wie beispielsweise ENSO, noch weiter verschärft. Allerdings hat PDAM (*Perusahaan Daerah Air Minum*), das staatliche Wasserversorgungsunternehmen, das im Jahr 1992 in Pacitan gegründet wurde, zur Verbesserung der Wasserversorgung in der Region beigetragen. Durch den Bau von IPA (*Instalasi Pengolahan Air*), einer Wasseraufbereitungsanlage, konnten 70 Prozent des Wasserbedarfs in den drei Bezirken abgedeckt werden. Derzeit bemüht PDAM sich um die Versorgung des restlichen Gebiets durch die Nutzung ganzjähriger Quellen. PDAM und das Ministerium für Öffentliche Arbeiten unterstützen den Bau von Wasseraufbereitungsanlagen, insbesondere in den drei Bezirken. Außerdem hat die lokale Bevölkerung der Karstregion in Pacitan sich angepasst, beispielsweise durch den Anbau von dürreresistenten Pflanzen (Maniok, Mais, Sojabohne, Erdnuss), durch Multi-Cropping dieser Sorten sowie durch die Verwendung des traditionellen javanischen Anbaukalenders *pranata mangsa* in einigen Gemeinden.

Die Wasserbewirtschaftung in Pacitan hat die Komplexität des Wassermanagements gemeistert. Seit PDAM im Jahr 2004 seine Leistungen ausbaute, sammelt die lokale Regierung von Pacitan von Dorfvorstehern Informationen über die Dörfer in den drei Bezirken, die stark unter Wassermangel leiden. So sollen in den entsprechenden Gebieten weitere Maßnahmen zur Bewältigung des Wassermangels vorbereitet werden. Allerdings werden die Regulierungen der Zentralregierung zur Anpassung an klimatische Veränderungen nicht gut umgesetzt. Zwar haben Arbeitsgruppen (Pokja) des DNPI durch eine Regierungsverordnung eine Strategie zur Reduktion von Treibhausgasemissionen und Maßnahmen zur Anpassung an den Klimawandel entworfen, doch die Top-Down-Implementierung hat nicht gut funktioniert. Daher sind die Einrichtung einer umfassenden Koordination zwischen staatlichen Institutionen im Wasser- und Klimasektor sowie die Einbindung von Public Private Partnerships in die Finanzierung von weiteren Entwicklungsprojekten von zentraler Bedeutung. Dabei muss die Rolle der lokalen Gemeinschaften berücksichtigt werden.

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## LIST OF ABBREVIATIONS

BBWS	Balai Besar Wilayah Sungai (River Basin Organization)
BIG	Badan Informasi Geospasial (Indonesian Geospatial and Information Agency)
BMKG	Badan Meteorologi Klimatologi dan Geofisika (Indonesian Agency for Meteorology, Climatology and Geophysics)
BNPB	Badan Nasional Penanggulangan Bencana (Indonesian National Board for Disaster Management)
BPS	Badan Pusat Statistik (Central Agency on Statistics)
BUMN	Badan Usaha Milik Negara (Government-owned Corporation)
DMI	Domestic Municipal Industry
DNPI	Dewan Nasional Perubahan Iklim (National Board on Climate Change)
DPR	Dewan Perwakilan Rakyat (House of Representatives)
ENSO	El Niño Southern Oscillation
FAO	Food and Agriculture Organization
FGD	Focused Group Discussion
GAPENSI	Gabungan Pemborong Nasional Indonesia
HIPPAM	Himpunan Penduduk Pemakai Air Minum (Community-based Water Users Association)
IPA	Instalasi Pengolahan Air (Water Treatment Installation)
IPCC	Intergovernmental Panel on Climate Change
MPR	Majelis Permusyawaratan Rakyat (People's Representative Assembly)
NOAA	National Oceanic and Atmospheric Administration
ONI	Ocean Niño Index
PAH	Penampung Air Hujan (Rain Water Harvesting)
PDAM	Perusahaan Daerah Air Minum (Piped Water Supply)
PERDA	Peraturan Daerah (Regional Regulation)
PERPAMSI	Persatuan Perusahaan Air Minum Indonesia (Public Water Association)
PerPres	Peraturan Presiden (Presidential Decree)

PIK-Potsdam	Potsdam-Institut für Klimafolgenforschung (Potsdam Institute for Climate Impact Research)
PP	Peraturan Pemerintah (Government Regulation)
POKJA AMPL	Kelompok Kerja Air Minum dan Penyehatan Lingkungan (Working Group on Water and Environmental Issues)
PPP	Public-Private Partnership
PSBA	Pusat Studi Bencana Alam (Research Centre for Disasters)
PSDA	Pengelolaan Sumber Daya Air (Public Water Management Agency)
SST	Sea Surface Temperature
SUSENAS	Survei Sosial Ekonomi Nasional (National Socio-economic Survey)
UN	United Nations
WHO	World Health Organization

# 1. INTRODUCTION

## 1.1. Research Background

The current global climate conditions have become a constraint for many sectors of human activities. Increased intensity of drought as well as flooding and seasonal changes of rainfall and temperature may alter the cultivation seasons, planting and harvesting calendars, water availability, pest, weed, and disease populations and many other forms of uncertainties in agricultural systems (ROSEGRANT 2008). In terms of long-term adaptation, application of new technologies, new land management techniques, and techniques related to water use efficiency are also considered as major structural changes required to overcome the adversities of climate change (FAO 2008).

As described in the Intergovernmental Panel on Climate Change or IPCC Report (ARNELL 2001), climate variability plays an important role in the hydrological cycle, where reduced amounts of precipitation correlate with groundwater levels and surface water systems. Particularly in the areas where rain fed agriculture is primary, high climate variability affects water supply and ultimately exposes these areas to increased drought in the future due to climate change. Accordingly, Giertz (2006) stated that the availability of water from surface rivers or shallow groundwater depends on the seasonality and inter-annual variability of stream flow and that safe water supply is determined by seasonal low flows, particularly in semi-arid areas where the dry season can be prolonged due to changes in climate variability, thus affecting water supplies.

However, non-climatic-drivers affect global freshwater resources as well, as mentioned in IPCC Report (KUNDZEWICZ, MATA, ARNELL, DÖLL, JIMENEZ, MILLER, OKI, SEN, and SHIKLOMANOV 2007), where land use change, construction and management of reservoirs, pollutant emissions and water and wastewater treatment are considered as non-climatic-drivers that influence water resources both in quality and quantity. Water management plays an important role in climate change as well, as the vulnerability of freshwater systems depends on it. Thus, mainstream Integrated Water Resource Management or IWRM policies are needed, particularly in areas of water supply vulnerability, in order to decrease the vulnerability of freshwater systems to climate change.

Water usage is an integral part of human life. Over the next decade, both urban and rural areas are expected to be affected by both supply and demand issues. Yet water is becoming scarcer globally and there are indications that it will become even scarcer in the future, proportional to population growth worldwide. Water is becoming scarce not only in arid and semi-arid areas, but also in areas where water resources are immense. The sustainable use of water in water scarce areas, including the use of technology, is the top

priority in the agricultural sector (PEREIRA, CORDERY and LACOVIDES 2009). Furthermore, imbalances between supply and demand and the degradation of surface and groundwater quality often occur in arid and semi-arid areas as well.

Simonovic (2009) highlighted as a complex system of nature, a water resources system involves four subsystems: the individual, organizations, society and the environment. Furthermore, Bauer (2006) added that in qualitative and quantitative term, the balance of groundwater is not only influenced by the increasing land consumption, but also the ecological functions of soil, such as soil-water balance and the surface water. The relation between subsystems must be fully integrated in order to reach sustainable water resources management. Individuals are as actors that move organizations and society in decision making, norms and behaviour, whereas society is placed in the environment that encompasses water as one of the earth's elements.

Areas where precipitation and streamflow are concentrated over a period of months and where year-to-year variations are high, are more likely to be vulnerable to climate vulnerabilities, in particular precipitation and temperature vulnerability (LENTON 2004). Adding to that Arnell (2001) emphasized in IPCC Report that there are two drivers in water availability: (1) a climatic driver that consists of temperature, precipitation and evaporative demand, and (2) a non-climatic driver that consists of water resources that are affected by land use change, the construction and management of reservoirs, pollutant emissions and water and waste water management.

Recent studies (ANNANDALE 2012, GLEESON 2012) have shown that globally we are using more groundwater than what is naturally replenished, whereas groundwater systems generally respond more slowly to climate change than surface water systems (river water). Groundwater levels correspond more robustly with temperature and depend on the seasonality and inter-annual variability of stream flow. Therefore, in areas that are more vulnerable to drought, extreme climate events may extend the dry season which particularly affects the community that depends on reservoirs or deep groundwater (GIERTZ 2006).

The amount of water on earth's surface varies through time and space. Severe conditions during dry seasons where the amount of water flowing in rivers and other water sources decrease will affect the reliability with which water can be supplied and water demand as well. Therefore, the demand for water can be supplied particularly during the rainy season when flows are high; however, during the dry season it is not possible to supply the demand of water for community. Annandale (2012) added that droughts that last from two to seven consecutive years, or even longer, mean the annual amounts of water that flows in the rivers can be significantly lower than the long-term mean annual flow. Thus, the area with seasonal recharge of groundwater that occurs regularly during



rainy season may also get less or even no water during dry seasons. Therefore, in order to store excess amounts of water during rainy seasons for the use of water in dry seasons, reservoirs or other water storages can be used to provide water for the community particularly during the dry season.

Bonell and Balek (2006) stated that climatic factors and vegetation cover play an important role in recharge and discharge of groundwater; although topography and the geomorphic structure of the land surface affect the scope and location of recharge and discharge area. In terms of natural hazard regulation, ecosystem is also essential, by its capacity to buffer extreme climate events where the impact of it may increase the vulnerability of society. Moreover, within the context of climate change, the uncertainty of climate variability also plays an integral part in water resource management.

Some feasible impacts of climate uncertainties like changes of precipitation, runoff pattern, sea level rise; land use and population shifts may affect water planning and project evaluation in terms of water management. Increases in temperature alters the hydrologic cycle, intensifies evapotranspiration rates and alters soil moisture and infiltration rate, changing in precipitation alters the magnitude and timing of runoff, and the intensity and frequency of flood and drought (FREDERICK and MAJOR 1997). Schaake (1990) also estimated the runoff elasticity is higher in drier climate areas and elasticity with respect to precipitation is greater than that for evapotranspiration (the percentage of change in runoff resulting from a 1 per cent change in precipitation and temperature). Therefore high temperature will decrease runoff much less than a warming with a decrease in precipitation.

In the equatorial areas where the ocean dynamic exhibits a close connection between the seasonal-interannual time scale between the large scale atmospheric and oceanic circulation and extreme climate events, the El Niño Southern Oscillation/ENSO occurs (RASMUSSEN 1987). There are several definitions of El Niño; Berlage (1966) defined it as a fluctuation that is dominated by an exchange of air between the South Pacific subtropical high and the Indonesian equatorial low. Gray (1993) described El Niño as a period of between 12 and 18 months during which anomalously warm sea surface temperatures occur in the eastern half of the equatorial Pacific. El Niño events related to the existence of anomalously warm sea surface temperature in the equatorial Pacific cause drought in the eastern part of Indonesia and most of Java Island; whereas strong coastal upwelling that causes anomalously heavy rainfall off the coast of Peru create a favourable physical environment for biological productivity, due to the upwelling of nutrient-rich water from lower levels (QUINN, ZOPF, SHORT, KUO YANG 1987).

Hendon (2002) deduced that the rainfall in the Indonesian archipelago is coherent and strongly related with ENSO variations in the Pacific basin, where the

anomaly condition can lead to strong consequences when early monsoon rainfall is delayed or reduced. Adding to that, drought in the Indonesian regions is interpreted to result from remotely forced subsidence that interconnects with an eastward shift of convection into the central Pacific and weakening of the Walker circulation. Thus, the drought-prone areas, e.g. Gunung Sewu in southern Java Island, including Pacitan have high elasticity to high temperature and lack of rainfall, especially during the years of El Niño. Wooster (1960) categorised El Niño events into strong, moderate, weak or very weak. The categorization is based on the magnitude, intensity and the time of year the event occurred, where generally, El Niño occurs during the first half of the year.

According to Stakhiv (1997), adaptive management affiliated with societal response to variability and change are built to upgrade and intensify the innovative and cost effective supply-side and demand-side management measures, and continue to create institutions that are more flexible in adapting to social and physical changes. In terms of climate change, the definition of adaptation is mentioned by several researchers as adjustment in behaviour that exist in individuals, groups and institutions in order to reduce the vulnerability to climate; thus adaptation can be seen as a form of reaction that depends on the degree of spontaneity or planned action (PIELKE 1998; FANKHAUSER 1998; SMIT and PILIFOSOVA 2000). Therefore, the assessment of impacts, vulnerabilities and the development and evaluation of response options are essential in the context of adaptation to climate change. Adding to that, the characteristic of communities, groups and regions that influence the tendencies to adapt and their vulnerability to climate change need to be considered.

In terms of water resource management, adaptation can be defined as the ability of a community or group to cope with changes that are associated with a lack or excess of water by forming technical support through infrastructure, e.g. building reservoirs, wells, and pumps to increase water supplies; improve water supply management and agricultural practices that are more resistant to drought or lack of water (FREDERICK 1997; SMIT and WANDEL 2006). Dregne (1987) mentioned that the ability to adapt with climate variability in the dry regions is related to crop selection, moisture conservation, erosion control and maintenance of soil fertility. Hence, if rain comes early, long-season cultivars are planted to take advantage of their greater yield producing potential. If rain comes late or if dry periods kill crops planted early, short-seasons cultivars are a normal response to temporal variability in rainfall.

In the early approach of adaptation to climate change, the “top-down” perspectives were carried out from global scale climate model scenarios to sectoral impact studies. The recent approach to community-based adaptation to climate change that include participatory assessment, knowledge building and capacities of local

community, has been developed in disaster risk reduction and community development work that affiliated with sectoral-specific approaches, e.g. farmer participatory research to integrate scientific and local knowledge of climate change and to plan adaptation measures (BERGER, REID, ALAM, CANNON, HUQ, MILLIGAN 2009). Thus, a number of methods to assess participatory approaches have been developed since the 1980s, e.g. rapid rural appraisal that developed into participatory rural appraisal in the 1990s and related techniques to collect information at the community level concerning livelihood and daily existence (CHAMBERS 1994). Furthermore, Wahl-Post (2006) and Huitema (2009) mentioned that in terms of water resource management, successful governance depends on adaptive institutions that are able to cope with complexity and uncertainty and certain elements need to be concentrated in order to accomplish institutional adaptation, including adequate access and distribution of information, cooperation in the context of public participation and sectoral integration.

Karst studies particularly in the tropic regions, like Gunung Sewu on the south coast of Java Island had been initiated by Franz Junghuhn during his visit to Java Island in 1836 (HOLTHUIS 1984) and then continued by other researchers, for example Lehmann in 1936 who carried out his research as a fundament of modern tropical karst geomorphology; Flathe and Pfeiffer in 1965; Balasz in 1968; Uhlig in 1980 (JENNINGS 1985; WALTHAM 1985). Junghuhn (1845 in Uhlig 1980:2) described Gunung Sewu as “rounded, hemispherical mountains 100 to 200 feet high which rise up in their hundreds one beside the other in all directions, and which are separated from each other by narrow, labyrinthic, interconnected valleys”. Yet, Lehmann (1936 in Uhlig 1980:2) also added “The relief of Goenoeng Sewoe gives the impression of being the reverse of a normal mature doline landscape. Instead of the dolines which in the Dinaric Karst puncture the karst plateau like a sieve with a series of more or less circular bases, and instead of narrow crests and angular residual pillars between the merging dolines in a maturing karst landscape, the hollow shapes here are angular with concave –inwards indented-boundary lines”.

The descriptions of tropical karst in Gunung Sewu has been mentioned by several researchers (LEHMANN 1936; FLATHE & PFEIFFER 1965; BALASZ 1968, VERSTAPPEN 1969, WALTHAM 1983 in HARYONO 2008) as landscape of cone (or kegel) karst characterised by sinusoidal or hemispherical hills interspersed with enclosed star-shaped depressions or interconnected valleys. The characteristic of karst aquifers can be different from other aquifers, given the high heterogeneity that is organised by groundwater flow, large voids, high flow velocities up to several hundreds of m/h and high flow rate springs of up to some tens of m<sup>3</sup>/s. Karst aquifers are not always an exploitable aquifer due to the origin of the karst features and the condition of their development,

though most of the time karst aquifers contains groundwater that leads to water supply (BAKALOWICZ 2004). Furthermore, not all karst aquifers are susceptible to precipitation fluctuation, in comparison with other porous media; it shows faster responses and is thus more vulnerable to extreme weather events such as floods and droughts; thus during high intensity of rainfall events, the low aquifer porosity cannot store and transmit the large volumes of infiltrating rainwater and this has caused karst aquifer in open hydrogeologic structures that directly exposed to precipitation to be more vulnerable (KRESIC 2013).

Extreme climate events like ENSO have contributed to irregular climatic conditions across the Indo-Pacific Maritime Continent, including Indonesia, Malaysia, New Guinea and the surrounding areas. During ENSO years, the Walker Circulation weakens as the Indonesian Low migrates eastward into the tropical Pacific, resulting in drought in most areas of Indonesia (HENDON 2002; D'Arrigo and WILSON 2006). Adding to that, Rasmusson (1987) mentioned that the typical ENSO anomalies in Indonesia occur from the early dry season to the beginning of rainy season, or from early March to the end of November.

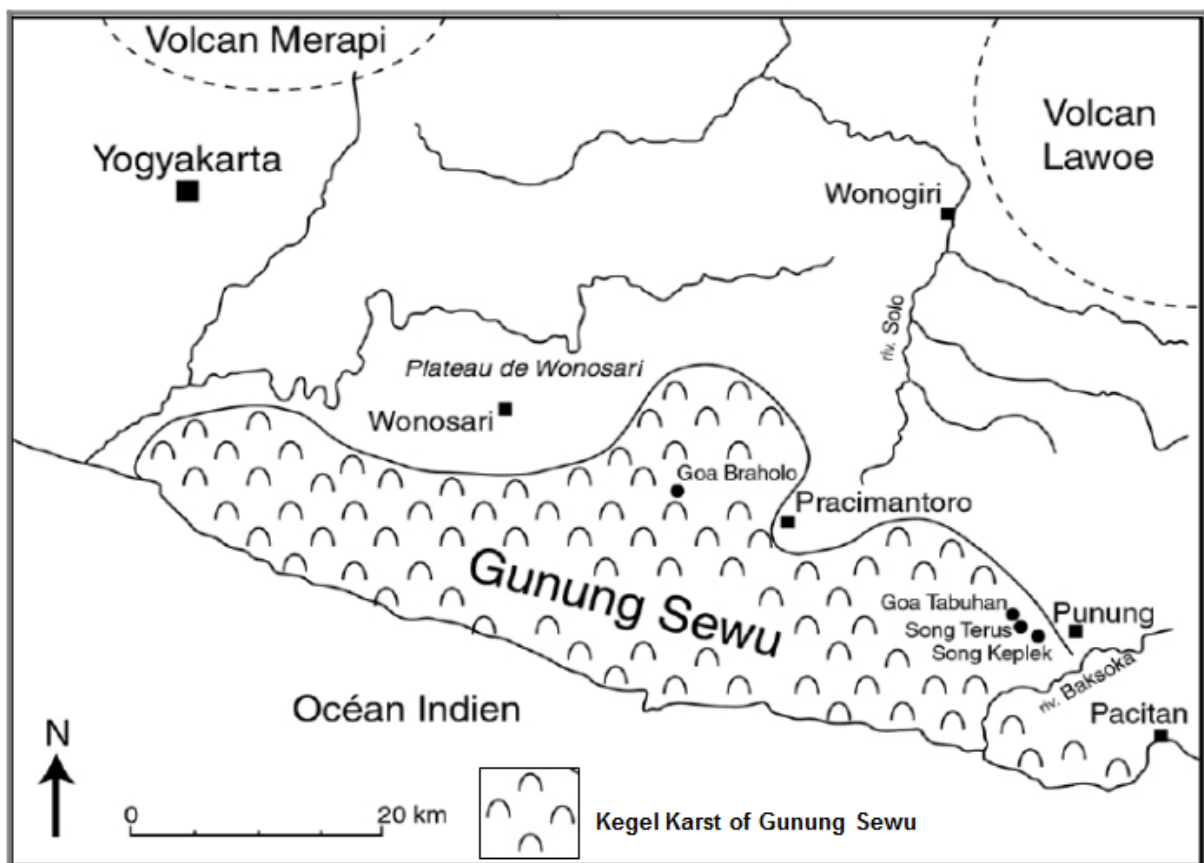
With 2700 mm of rainfall per year, Indonesia is endowed with plentiful potential water sources, with 80% of water sources coming from surface water systems and 20% from groundwater (FAO 2010). However, the abundance of water resource potential in Indonesia is not followed by the equitable distribution of those water resources throughout the country. Due to great variation of rainfall seasonality, population density and resource capability differences across the island nation, many areas in Indonesia experience water issues, especially during the dry season. Java is the most populous island, having almost 60% of the total national population; receive 2000 m<sup>3</sup> of rainfall/capita/year while Papua, where it is inhabited by only 2% of the total population, receives 282,000 m<sup>3</sup>/capita/year (MINISTRY OF SETTLEMENTS AND REGIONAL INFRASTRUCTURE 2003:13).

The Karst area in Indonesia consists of a total area 154.000 km<sup>2</sup> of which 15% is protected (SURONO 1992; SUNKAR 2008). Gunung Sewu karst area encompasses the Southern Coast of Java Island, from Parangtritis Beach in Yogyakarta Special Province to Teleng Ria Beach in Pacitan, East Java Province with an approximate area of 1220 km<sup>2</sup> and extends 85 km west-east and between 10-25 km north-south (FLATHE 1965; HARYONO 2008). Gunung Sewu karst area comprises parts of three provinces, namely Yogyakarta Special Province in the most western part, Central Java Province (Wonogiri District) in the middle part, and East Java Province in the most eastern part, where Pacitan District is located.

Administratively, there are three sub-districts (*Kecamatan*) in Pacitan included in Gunung Sewu karst area, namely: *Kecamatan* Donorojo, *Kecamatan* Pringkuku, and *Kecamatan* Punung. These *Kecamatan* are located in the most western part of Pacitan

and, except for Punung, border the Indian Ocean. As a part of Gunung Sewu karst area, allogenic recharge from surface river and point recharge through ponors that are well spread in these three *Kecamatan* as well, where point recharges are mostly from ponors draining off from closed depressions during the rainy season, where the depositions are eroded by rivers and the permeation of water that ultimately forms karst and covers thousands of small hills (HARYONO 2008).

Water scarcity is one of the main issues in Pacitan; due to the karst structure in the coastal area, where the karst aquifer is highly vulnerable to dangers for human consumption since water from the surface, including pollutants, penetrates to the ground almost without filtration. Moreover, anthropogenic activities have made the condition worse due to land degradation and poor water management (Pusat Studi Bencana (PSBA)-Bappeda Pacitan 2007). Therefore, innovation in land and water use, adaptation technologies and developing fairness in the use of natural resources are playing an important role in developing adaptation strategies for water scarcity.



**Map 1. Location of Gunung Sewu (drawn from Barstra 1976)**

Map 1 above shows where Gunung Sewu is located in Java Island, where it is a part of the Southern Mountain of Java Island, meanwhile the northern part of it is adjacent to the Central Depression of Java occupied by active Quaternary volcanoes and southern part is bordered by the Indian Ocean. Administratively, there are three provinces that are

included in Gunung Sewu karst areas, namely Gunungkidul in Yogyakarta Province on the most west part, Wonogiri in Central Java Province on the central part and Pacitan in East Java Province in the most eastern part. As it is shown in the figure above, karstification that are formed in tropical karst morphology, named as kegel karst, are spread from Gunungkidul to Pacitan,

## 1.2. Research Questions and Hypotheses

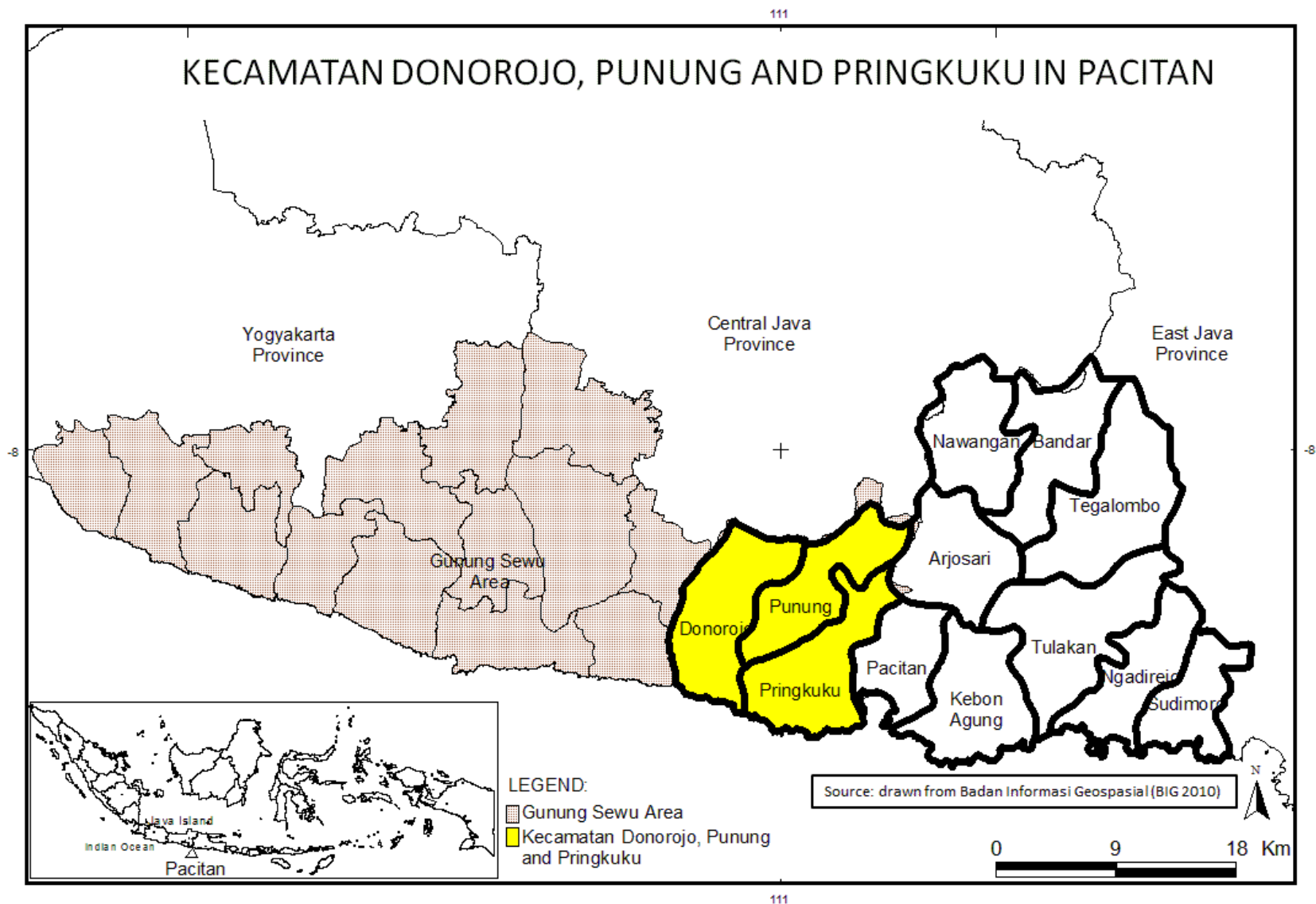
The research is concentrated in the most eastern part of the karst area in Gunung Sewu that is administratively included in Pacitan District, East Java Province, namely: *Kecamatan* (Sub-District) Donorojo, *Kecamatan* Pringkuku and *Kecamatan* Punung as shown in Figure below. These three *Kecamatan* are located in the most western part of Pacitan District. The research focuses on water availability in relation to extreme climate events, like the shifting of planting season and the existing adaptation in terms of the planting season in Javanese culture called *pranata mangsa*. In addition, the role of local and national stake holders especially in the karst areas is also a fundamental issue in the research. Detail of research questions are as follows:

1. What are the significant impacts of climate change to water availability in Karst area in Pacitan?
2. What are the existing adaptation strategies to cope with water scarcity, i.e. local wisdom in terms of adapting to water scarcity in Karst areas?
3. How big is the role of local and national stake holders in terms of water use and enhanced integrated water management especially in the karst area?

In this sub-chapter, research hypotheses are also briefly described to establish a comprehensive analysis based on the above research questions, as follows:

1. Water is an indispensable commodity for every individual, thus the access to water resources is also essential
2. There is a correlation between climate variability, karst topography, water management, water scarcity and number of population in the karst area of Pacitan
3. The local community acknowledge the existing adaptive capacity and local wisdom that is attributable to water use in karst areas.





Map 2. *Kecamatan* Donorojo, Punung and Pringkuku in Pacitan (own figure drawn from Badan Informasi Geospasial 2010)

### 1.3. Objectives of Research

The research is focused on the concept of water scarcity in Pacitan that includes Gunung Sewu karst areas, namely *Kecamatan* Donorojo, *Kecamatan* Pringkuku, and *Kecamatan* Punung as shown in Map 2, and the relation between water scarcity phenomenon in the respective areas due to karst condition with the role of extreme climate event like ENSO, as well as the adaptive capacity in different sectors. The research also reviews the role of stakeholders in terms of water management and climate change adaptation; thus the objectives of the research can be described as follows:

1. Investigating extreme climate events and their relation to water scarcity in Pacitan
2. Analysing the existing adaptive capacity and responses of community in terms of water scarcity in Pacitan
3. Analysing the role of stakeholders at all levels in order to enhance integrated water resource management

### 1.4. Research Method

This sub-chapter briefly illustrates the research method that covers primary and secondary data. The primary data consists of base map of Pacitan, a geological map, a land use map, the number of population, water discharge, and water source distribution map. Time series climate parameters that consist of precipitation and temperature for 31 years (1981 to 2012) were attained from *Badan Meteorologi dan Geofisika Pacitan*. The basemap that is used in this research was obtained from *Badan Informasi Geospasial* (BIG) which shows the Provinces, *Kecamatan* and *Desa* in the municipalities of Pacitan in 2010. The geological map of Pacitan was obtained from *Peta Lembar Geologi Pacitan* 1992 that depicts the deployment of carbonate in Pacitan, particularly in Gunung Sewu karst areas. While the land use map was attained from Ministry of Forestry in 2011, and water discharge are obtained from the municipal agencies of Pacitan (*Kecamatan*) and Ministry of Public Work. These physical data are drawn from central and local government agencies that provide secondary data. Meanwhile, the primary data that was used in this research consists of semi-structured interviews with community and *Focused Group Discussion* (FGD) with the local stake holders and local community, as well as qualitative data which is shown in Figure below with red boxes. There are 40 respondents used in this research from 38 villages (*desa*<sup>1</sup>) and three FGD in every *Kecamatan*. The interviews and FGD were conducted from 1<sup>st</sup> of April to 5<sup>th</sup> of July 2013 and started with administrative works, such as permission letters from East Java Province and other local

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<sup>1</sup> *Desa* in Indonesian language means village and administratively it is a sub-ordinate from *Kecamatan* where the head of *desa* is called *kepala desa*



governmental agencies in Pacitan as well. Secondary data are collected to correspond with the information regarding the existing adaptive strategies on water use, and water management related policies and the physical data as shown in Figure 2 and 3 below. Detail of data analysis is described in Chapter 5. This research also emphasized the coverage area of Gunung Sewu karst areas in Pacitan, namely Kecamatan Donorojo, Kecamatan Punung, and Kecamatan Pringkuku.

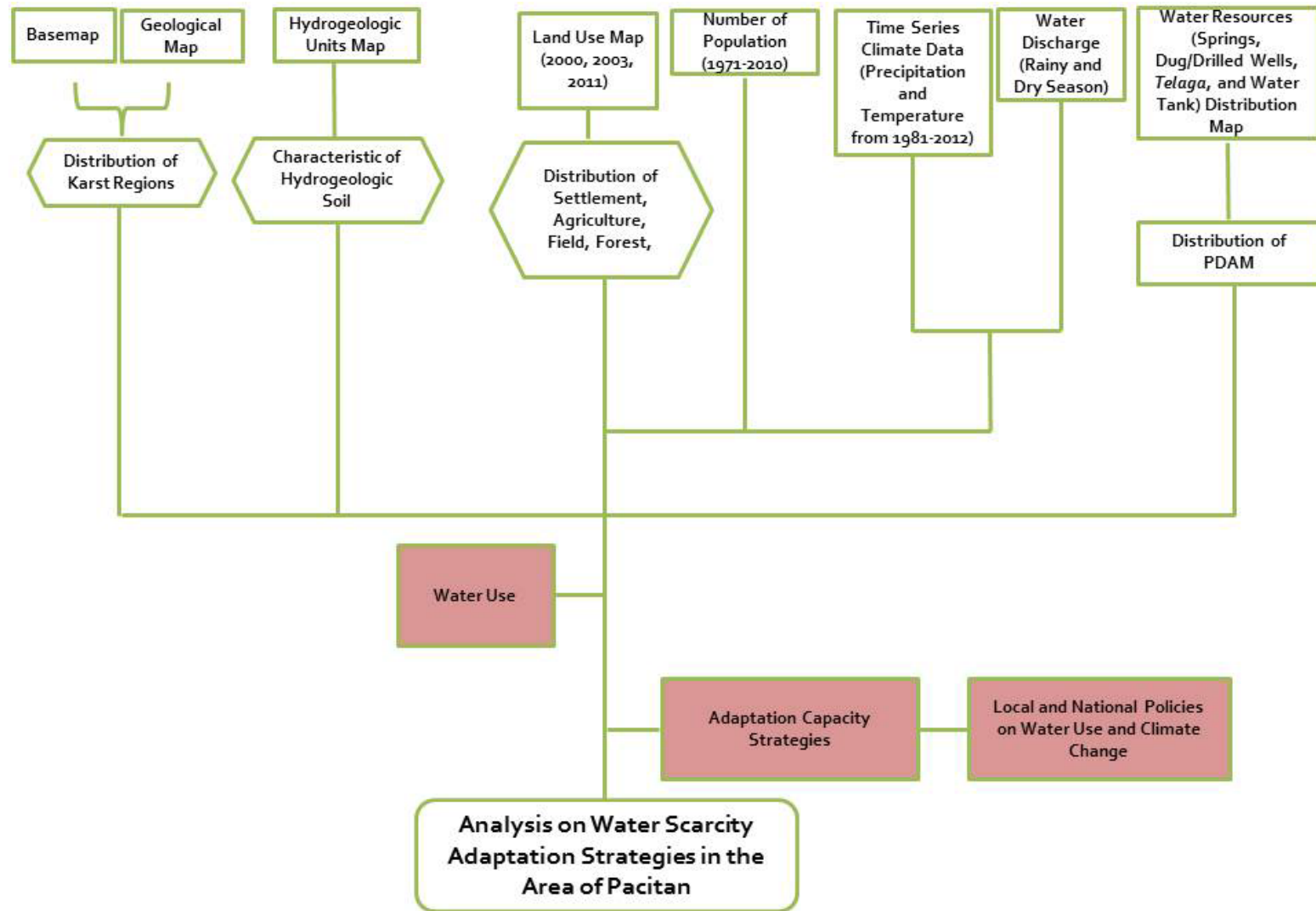


Figure 1. Research method

## 2. WATER SCARCITY

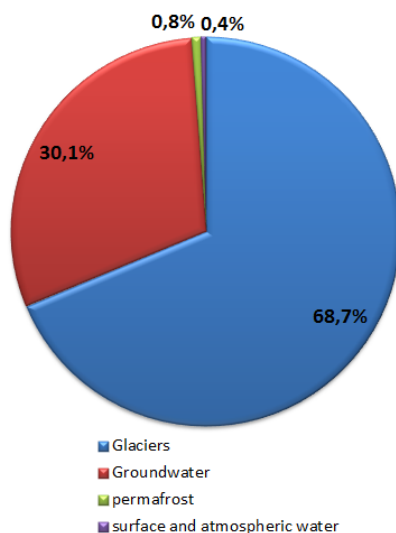
This chapter reviews in general the basic concept of water scarcity in global distribution and what are the causes of water scarcity in terms of water management and in relation to climate variability.

### 2.1. Global Water Scarcity

#### 2.1.1 Basic Concept of Water Scarcity

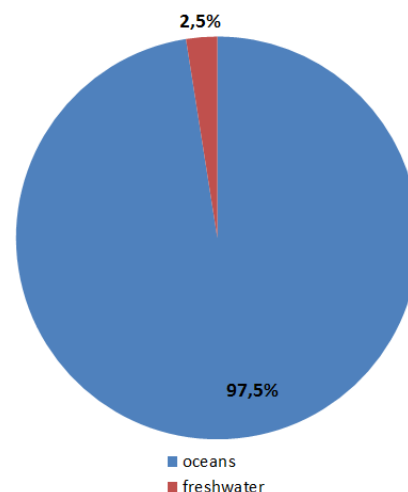
The surface of the earth is 71.1% covered by water and about 97.5% of this water is salt water (Fig. 2). Thus, the vast majority of global water is unusable for human consumption without treatment e.g. desalination. The 2.5% of water, that is fresh water, is comprised of glaciers, permafrost, groundwater and surface and atmospheric water as shown in Fig. 3 (GEO 2002). Figures below show that less than 3% of freshwater is locked in two polar icecaps, and merely 1% of freshwater is theoretically available for agriculture, industry and human consumption. Freshwater for human consumption is also produced by precipitation on land, with a small amount produced by water desalination. Due to changes in the state of the ocean, precipitation patterns are altering in ways that often negatively impact human population.

**Distribution of Freshwater in the World**



**Figure 2. Distribution of freshwater in the world (drawn from Global Environmental Outlook 4 UNEP 2007)**

**Global Distribution of the Water in the World**



**Figure 3. Global distribution of the water in the world (drawn from Global Environmental Outlook 4 UNEP 2007)**

Areas where water has always been limited are capable of coping with lack of water because they are able to develop organizational and institutional water technologies and management skills within the local communities in the context of water management

for domestic use, food production and local industry. It is essential to develop these societal skills in order to cope with the lack of water and to assist the local people to live in harmony with the environmental constraints that are particularly related with water resources.

Water scarcity in the context of availability has become the major issue in recent years and a number of assessments and studies in terms of global water availability have been carried out (POSTEL 1992; GARDNER and ENGELMAN 1997; GLEICK 1998; SECKLER, AMARASINGHE, MOLDEN, DE SILVA, and BAKER 1998; SAVENIJE 2000; FALKENMARK and ROCKSTRÖM 2005; SHIKLOMANOV 2007; PEREIRA et al 2009). Thus the definition of water scarcity has been varied as well as the development of the studies. Therefore, White (2012) stated that there is no consensus on how the term water scarcity should be defined or measured. In general, water scarcity is associated with imbalances between availability and demand, degradation of surface and groundwater quality and different access to water.

FAO (2007, 2008) described that in general water scarcity is the imbalance between water availability and demand for water in an area, under prevailing institutional arrangements and lack of understanding of the interrelations between different sectors where water resources occur. Adding to that, water scarcity can be also defined as a situation where water availability in a country or in an area is less than 1000m<sup>3</sup>/person/year, in some parts of the world even less than 500m<sup>3</sup>/person/year, which could be considered severe water scarcity. Meanwhile, the threshold of water use is 2000m<sup>3</sup>/person/year, which can indicate that the area is having water stress, since in this condition an area could face large problems when drought occurs (PEREIRA, OWEIS, and ZAIRI 2002) (KUNDZEWIC, MATA, ARNELL, DÖLL, KABAT, JIMÉNEZ, MILLER, OKI, ŞEN and SHIKLOMANOV 2007). Nevertheless, the concept of water scarcity is commonly defined in different terms, where renewable resources are augmented by desalination; non-renewable groundwater resources and waste-water re-use to compensate for the renewable water scarcity.

According to the Falkenmark Water Stress Indicator, Gardner (1997), and Savenije (2000), 1700 m<sup>3</sup>/person/year is considered as the individual annual requirement. Below this level, water scarcity arises in different levels of severity. Industrial use may be several times greater than this amount; however a sanitary revolution in the industrial sector could seriously reduce the industrial water use. Brown and Matlock (2011) also added water barrier differentiation, proposed by Falkenmark (1989) that is based on the per capita usage and shown in Table 1 below. The condition of no water stress is determined by having more than 1700 m<sup>3</sup> per person per capita, and absolute scarcity is characterized by less than 500 m<sup>3</sup> per person per capita.

Furthermore, FAO Water Reports (2008) defined water scarcity in the context of an imbalance between supply and excess demand for freshwater in a specific area under common institutional management and related to the capacity of the society to cope with the altering level of supply and demand for water. Scarcity occurs as well when there is low or even no institutional arrangement to ameliorate access of the community to water supply and poor maintained infrastructure; whereas, annual or seasonal differences in climate or a range of hydrological and hydro-geological factors contribute to a low level of water resources as well. Thus those definitions mean that water scarcity is a relative concept and has an explicit recognition, where the demands vary considerably between and within regions depending on the sectorial water usage and also underlined the local climate condition within the region.

**Table 1. Water categorization based on the per capita usage (FALKENMARK 1989)**

Index (m3 per capita)	Categorization/Condition
>1700 m3	No stress
1000-1700	Stress
500-1000	Scarcity
<500	Absolute scarcity

Based on the World Bank Development Report (2007), there are three levels of scarcity: scarcity of physical resource where infrastructure and water technologies play an important role, scarcity of organizational capacity where the demand of management and integrated planning drive reliable services to the community, and scarcity of accountability that refers to the accountability of the government to their water related policies.

Meanwhile, the dimension of water scarcity can be divided into physical- and economic scarcity. Physical scarcity occurs when physical conditions in an area do not support or provide sufficient water to meet demand for water by water users, where severe environmental degradation, declining groundwater and water allocations that favour some groups over others. Meanwhile, economic scarcity is defined as a situation where water resources exist, but water users are experiencing lack of water, due to human, institutional, political and financial capital requirements that limit the access to water sources (SECKLER 1998; RIJSBERMAN 2006; FAO Water Report 2008).

Moreover, the existence of physical or economic water scarcity is artificially created in that access and availability is restricted regardless of an apparent abundance of water. Both physical and economic water scarcity may be exacerbated by climate change, where change of temperature and precipitation, combined with alteration in the intensity and frequency of extreme hydrometeorological events, will have great impact to water resources (O'BRIEN and LEICHENKO 2008)

Nevertheless, poor access to water is often confused with physical water scarcity, which is widely discerned as the key aspect undermining water security. Access to water and water services is also a key aspect of water security, but is not always interpreted as scarcity, although this is often cited as the reason. However, the policy that induced consequences of mismanagement is what mostly passes as water scarcity. Poor access to water and water services could also result from political and economic policies. Generally, people who do not have access to water are geographically, economically, institutionally, and socially marginalised (MUKHEIBIR 2010).

Rijsberman (2006) defined that a water insecure condition occurs when a person does not have access to safe and affordable water to satisfy her or his needs for drinking, washing or their livelihoods. When a large number of people in an area are water insecure for a significant length of time, then we can call that area a water scarce area. However, there is no commonly accepted definition of water scarcity. An area defined as water scarce, depends on (1) how to define the need for water by the people and whether the needs of the environment for water are taken into account in that definition, (2) what fraction of the resource is made available, or could be made available, to satisfy these needs, (3) the temporal and spatial scales used to define scarcity. Rijsberman also formulated the limitations of the critical ratio and similar indicators for water demands. These are:

- (1) The availability of data water resources does not take into account how much water could be made available for human use
- (2) The water withdrawal data does not take into account how much water is consumptively used (or evapotranspired) and how much could be available for recycling, through returns flows
- (3) The indicators do not take into account the adaptive capacity of a society to cope with stress.

### **2.1.2 Cause of Water Scarcity**

The causes of water scarcity are interrelated, whereas water scarcity can be seen as a relative concept of demand and supply of water. Abrams (2009) added that the determination of water scarcity is more qualitative rather than quantitative, as its concept is a social concept that describes water scarcity as a combination between supply and demand in a given region where lack of water occurs; therefore it may vary widely from one condition to another. If demand grows extensively beyond supply then scarcity may occur, in contrast uncoordinated planning and physical availability of water limited the water supply *per se*. Furthermore, Molle (2008) mentioned that during low rainfall, high water demand that cannot be fulfilled generates additional investment in water

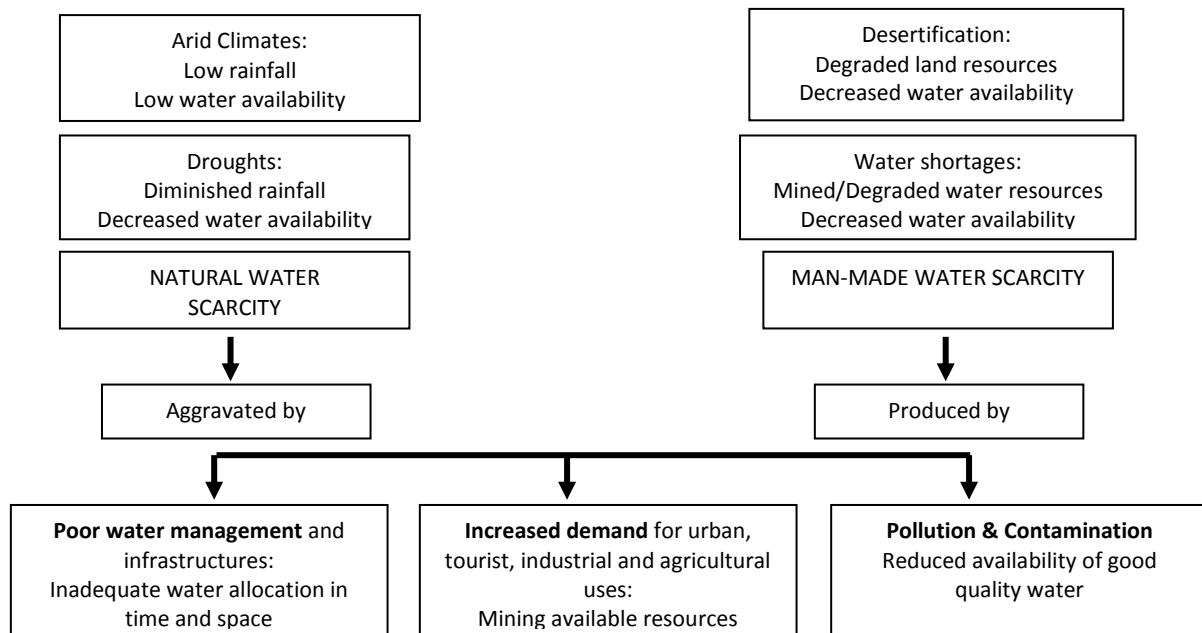
technologies, whereas during the rainy season where rainfall is high, the excess of water flows directly to the sea and is seen as lost opportunity; thus water-save-technology to save and preserve water during rainy season are considered essential. Therefore water scarcity should take social, environmental, and economical dimensions into account as well.

Meanwhile, according to the FAO Water Report (2008) the annual availability of water supply is determined not only by inter-annual variability of climate but also by the geomorphological conditions. Particular geological conditions of karst, determine the availability of groundwater recharge, where it fluctuates seasonally and not every water supply can be used by the communities as a reliable constant supply. Moreover the inter-annual variability of rainfall occurs unevenly over time, where the peak of rainfall may coincide with the low demand season or large quantities of water sources are located far away from the community centres. The inter-annual variability of rainfall affects particularly those regions where the subsistence sectors are dominated by rainfed agriculture. Increase of temperature and late onset of rainfall alters the hydrological regimes in the regions of water sources which affects water demand as well.

Postel (1992) formulated that the water cycle makes water available merely in a given location and in limited time as well, which means water supply per person, a broad indicator of water security, drops as population grows. Therefore, water supply per capita in worldwide terms is decreasing as the world population is growing. In some cases, water problems start directly from mismanagement and degradation of land. When rain hits the earth, it either runs off immediately into rivers and streams to head back to the sea, or it soaks into the land to replenish soil moisture and groundwater supplies, or it is evaporated or transpired (by plants) back into the atmosphere. Land use changes, e.g. deforestation, over grazing and settlement development may alter the proportion of rainfall. Degraded lands due to reduced vegetative cover and soil less able to absorb and hold water, will increase flashrunoff and decrease seepage into the soil and aquifer recharge. These will result in less soil moisture and groundwater available to draw upon during the dry season, and during the rainy season the rapid runoff intensifies flooding and soil erosion.

Furthermore, Pereira et al (2009) mentioned that water scarcity can result from two causes, namely natural scarcity that usually results from arid and semi-arid climates and drought, and man-made scarcity that is associated with desertification and water management, as shown in Figure 4 below. Natural water scarcity can be aggravated by human influences, like population growth and poor water management. Meanwhile man-made water scarcity is a consequence of natural water scarcity and other anthropogenic activities. The interactions between both natural and man-made scarcity may result in

water scarcity as well. Poor management and inadequate water policies that drives uncontrolled pollution and lack of water infrastructure, the augmentation of water demand in arid, semi-arid and sub-humid climates that exacerbates the natural flow of water availability and water scarcity become tangible for the communities.



**Figure 4. Natural and man-made water scarcity (PEREIRA 2009: 8)**

In other studies (WILHITE and GLANTZ 1987; TATE and GUSTAND 2000; JAEGER, PLATINGA, CHANG, DELLO, GRANT, HULSE, McDONNELL, LANCASTER, MORADKHANI, MORZILLO, MOTE, NOLIN, SANTELMANN, WU 2013), water scarcity is closely related with aridity and drought, where variations in temperatures and precipitation occur and hydrologic regimes are marked by large variations in water discharges. Meanwhile, drought is defined as an imbalance of water availability that consists of a persistent lower-than-average precipitation and resulting low carrying capacity in the ecosystems. Water scarcity can also be induced by the availability cost of providing or acquiring water, thus if water suppliers (e.g. a municipal water company) is able to provide water at a constant cost per unit of water, the quantity of water can be increased without raising the price. On the other hand, a water scarce condition appears for a community in an arid regions or regions with geological constraints if the cost to access water is high.

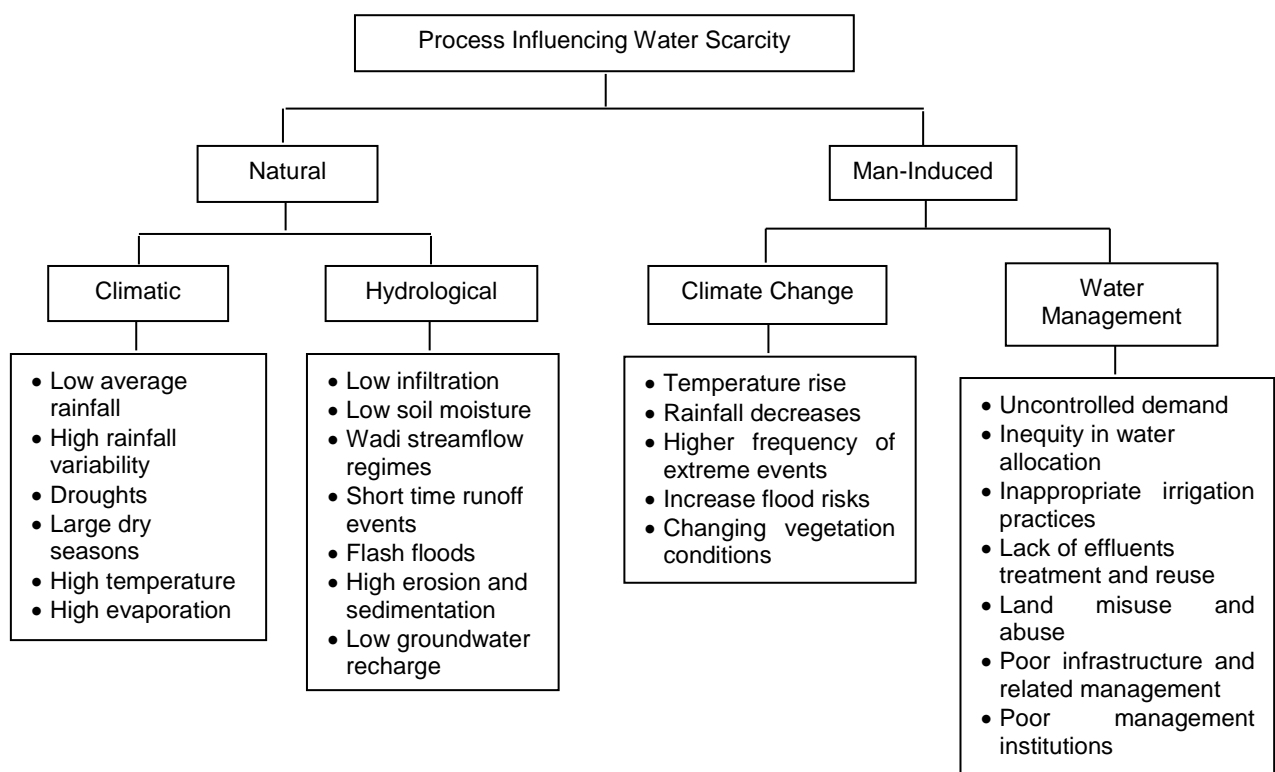
## 2.1. Climate Change and its Impact on Water Scarcity

Climate variability plays an important role in hydrological drought, where it is defined as a period when river or groundwater levels are low. Meanwhile, meteorological drought occurs when precipitation is well below average. A “water resource” drought is



generally described as the situation when the water use is being affected by low river, groundwater or reservoir levels (ARNELL, LIU, COMPAGNUCCI, DA CUNHA, HANAKI, HOWE, MAILU and SHIKLOMANOV 2001)(KUNDZEWICZ, MATA, ARNELL, DÖLL, KABAT, JIMÉNEZ, MILLER, OKI, ŞEN, and SHIKLOMANOV 2007).

Nevertheless, Pereira, (2009) stated that nowadays there is an ambiguity between climate variability and climate change, which is currently considered as the cause for water scarcity. Climate change is defined as a long-term change and associated with global warming due to anthropogenic activities, meanwhile climate variability is a term for part of earth's climate system that occurs at various spatial and temporal scales. Thus, it is necessary to perceive whether water scarcity in a given area results from anthropogenic activities and poor water management or is solely due to climatic and hydrological conditions, as depicted in Figure 5 below.

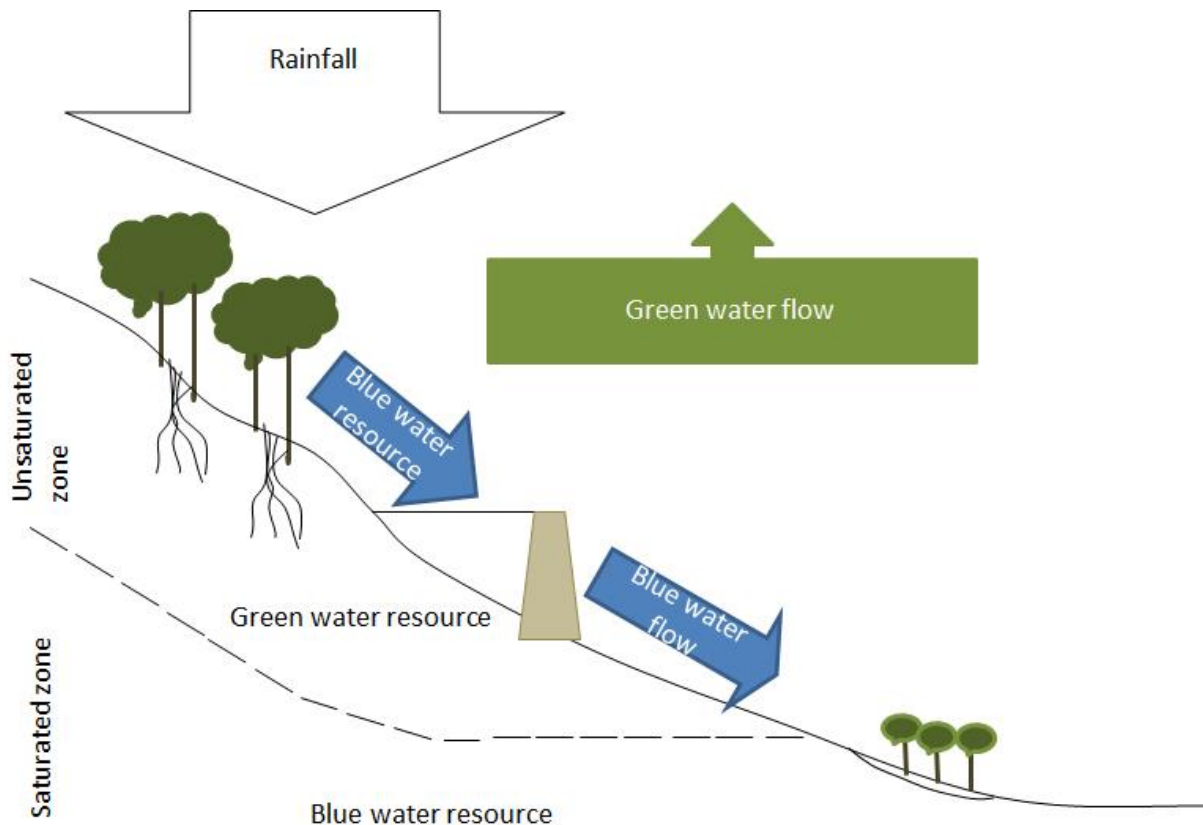


**Figure 5. Process influencing water scarcity by natural and man-induced (PEREIRA 2009:26)**

Falkenmark and Rockström (2005) had introduced a blue and green water concept in terms of the water resources issue and its relation to water availability. Blue water is the component of the rainfall that moves through the hydrological cycle and ends up in rivers, lakes and groundwater, which are the sources that we primarily manage and use. Meanwhile, green water is the rainfall that is intercepted by vegetation and by the soil, and is taken up by plants to create biomass and then evapotranspired back into the atmosphere. Still according to Falkenmark and Rockström, the green part of the

hydrological cycle has not been given much attention and is poorly managed, since there is almost twice of much water in the green cycle as opposed to the blue cycle.

Furthermore, Savanije (2000) also mentioned that green water is probably the most under-valued resource, yet it plays an important role by far in the world's biomass and food production. The total amount of green water resources available over a given period of time equals the accumulated amount of transpiration over that period. In this definition, irrigation is not taken into account. Green water is transpiration resulting directly from rainfall in rainfed agriculture, pasture and forestry. Albeit irrigation is dominating the water use of humans up until the present, which accounts for almost 70% of global water withdrawals and for more than 90% of global consumptive water use, defined as water volume that is not available for reuse downstream (SHIKLOMANOV 2000). Below Figure 6 shows the concept of blue and green water in relation to water-source planning and management.

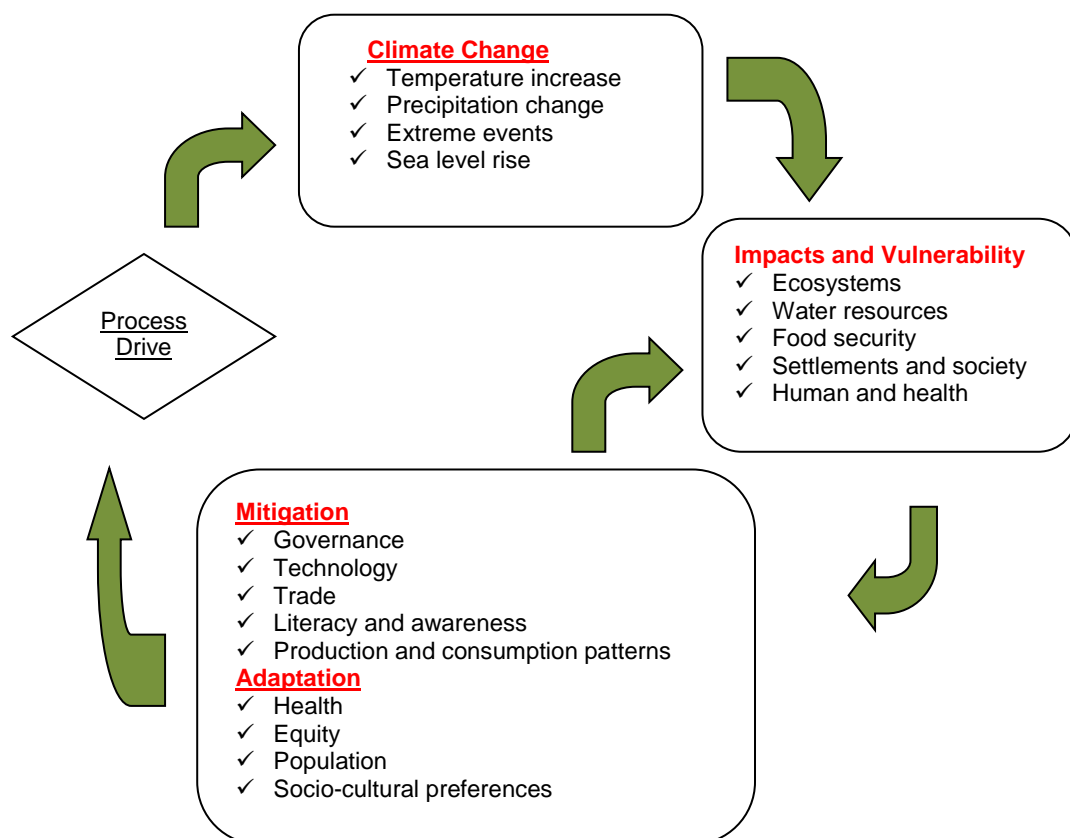


**Figure 6. Conceptualization of blue and green water in relation to water-resource planning and management (drawn from Falkenmark and Rockström, 2005)**

On a global scale, scientists have examined that an increase of temperature of 1 to 2 degrees Celsius in combination with changes in precipitation, due to changes in climate variability affect the amount of water availability in particular river basins and reduces the amount of annual runoff by 40-70% (POSTEL 1992). Furthermore, the increase of global temperature toward 4 degree Celsius is likely to occur in association

with growing water demand as the world population increases and exacerbates existing water scarcity in many regions, for instance where river basins that are dominated by a monsoon regime are particularly vulnerable to changes in the seasonality of runoff, which may have large impacts on water availability (PIK-Potsdam 2012).

Pereira (2009) hypothesized that the impacts of climate change refer to losses in biodiversity due to changes in environmental conditioning affecting the ecosystems, as well as settlement and health to community. Mitigation and adaption responses are made due to the change in climate areas and conditions, where actual crop patterns may have to be modified due to the changes in environmental conditions influencing the crop cycles, for instance. These responses are also taken to cope with the increase of temperature, precipitation and other climate variability that have been changed to minimize the impacts and vulnerability that are caused by the climate change, as shown in Figure 7 below.



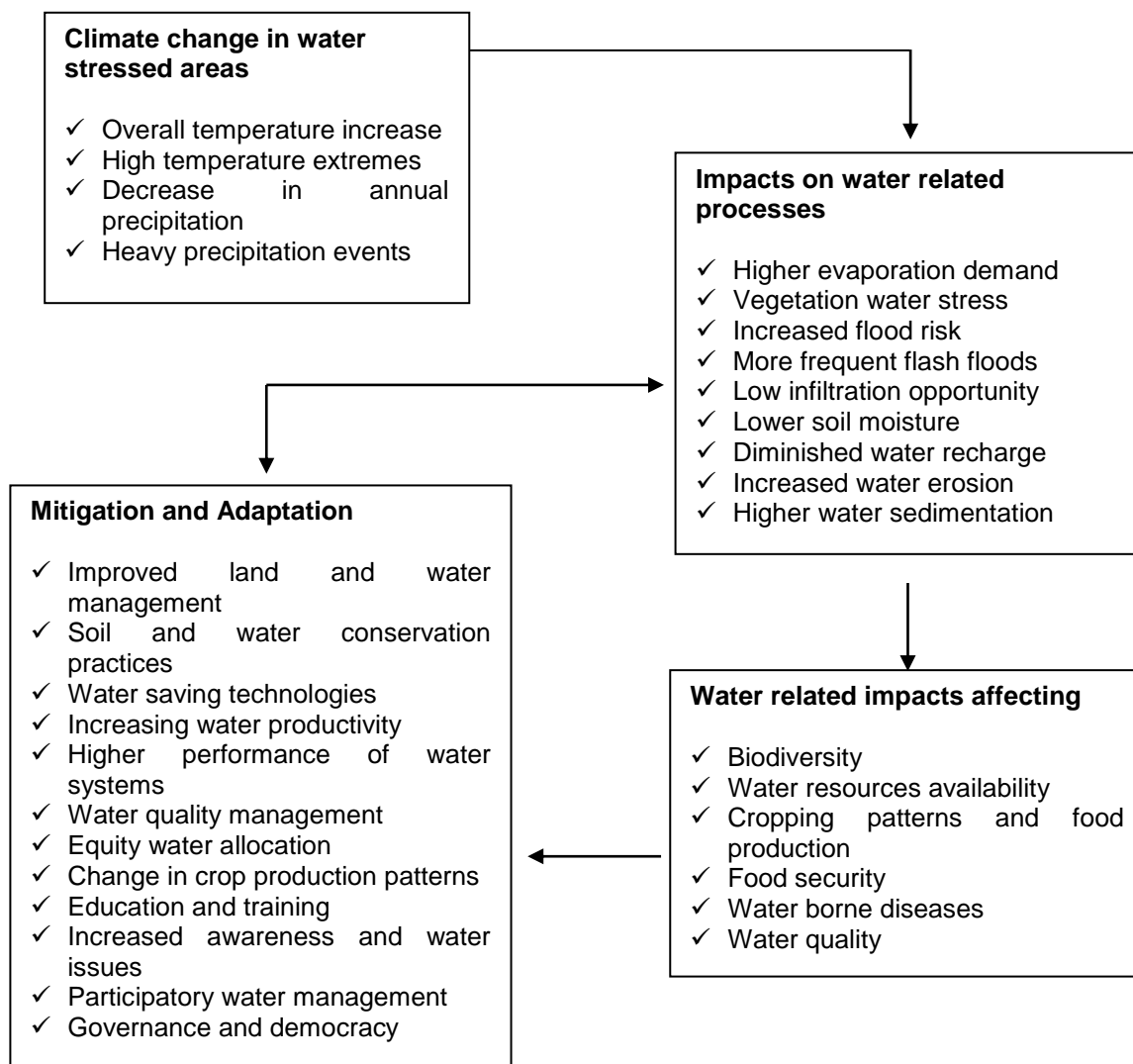
**Figure 7. Climate change impacts, mitigation and adaptation responses (IPCC Report in Pereira 2009:40)**

According to IPCC (2007), that there are anticipated impacts of climate change on freshwater resources and their management, as depicted in figure below:

- (1) By mid-century, annual average river runoff and water availability are projected to increase by 10-40% at high latitudes and in some wet tropical countries, and decrease by 10-30% over some dry areas at mid-latitudes and in the dry-tropics, some of which

are presently water stressed areas. In some places and in particular seasons, changes differ from these annual figures

- (2) Drought-affected or water stressed areas will likely increase in extent
- (3) Heavy precipitation events are likely to increase in frequency and intensity, and thus to augment flood risk
- (4) In the course of the century, water supplies stored in glaciers and snow cover are projected to decline, reducing water availability in areas supplied by melt-water from major mountain ranges, where more than one-sixth of the world population currently lives.



**Figure 8. Climate change impacts on water scarcity and related mitigation and adaptation measures (Pereira 2009:42)**

Pereira (2009) added that water scarce areas are highly vulnerable to climate change and the impacts need to be recognized; therefore, appropriate mitigation and adaption measures can be developed and implemented in order to cope with it. Furthermore, Mukheibir (2010) stated that risk and vulnerability, and projected impacts of climate change are the key risks in water security. Additionally, an increase in climate

variability is expected to alter the present hydrological resources and add pressure on the availability of future resources in across the globe. The uncertainties that remain in terms of timing, direction and extent of the climatic changes, as well as the societal implication, are considered the key factors that effect climate change for water supply systems, which greatly complicates rational water resource planning (GLEICK 1998; MUKHEIBIR 2010).

## **2.2. Water Scarcity in Indonesia**

According to Pawitan (2009), common water-related issues in Indonesia are as follows:

- (1) Population pressure, especially in Java Island and other developing areas
- (2) Degraded natural resources, sea level rise and extreme weather events
- (3) Increased pollution and exposure to water-and vector-borne disease
- (4) Decreased water availability and quality
- (5) Natural resources management issues; local government regulation tends to exploit natural resources, without considering carrying capacity and good management practice.

Located at the equator, Indonesia is influenced by monsoonal variations. Yet, the change in climate variability threatens to disrupt the regular, alternating periods of rain and dry seasons. The shorter rainy season will be subsequently followed by a longer dry season which may lead to increased drought and higher daily temperature. Meanwhile, strong and intensive rainfall can damage several ecosystems, resulting in landslides; coastal erosion and sedimentation, which increases the vulnerability of water resource (PANGAU-ADAM 2009).

Furthermore, Brontowijono (2008) mentioned that due to its location, Indonesia has the specific climate characteristics of high temperature and high air humidity, where during dry season many people experience lack of water, while floods occur every year due to high rainfall during the rainy season. Adding to that, Syaukat (2011) stated that the water crisis results from water competition among water users due to the imbalance between water supply and demand, seasonal water characteristics. Water infrastructure development has been postponed due to funding problems and coordination of Integrated Water Resource Management mainstream policies, and the water pricing issue.

### **2.2.1. Population of Indonesia**

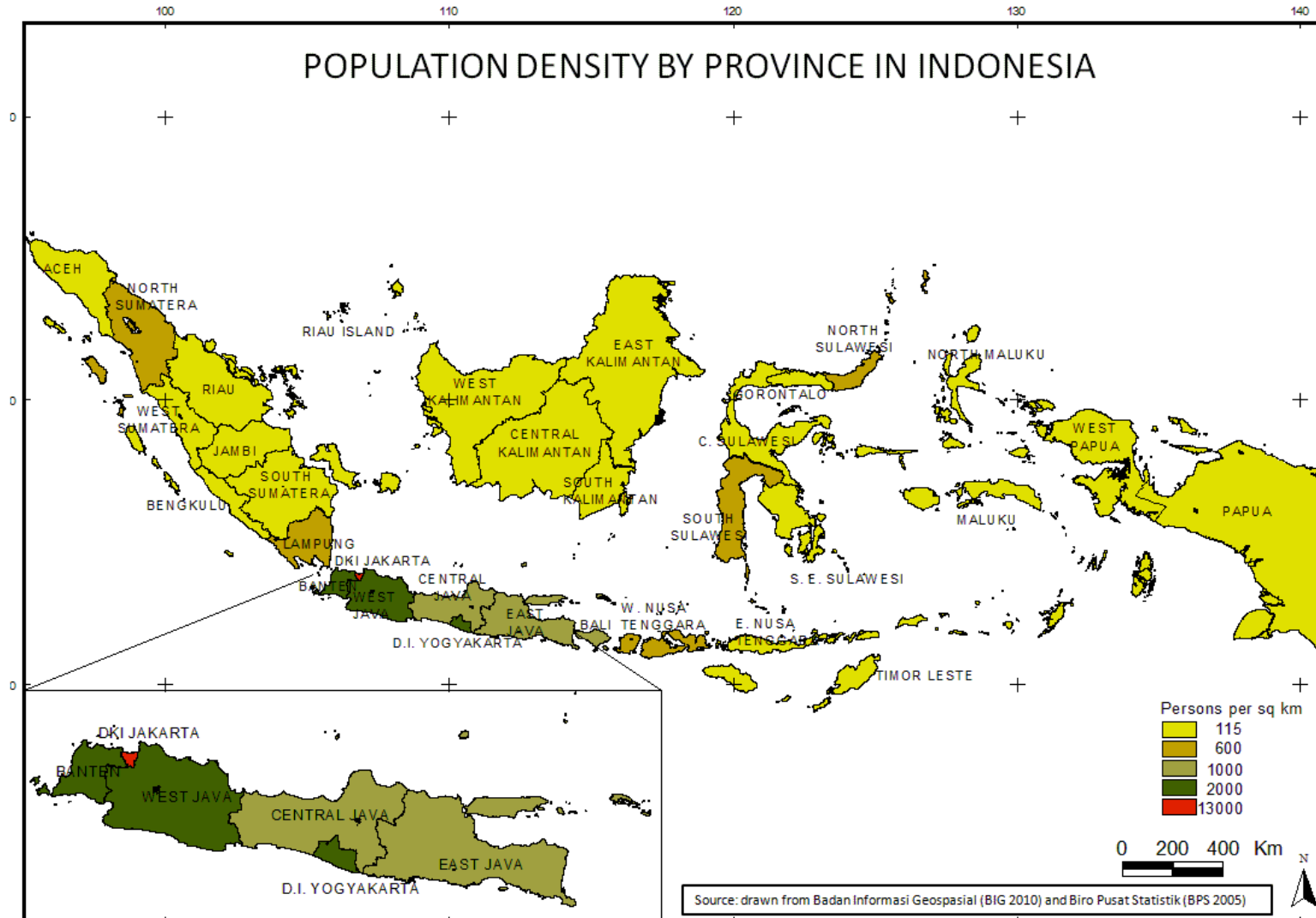
According to the report of Central Bureau of Statistic Pacitan/BPS (BADAN PUSAT STATISTIK 2010), the result of the last census in 2010 showed that the inhabitants of Indonesia have reached 237 million, unevenly dispersed across Indonesia.

The increasing population in Indonesia is not followed by the equal distribution of population regionally by province or by island. Map 3 below shows that with almost 60% of the total Indonesian population, Java Island has become the most populous island in the country, despite having limited natural resources, including water. Meanwhile, other major islands like Kalimantan, Sulawesi and Papua have less than 10% of the total population.

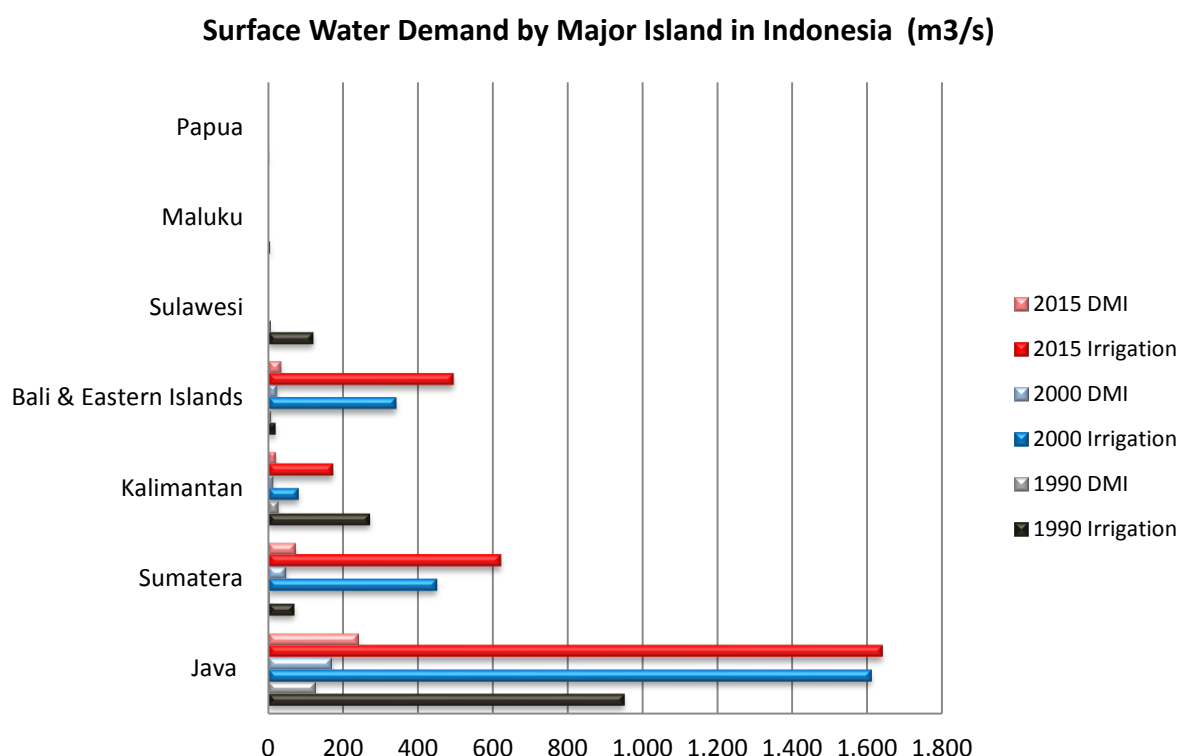
Pawitan (2009) mentioned that there is a significant increase population density on Java Island from 9 persons/km<sup>2</sup> to 880 persons/km<sup>2</sup>. In 1815 the average was 35 persons/km<sup>2</sup>, and this number had increased up to 330 person/km<sup>2</sup> by 1930 and 1000 persons/km<sup>2</sup> in the year 2000. The increase of population has severely affected the land use, with consequences that alter the hydrologic regimes and environmental qualities.

The large population and high population density in Java affect the surface water demand. Irrigation and Domestic, Municipal, Industry (DMI), as it is shown in Figure 9 below, on Java represents the highest surface water demand from 1990 to 2000, in comparison with other major islands. Figure 9 also depicts that irrigation uses more water than DMI needs in Indonesia. As Java Island has become one of the main rice production areas in Indonesia, the level of irrigation demand has increased by 40% and DMI by 26% from 1990 to 2000 respectively.

Nonetheless, Sumatera has experienced a more than 80% increase in both in irrigation and DMI needs as Sumatera has expanded its palm oil plantation areas which require large amounts of water during the seeding phase in order to have a good quality of palm oil (PAHAN 2007). Figure 9 below also shows that the water demand for irrigation in Bali and the Eastern Islands has increased by 94% between 1990 to 2000, whereas 69% for DMI and 93% in Sumatera respectively.



Map 3. Population density by province in Indonesia (own figure drawn from Badan Informasi Geospasial/BIG 2010 and *Badan Pusat Statistik* 2005)

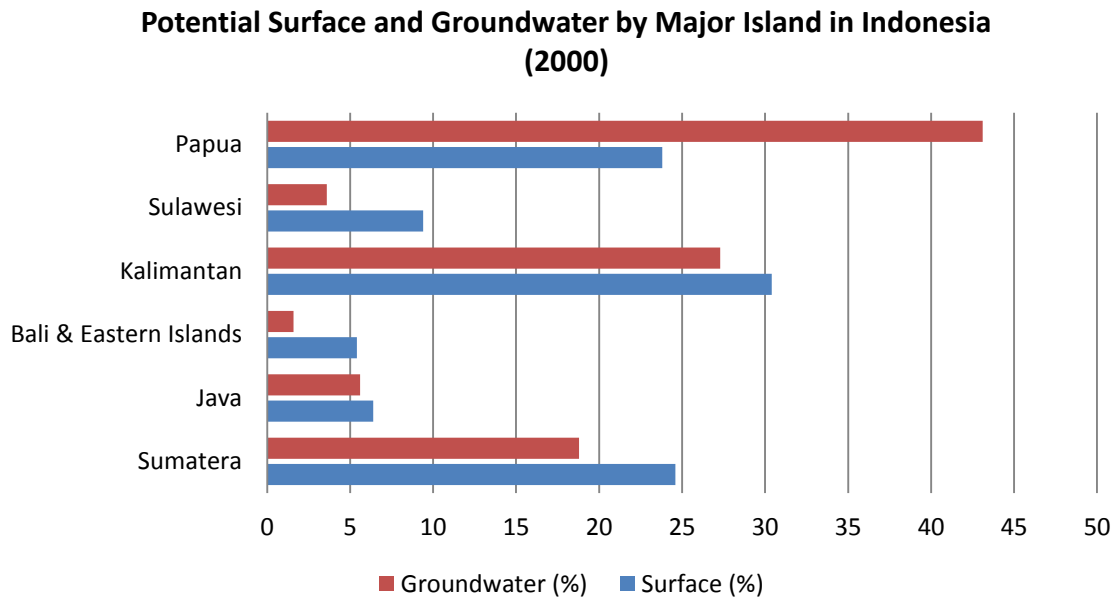


**Figure 9. Surface water demand by major island in Indonesia (drawn from Ministry of Settlements and Regional Development 2003)**

Meanwhile Java has merely 6% of the potential surface and groundwater in comparison with other major islands in Indonesia as shown in Figure 10 below. Papua has the highest percentage in groundwater followed by Kalimantan and Sumatera, whereas Kalimantan has the highest surface water followed by Sumatera, Papua and Sulawesi. There is a contradiction where Java Island as the region with least potential surface and groundwater, has the highest water demand, due to high density of population. Meanwhile regions with abundant potential sources of water have less water demand.

The report of Indonesian Statistic Bureau (BADAN PUSAT STATISTIK 2010) says East Java, where Pacitan administratively is located, is one of the most populous provinces in Indonesia. In 2010, about 30% of the population on Java Island were concentrated in East Java. The proportion of the population in rural areas is 52% of the total population in East Java, as depicted in Figure 10.

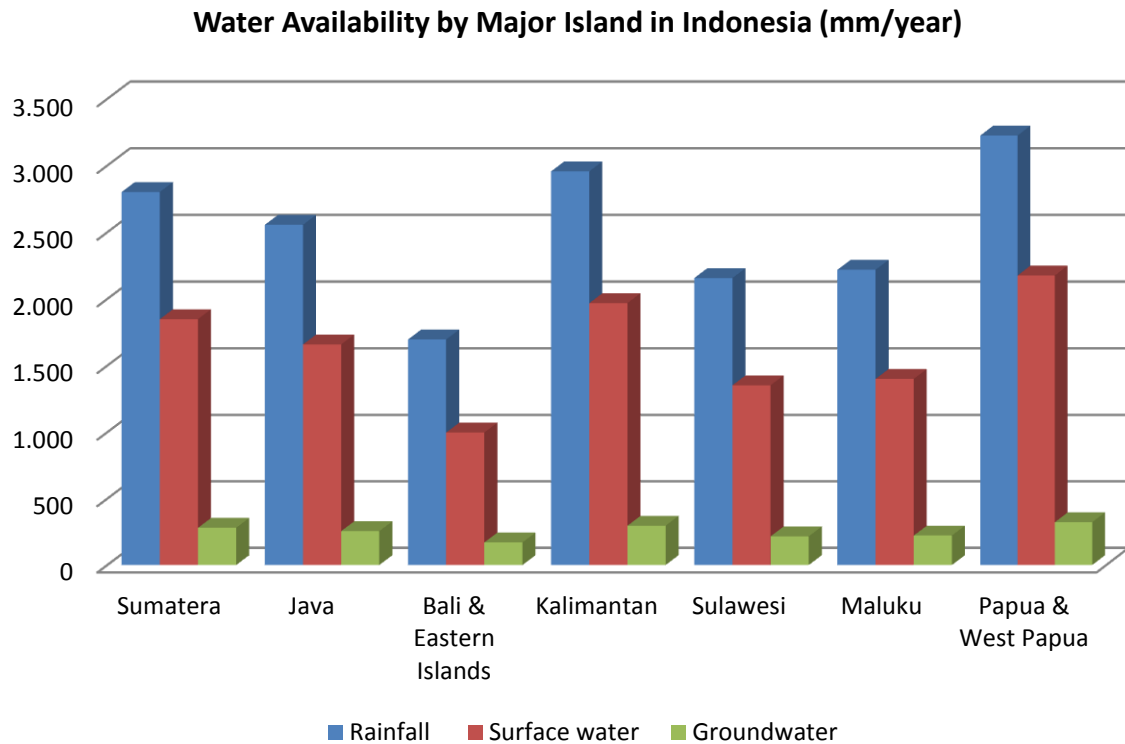




**Figure 10. Potential surface and groundwater by major island in Indonesia year 2000 (drawn from Ministry of Settlements and Regional Development 2003)**

### **2.2.2. Uneven Water Resource Distribution**

Brontowijono (2008) mentioned, that the uneven water availability among islands in Indonesia, the uncertainties of climate variability and poor water use management exacerbate the water issue spatially and seasonally in Indonesia. Java Island as the most populous island in the country, inhabited by almost 60% of the total population in Indonesia, but has merely 6% of the national fresh water. In addition, the water quality in Java including Madura, Bali and Nusa Tenggara are in a critical condition, whereas in Sumatera, Kalimantan and Papua, the water resources are still abundant. This large variation in water resources potential poses a challenge for national development and requires sound planning and management system in water resources. Figure 11 below depicts the total water availability represented by rainfall, runoff and groundwater by major island in Indonesia. The figure shows that Indonesia has potential rainfall and runoff in the major islands, especially in the big islands where the population densities are not large like Sumatera, Kalimantan and Papua. The figure also shows that rainfall is the main source to replenish water sources in Indonesia, whereas the use of groundwater in general is significantly less than surface water.

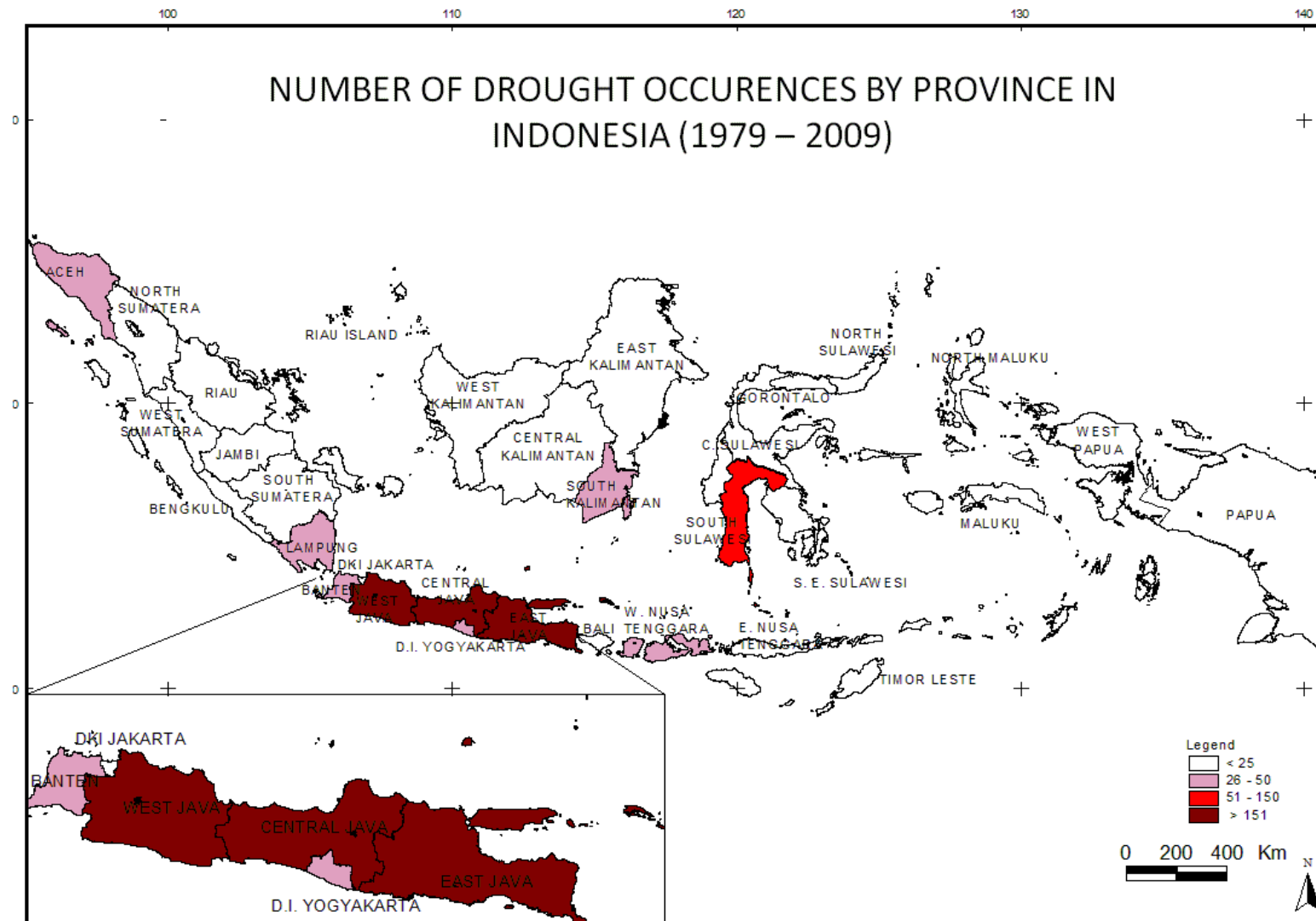


**Figure 11. Water availability by Major Island in Indonesia (drawn from Pawitan 2009)**

### 2.2.3. Drought Occurrences

Despite of the abundance of potential water resource, seasonal and spatial variation in the rainfall pattern and lack of adequate storage creates competition and conflict among users. Especially during the dry season, people face difficulties fulfilling the needs of daily water use for agricultural and domestic purposes. During the rainy season floods occurs every year or periodically. According to Brontowijono (2008), during recent decades, there has been a worsening of the impact of drought in some areas in Indonesia. Millions of hectares of agricultural crops failed to harvest, worsening the malnutrition problem.

A BNPB Report (*Badan Nasional Penanggulangan Bencana*/BNPB 2010) says, most provinces in Java Island, including East Java where Pacitan is located, have had the highest number of drought occurrence in Indonesia in the last three decades. The high density of population in Java Island combined with the least potential water sources drives high vulnerability to drought, particularly during the dry season when the amount of rainfall decreases. Below is Map 4, showing the number of drought occurrences by province in Indonesia from 1979-2009.



**Map 4. Number of drought occurrences by Province in Indonesia (drawn from *Badan Informasi Geospasial/BIG 2010* and *Badan Nasional Penanggulangan Bencana/BNPB 2009*)**

#### **2.2.4. Water Resource Degradation**

Due to population increase and land use change, the degradation of water resources, both in quantity and quality, has become a serious issue in Indonesia. About 23% of national irrigation systems are in poor condition and 73% of these are located in Java and Sumatera. About 18.4% of monitored reservoirs are in below-average condition, yet the irrigation groundwater aquifers in Java lack maintenance (The State Ministry of National Development 2011:7).

Samekto and Winata (2010) stated that forests in upstream areas are in a critical condition due to deforestation, and this number increased between 1992 to 2003 to a total of 18.5 million hectares. Not all deforestation results from approved land conversion to settlement and industrial areas, illegal logging has also increased 50% between 1985 to 2001. The phenomenon has caused a decreased ability of river basins to store water, particularly during the dry season and this has resulted in high demand for water in the areas where water is scarce. According to the Ministry of Social (BANSOS/KEMENTERIAN SOSIAL 2010), there are several areas in Pacitan which suffered water scarcity during the dry season, particularly in the western part, where the karst areas are located. In the regions that have particular geological conditions like karst where rainfall during the rainy season falls directly into river basins and conduits resulting in groundwater with extensive water supply, it is a challenge to find available surface water during the dry season. In the eastern part of Pacitan, there were at least 13 villages in 2009 that suffered water scarcity during dry season (Antara News 2009). The communities need to find adaptation strategies to store water during rainy season and use it in the dry season. Adding to that, Nestmann (2012) stated that the porous texture in karst areas ensures precipitation trickles down immediately into sinkholes and caves resulting in a high infiltration rate in groundwater systems. Therefore, adapted technologies developed by government, together with local and international institutions, as well as local knowledge in the context of water management in karst area are essential.

#### **2.2.5. Coordination and Institution**

The result of the Dublin Statement on Water and Sustainable Development in 1992 (PRINZ 2000; BANDARAGODA 2006), is that one of the key concepts is: "Integrated water resources management, implying an inter-sector approach, representation of all stakeholders, all physical aspects of water resources, and sustainability and environmental consideration"

In addition, one of the main principles in Dublin Statement on Water and Sustainable Development in 1992 were: “Water resources development and management should be based on a participatory approach, involving all relevant stakeholders”

Therefore, it is essential to have comprehensive involvement from related stakeholders, as well as a participatory approach from the community as water user of the river basin, in order to make water resources management effective. Hence, the coordination among stakeholders and related water institutions through strong law enforcement is also important. In essence, participation of local community as water users and their local knowledge attributable to water use leads to empowerment of the natural resource use and its constraint. In addition, Jaspers (2003) mentioned that the participation of stakeholders in decision making or other functions of management in water resource planning is the main concept of integrated river basin management.

There are several other water management related actors in Indonesia in the form of River Basin Organization (RBOs), and councils and water users association, namely *Balai Pengelolaan Sumber Daya Air* (Balai PSDA), *Perum Jasa Tirta* which manage river basins in Java and as joint governance between The State Ministry of State Owned Enterprises (BUMN) and private enterprises, *Balai Besar Wilayah Sungai* (BBWS) and *Balai Wilayah Sungai* (BWS) which are also River Basin Organization that work under the authority of the Ministry of Public Works (RAMU 2007).

The Indonesian Government has formulated the basic principles regarding Water Resources in Law No 7/2004 (UNDANG UNDANG 2004), however, the law enforcement is less well-implemented and inflexible in bureaucracy (SJARIEF 2007). Furthermore, the negative impacts of weak law enforcement in terms of natural resources exploitation, including water, prove there is a less cohesive and integrated coordination within water management related actors in Indonesia (BRONTOWIJONO 2008).

#### **2.2.6. Water Privatization**

As stated in the Dublin Statement on Water and Development in 1992 and the United Nation Committee on Economic, Cultural and Social Rights in 2002, there are five key elements of the Human Right for water use, namely:

- (1) Water must be available in sufficient quantity for personal and domestic needs
- (2) Water must be adequate quality
- (3) Water must be accessible to people within or in close proximity to their homes
- (4) There should be equal access to water; the Committee extensively referred to government should confront obstacles that are faced by extensive range of groups in accessing water, including women, people with disabilities, children, refugees, prisoners, and nomadic communities

- (5) Water pricing; the Committee stated that water should be in affordable price (LANGFORD 2005)

Furthermore, the human right in terms of water use, as stated in WHO in 2002, stated:

- (1) Respect; The obligation to respect requires that States Parties (that is governments ratifying the treaty) refrain from interfering directly or indirectly with the enjoyment of the right to water
- (2) Protect; The obligation to protect requires that States Parties prevent third parties such as corporations from interfering in any way with the enjoyment of the right to water
- (3) Fulfil; The obligation to fulfil requires that States Parties adopt the necessary measures to achieve the full realization of the right to water (WIGNYOSUKARTO 2008)

Still according to Wignyosukarto (2008), the understanding of a “water right” and “the right to water” is still unclear. By definition, a water right is used as leverage by the States and governments as the institution that controls water and gives the authorization to institutions to manage water. Hence, the law that rules “water rights” assumed that water is the commodity that needs legal protection for the institutions which control the water. Meanwhile, “the right of water” emphasised water as an inseparable commodity from being human, hence, it is an absolute right for every individual.

In essence, it is stated in Indonesian Constitution (Undang Undang Dasar) 1945, Section 33 Article (2), (3), and (4), that natural resources including water should be managed by the state and the optimally used for the prosperity of people. Conversely, in Law No. 7/2004 on Water Resources, especially Section 7 Articles (1) and (2), Section 8 Article (1), and Section 9 Article (1) stated, that the right of water utilization is given to private sectors more freely (GOI 2004).

In addition, Irianto (2005) mentioned that water privatization is the negative impact of giving the right to use water to the private sector, because it leads away from the commodification of water as an absolute right for every individual, to inter-sectoral liberal competition which results in the collapse of weak sectors like agriculture and poor communities by strong groups of industry, commercial sectors and the packaged drinking-water industry. There is difficulty in stopping the practice of water commercialization even though it causes financial loss especially to people and to the environment generally.

Brontowiyono (2008) stated that water in private-ownership and water pricing is not always related. Although in Germany, water pricing has a significant impact in conserving water resources through economizing water use. Nevertheless, according to

Syaukat (2011), privatization is not necessarily disadvantageous for the water users, as long as the role of the government as the regulator is able to ensure that the *concessionaires* between government and private sectors have adequate funding, capacity, technical, managerial and economic expertise. Therefore, integrated surface and groundwater management, and IWRM mainstream policies are able to make water users the beneficiaries. A coherent cooperation between government and private actors or Public-Private Partnership (PPP) may be needed to overcome the inadequacies of finance development, as long as the water users are still the beneficiaries of the program, which is still a challenge for both actors. Nyirishema and Verweji (2013) stated that community awareness, public participation, transparency and accountability within PPP are challenges for establishing PPP in the rural water sector, resulting in less cost recovery for future rehabilitation in rural water infrastructure when it is absent.

### 3. DESCRIPTION OF PACITAN

In this chapter, Pacitan particularly the three *Kecamatan* are described in their geographical, climatological, karst geomorphology, hydrogeology, land use, and social-economic aspects, including the description of Piped Water Supply (*Perusahaan Daerah Air Minum*/PDAM).

#### 3.1. Geographical Aspect of Pacitan

Karst phenomenon in Gunung Sewu or the Southern Mountain of Java is formed by Neogen limestone from Middle Miocene and Upper Pliocene Period and called the *Wonosari-Punung* formation. In the geological map it is coded as Tmwl; whereas the limestone is composed of large mass coral limestone in the southern part and bedded chalk in the northern part (BALASZ 1968; WALTHAM 1985; SURONO 1992; HARYONO 2008). In addition, Yuwono (2009) mentioned that coastal cliffs and bays dominate the southern part, where the inland consist of conical hills with polygonal dolines and a labyrinthine network of dry valleys. The soil in Gunung Sewu is dominated by deposition of limestone and coral from the Miocene Period, which have been eroded by rivers and the permeation of water that ultimately forms karst and covers thousands of hills. This condition leads to sub-surface water sources and depressions that are filled with rain during the rainy season and apart from the doline, the karst is relatively barren and has less surface water sources.

As a part of Gunung Sewu, Pacitan also consists of limestone that morphologically has medium to high relief in the hilly karst at a varying elevation of 60 to 220 meter and slope steepness from 16 to 88% (MARDIATNO 2008). Furthermore, according to PSBA and Bappeda Report (2008), more than 60% of Pacitan areas consist of conservation or buffer zone where the slope steepness is more than 40%, while perennial and agriculture field entail 25% and 6% respectively as shown in table below. Table 2 also shows that coastal areas entail less than 5% of Pacitan with slope steepness between 0 to 20%; where the community use these areas as tourism zones and the second area of 25% is used as perennial fields.

**Table 2. Variety of hills steepness in Pacitan**

Slope steepness (%)	Covers Area (%)	Area
0-20	± 4,36	Coastal
2-15	± 6,60	Agriculture field
15-40	± 25,87	Perennial field
≥ 40	± 63,17	Buffer zone/conservation area

The map below shows karst areas in Pacitan that belong to Gunung Sewu and located in the most western part of the Pacitan District, and the most eastern part of the

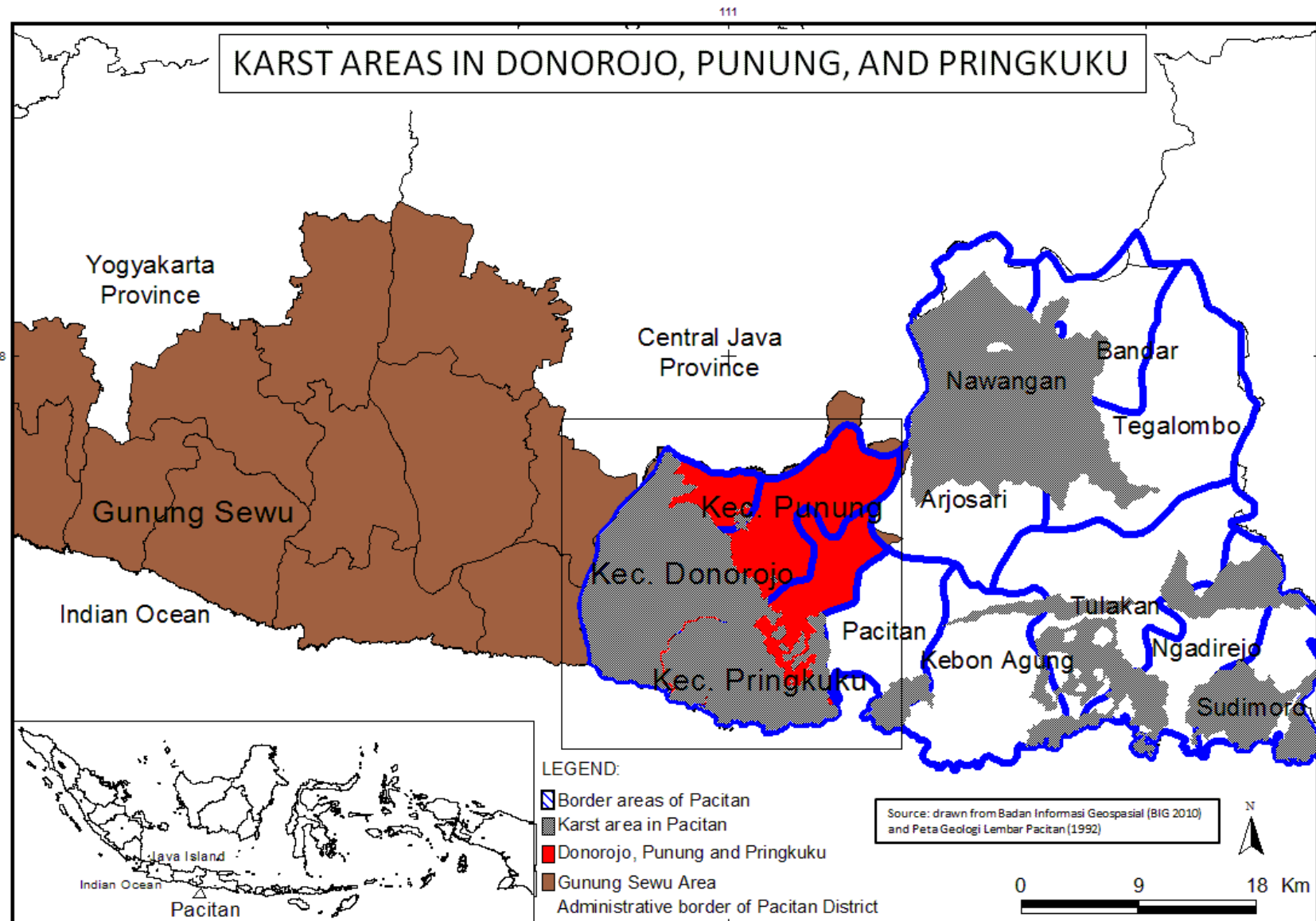


Gunung Sewu area. The blue line shows the administrative border of Pacitan that separates Pacitan District from Central Java Province. The red colour shows the three sub-districts of Pacitan (Donorojo, Punung, and Pringkuku) that belong to Gunung Sewu karst areas. The grey-shaded colour shows where karst areas in Pacitan are located.

As it can be seen from the map below that there are also karst areas in Pacitan in the north and small parts in the east and south; however those areas do not belong to Gunung Sewu karst and are shown in a brown colour. The karst areas in Pacitan that belong to Gunung Sewu are concentrated mostly in Donorojo, Pringkuku and some parts of Punung. As mentioned by Haryono (2008) and the Indonesian National Committee for Geoparks (2013), Gunung Sewu as a part of the southern mountains of Java Island were subjected to faulting and down warping forming two depressions, namely the Wonosari and Baturetno depressions where karstification is limited. The mountains ranges from Gunungkidul (in Yogyakarta Province), Wonogiri (in Central Java Province) continue eastward up to Pacitan (East Java Province) including Donorojo, Pringkuku and Punung.

In addition, Urushibara (1997) and Marwanto (1999) mentioned that the altitude of Gunung Sewu hills have an average of 400 meters above sea level (asl); where it is bordered in the western part by the Yogyakarta Plain it averages 50 meters asl and Pacitan in the eastern part averages 10 meters asl. The Bengawan Solo River that is flowing northward to the Java Sea used to flow southward to the Indian Ocean forming dry valleys that are associated with the uplift of the southern part of the southern mountain, yet the condition of low sea-level and dry climate also formed the dry valleys in the Pacitan karst areas.

Furthermore, according to the map from the Ministry of Public Works below, the karst areas are located in the most western part of Pacitan, where there are perennial fields and conservation zones with one or two planting-season types of dry field crops. Coastal areas are located in the southern part of Pacitan that are famous as tourism and surfing sites. Conservation areas are located in the northern part bordered with the Central Java Province where the soils are relatively fertile with potential groundwater and high steepness. The local government of Pacitan benefits from the northern part as vulture and tourist areas, as well as the coastal areas in the southern part.



Map 5. Karst Areas in Pacitan (own figure drawn from *Badan Informasi Geospasial 2010* and *Peta Geologi Lembar Pacitan 1992*).

### 3.2. Climatological Aspect of Pacitan

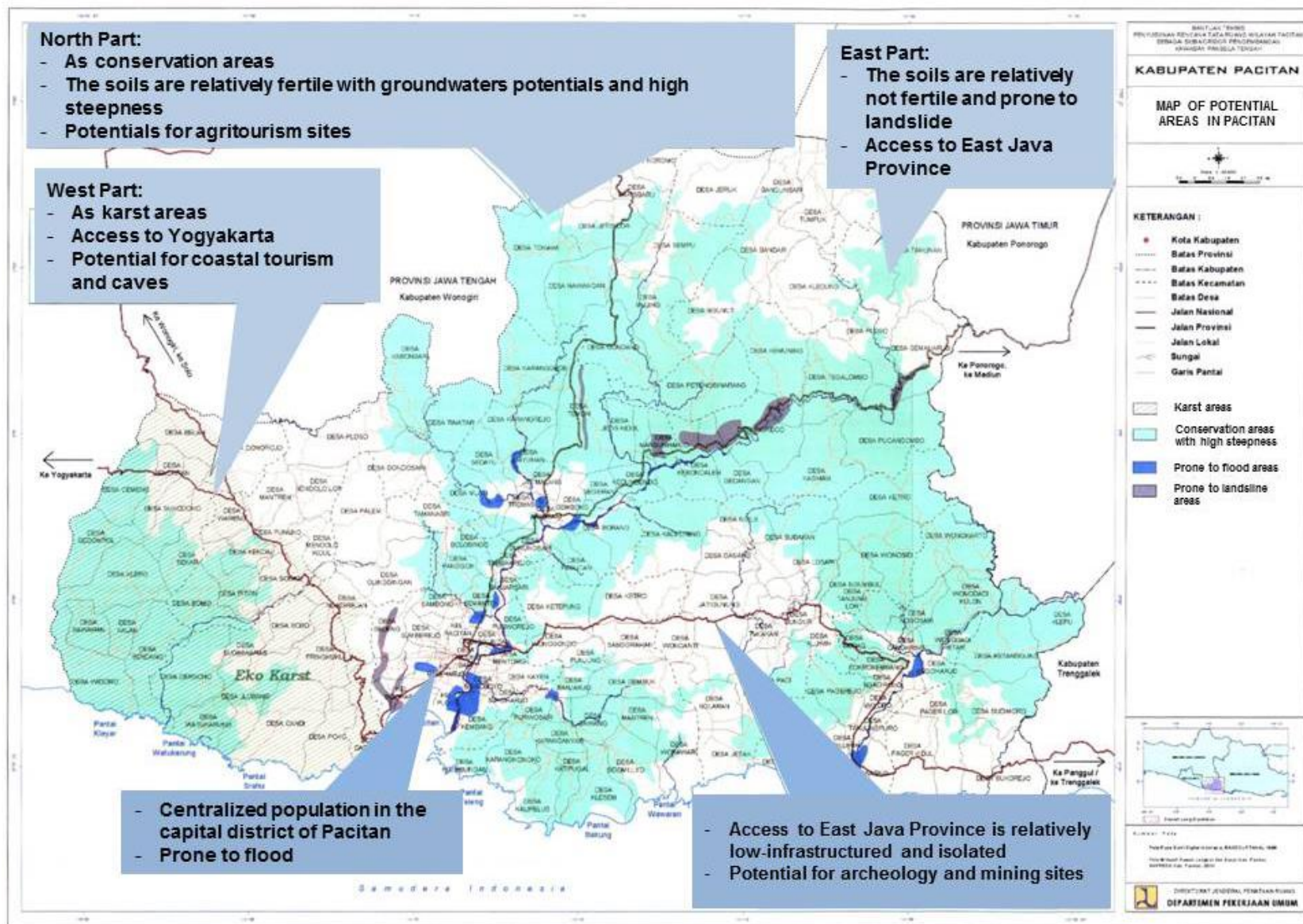
Makmur (2009) formulated that Indonesia has three general rainfall types, namely equatorial, local and monsoon as shown in Figure 12 below. The latter type encompasses the eastern part of Sumatera, the southern part of Kalimantan, a very small part of Sulawesi and the whole Java including Bali and Lesser Sunda Islands. In general, the monsoon rainfall type has a peak of rainfall from October to February and the dry season occurs from March to September. Extreme climate event like El Niño Southern Oscillation (ENSO) plays an important role in the monsoon areas, where high variability of the season can make high vulnerability to water scarcity. Makmur also stated that the ENSO in 1997 resulted in a dry season that lasted longer than 60 days and a rainy season that lasted less than 30 days.

As seen in Figure 12, Pacitan is part of Gunung Sewu in Java Island and is included in the monsoon and humid tropical karst area. The dry season starts in May and continues to August, with August as the driest period. The rainy season starts in October and last until March, with December as the wettest period. Adding to that, the Northwest and Southeast monsoons strongly influence the climate in the Gunung Sewu karst area, including Pacitan and produce a distinct wet season between October and April and a dry season, which may be extremely arid, between May and September (BALASZ 1968; HARYONO 2008).

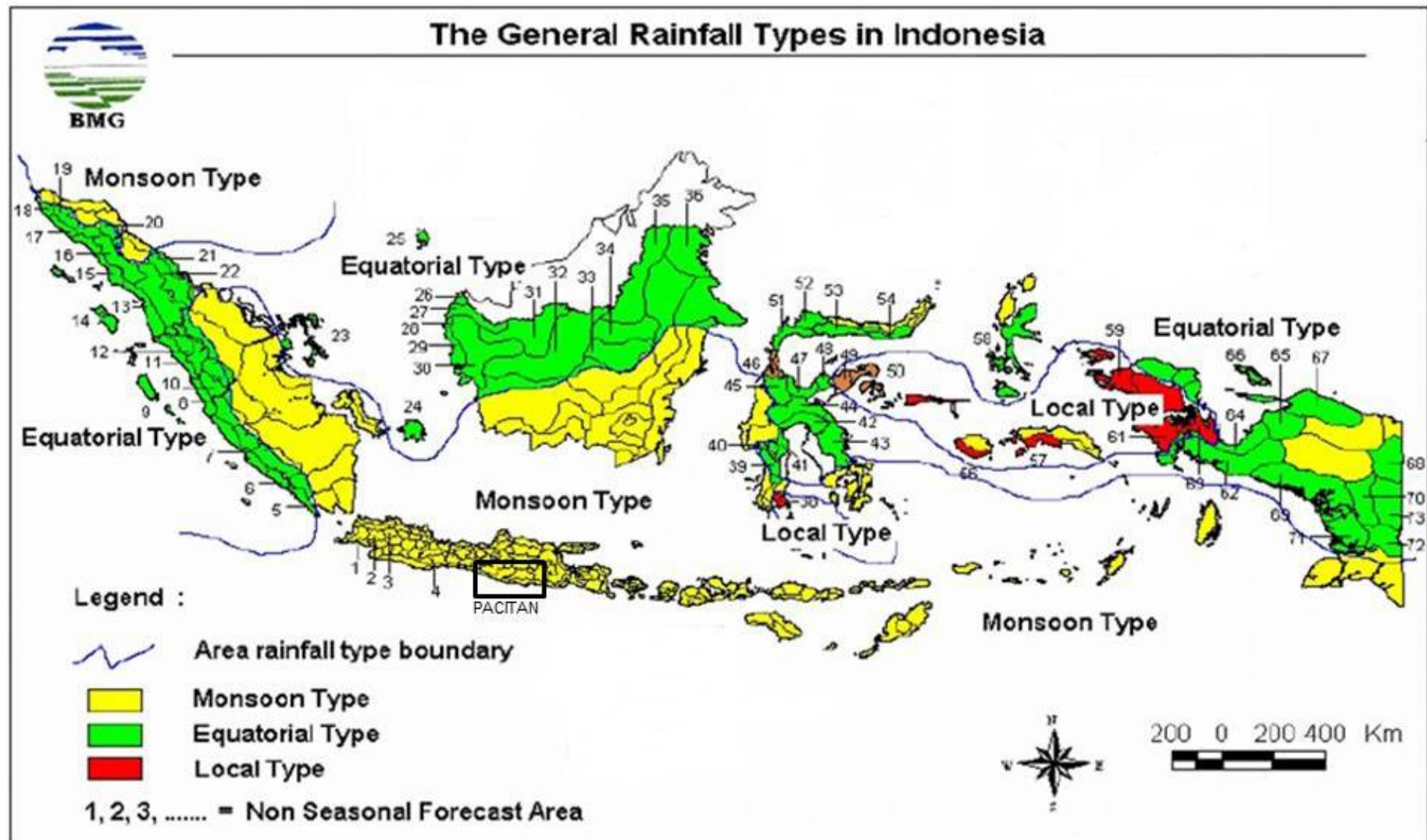
According to Figure 13 and 14 below, the mean monthly rainfall in Pacitan varies from 39 mm in July and 33 mm in February. In 2010 the highest number of rainy days occurred in January with 23 rainy days and the lowest number of rainy days occur in August with 4 rainy days. The statistic data for Pacitan from 1995 to 2012 shows Donorojo, Pringkuku and Punung have no rainy days, particularly during dry season from June to August; whereas the highest numbers of rainy days occur in January with 26 rainy days. Meanwhile the mean temperature in Pacitan from 1981 to 2012 ranged from 26°C to 28°C, showing the characteristics of tropical monsoon climate where the variation of monthly temperature is less than mean daily temperature. This highlighted that there is a distinct difference between the rainy and dry season in Pacitan, particularly the number of rainy days that occur, where there are plenty of rainy days during the rainy season and less rainy days during the dry season.

Meanwhile the annual rainfall data from *Badan Meteorologi dan Geofisika* (BMKG) or the Indonesian Agency for Meteorology, Climatology and Geophysics shows that annual rainfall in Pacitan varied from 681 mm in 2002 and 4556 mm in 1998; whereas the mean annual rainfall from 1981 to 2012 in Pacitan was 2288 mm as show in Figure 14 below. The rainfall variation depicted in Map 6 is also associated with the extreme climate events associated with ENSO, where during El Niño years, deep atmospheric convection

shifts water vapour in the Indonesian low pressure to migrate eastward in the tropical Pacific, resulting in drought in Indonesia, including in Java Island.

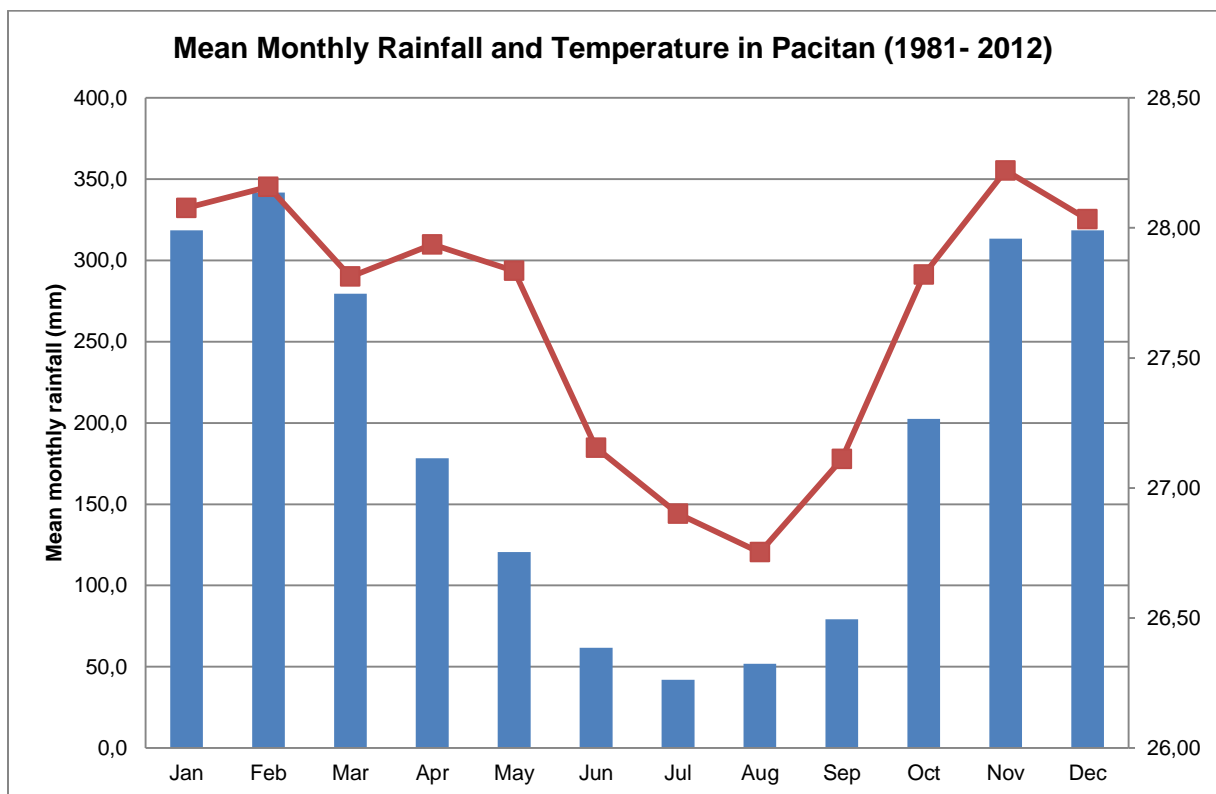




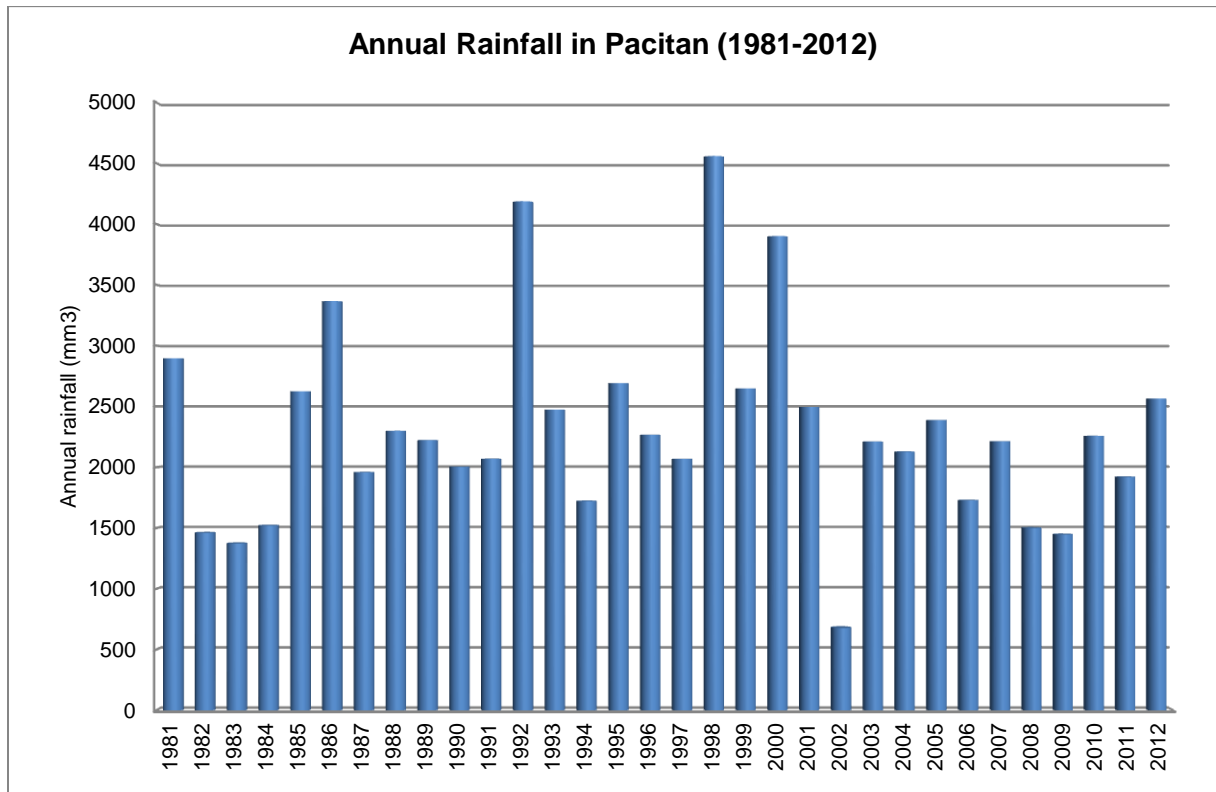


Map 6. The general rainfall types in Indonesia (modified from Makmur 2009)

El Niño (warm) and La Nina (cool) events can be identified from the ONI (Oceanic Niño Index) that monitors the changes or anomaly of sea surface temperature in the tropical pacific (Niño 3.4 Region) as related factors of ENSO. The events are defined as 5 consecutive overlapping 3-month periods at or above the +0.50 anomaly for warm (El Niño) events and at or below the -0.5 anomaly for cold (La Nina) events (NOAA 2014). Figure 15 below depicts El Niño years combined with the results of interviews from field work. It is shows that the community experienced longer dry season of 9 to 14 months duration in particular year like 1963/1964, 1985/1986, 1988, 1997/1998 and 2002.



**Figure 13. Mean monthly rainfall and temperature in Pacitan from 1981 to 2012 (drawn BMKG 2012)**



**Figure 14. Annual rainfall in Pacitan from 1981 to 2012 (drawn from BMKG 2012)**

During these periods, the community in Pacitan believe that there is a cycle of a long dry period every eight to ten years that affects agriculture in the areas of Donorojo and Punung and the fisheries sector in Pringkuku. The impact of long periods of dry weather in Pacitan, particularly in Donorojo, Punung and Pringkuku are visible in the community as it affects the water supply for the planting season as well as the fisheries harvest. The longer dry season caused by extreme climate events results in a shifting planting season and less water availability for the community, where some of the water supplies are taken by the river system network that depends on the rainfall.

Figure 16 and 17 below shows a distinct difference in *telaga* (little lakes filled with rainfall) between the dry and rainy season, where *telaga* are filled by rainfall during the rainy season and empty during the dry season. According to the interview results (2013), *telaga* are still used for agricultural purposes (not for domestic use) at the beginning of the rainy season when the water is not yet contaminated with other substances. During the dry season, the *telaga* are completely empty as the water trickles down into the extensive system of sinkholes and underground rivers. Several villages in Pringkuku are using *telaga* during the rainy season to grow fish particularly for freshwater fisheries that are organized by the head of the village.



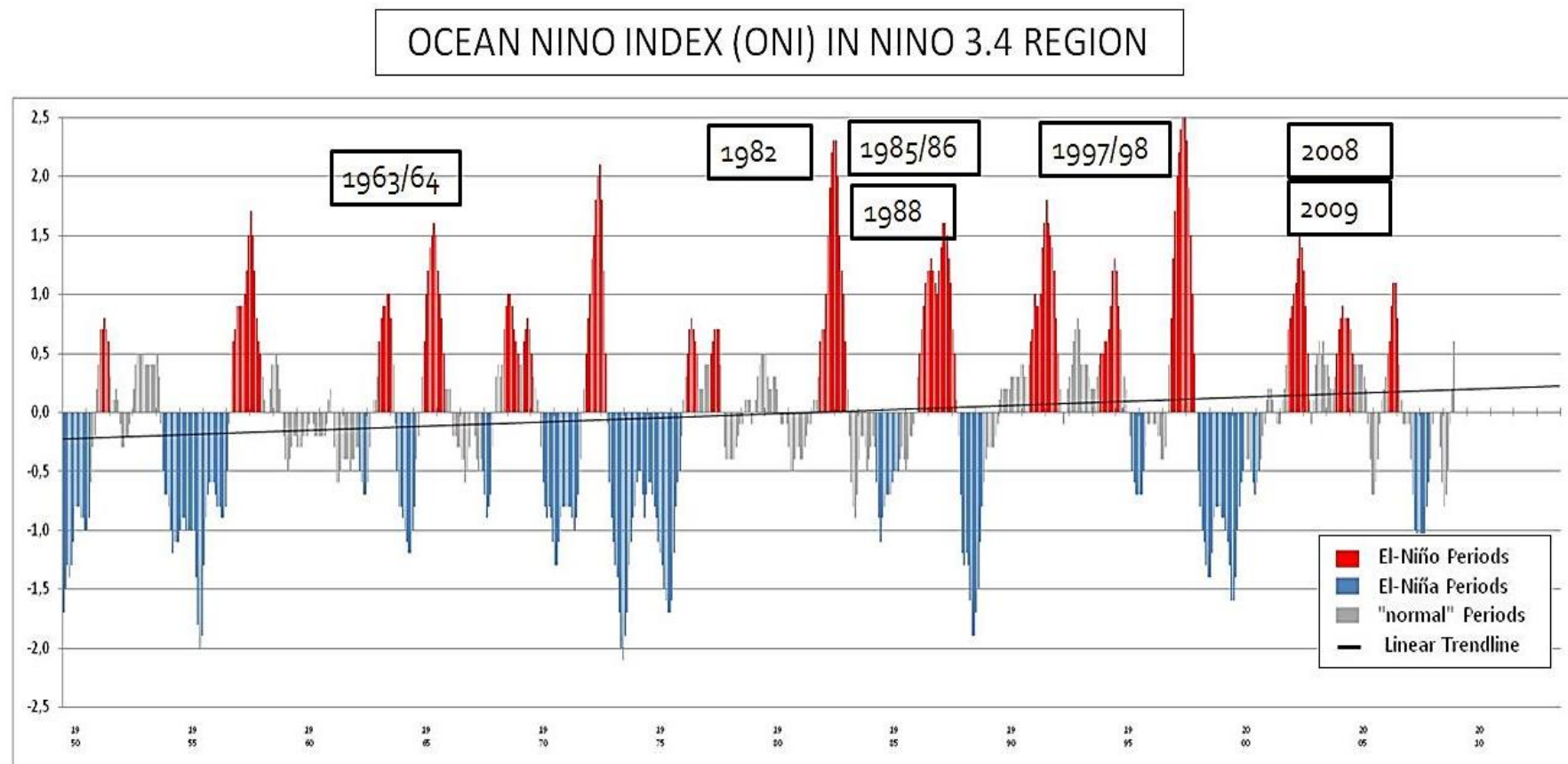


Figure 15. ONI Index in the Niño 3.4 Region from 1950 to 2010 combined with interview results in the box that shows the long period of the dry season ([http://www.cpc.ncep.noaa.gov/products/analysis\\_monitoring/ensostuff/ensoyears.shtml](http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml))



**Figure 16. *Telaga* at the beginning of rainy season (own photo 2013)**



**Figure 17. *Telaga* at the end of dry season (own photo 2013)**

### **3.3. Karst Geomorphology of Gunung Sewu and Pacitan**

The word “karst” can be traced from pre Indo-European times. It stems from *karra* which means stone, and the derivations are found in many languages from Europe and the Middle East. In northern Yugoslavia the word developed from *kras* to *kars*, which means stony. Barren ground is also the name for a district on the (former) Yugoslavian/Italian border in the area of Trieste, where it is referred to as the “classical karst”, being the site where its natural characteristics were first researched. In the Roman period, the regional name was *Carsus* and *Carso*. When the region became part of Austro-Hungarian Empire, the term was germanised as the Karst. The unique characteristics of *kras* or karst areas became known as “karst phenomena”, where we now consider karst to encompass terrain typically characterised by sinking streams, caves, enclosed depressions, fluted rock outcrops and large springs (FORD 1989).

Van Bemmelen (1970) described Gunung Sewu as a generally elevated block tilted ocean-ward in which the erosion has been rejuvenated. The northern border is marked by a complicated slope, where the eastern part consists partly of limestones with typical karst-phenomena called “Duizend” (thousand) mountains or Gunung Sewu. The narrow stretch south of the Brantas River in eastern Java consists mainly of limestones, with steep abrasion cliffs along the Indian Ocean.

Surono (1992) and Samodra (2005) highlighted how the limestone deposit in Gunung Sewu formed a more than 400 m thick rock sequence that is impermeable, thus the boundary between the limestone and the bedrock becomes the maximum depth that can be reached by dissolution. Furthermore, the Kladen (*Baksoka*) River, where the upstream is made from volcanic rock empties into the Indian Ocean, whereas other

surface rivers are filled seasonally and it will soon turn into underground rivers entering the limestone through ponors or the sinkhole system.

Lehmann (1936) initially described the landscape of the karst area in Gunung Sewu as cone- (or *kegel*) karst, which is characterised by sinusoidal or hemispherical hills (*kuppen*) interspersed with enclosed star-shaped depressions or inter-connected valleys. Later on, the research of Lehmann on karst in Gunung Sewu became the first modern work on humid tropical karst (HARYONO 2008).

Similiarly, Waltham (1985) mentioned that Gunung Sewu consists of over 1000 km<sup>2</sup> of cone karst developed from Miocene limestone. The overall relief rises to a central ridge around 300 m high. The landscapes formed an endless repetition of small rounded conical hills with thin soils, separated by dendritic valley systems mostly floored by several meters of clay soils, where all drainage goes directly underground into hundreds of valley floor sinkholes.

Meanwhile, Bartstra (1976) mentioned, that the eastern part of Gunung Sewu, where Pacitan is located, is formed by a mountain landscape, which is morphologically different from other parts of Gunung Sewu, and does not have a specific name and calls "*das östliche Sandstein-Breccien-bergland*". Part of the landscape is formed by a plateau area directly east of the village Punung, which is often included in the Gunung Sewu area. Thus, Lehmann (1936 in Ford 1989) named the plateau "tuffsandstein – hochfläche" or "sandsteinplateau". The distinction is important because the geology and geomorphology of the Eastern Plateau and Gunung Sewu (Western Plateau) are different and the majority of Paleolithic implements are to be found, not in the karst area, but precisely in the Eastern Plateau. However, many researchers still refer to Pacitan as a part of the Gunung Sewu karst area (UHLIG 1980)(KEATES 2004; MUKTI 2005; HARYONO 2008).

According to Bartstra (1976) and Uhlig (1980), the name of Gunung Sewu is misleading, as these mountains are merely hills only 80 m above the valleys and the highest peaks are only 500 m above sea level. On some older maps of the most eastern part of Gunung Sewu, the hills are called as *Puntuk Sewu*, which means -thousands of hills- in Javanese. These hills however, stand close to each other and cover an area of 30 km<sup>2</sup>, with a total of 40,000 hills for the entire Gunung Sewu.

Furthermore, the Gunung Sewu geologic unit represents a rimmed shelf carbonate platform extending relatively in an east-west direction. In the north of Gunung Sewu there is a relatively deep (200-400 m) fore arc basin, with volcanoclastic sedimentation derived from the volcanic arc to the north. In the Pacitan area to the east, the Wonosari Formation developed in a different facies called the Punung Formation. In Pacitan, Quaternary sediments with fluvial facies can be found in Baksoka River, where it consists of black clay, intercalated by thin layers of sand, silt and conglomerate, named

*Kalipucung* Formation (MUKTI 2005; BOUDAGHER-FADEL and LOKIER 2005; SAMODRA 2005).

Uhlig (1980), Lukas and Steinhilper (2005) also added that the weathering products of the limestone were fine-grained tuffs, deposited from volcanic activity in Central Java, formerly covering the area, and now washed into karst basin as shown in Figure 18. The hollows and flat surface are filled with sediment of brown terra rossa, with nutrient-rich and fine-grained soils, which are favourable for agricultural purposes. Due to the porous texture of the karst underground, most of the precipitation trickles immediately down into extensive system of sinkholes and caves. Thus, seasonal surface water rivers, brooks or springs can be found in the area. At the bottom of some karst basins, the depth of terra rossa deposition reached 30 m and becomes fairly impermeable. Therefore *telaga*, without drainage are filled by the heavy downpours during the rainy season, as shown in Figure 18. Many of these *telaga* have been improved as dams to secure main source of water supply. In addition, some wells have been dug into the terra rossa fillings of the basins. There are 450 *telagas* throughout the entire karst area. Nevertheless, only a few of these *telaga* keep their water throughout the dry season.

As is typical of karst areas, many caves have also formed and these are located in the most western part of Pacitan, and also in the eastern part, where the land is steep. Furthermore, Simanjuntak (2002) added that caves in Pacitan were used as the centre of Pacitan Culture during the Middle and Late Pleistocene for habitation and subsistence by hunter gatherer. Thus the local government of Pacitan secures the *Song Terus* cave as a historical site for archaeology. *Song Terus* cave was formed by a natural karstification process along a fracture system, where water percolation on the cave floor has formed proto-stalagmites

Samodra (2005) identified another sinkhole formed as the cave *Luweng Ombo* (Figure 19), which is formed of a single-haft with a diameter of 50 m and a depth of 65 m. It is also occupied by an underground river. *Luweng Jaran* is composed of large chambers and maze-passages and has more than 17 km of passages and occupied by an underground river. Due to the depth of its vertical hole, *Luweng Jaran* is inhabited by swiftlet and connected by a short passage. In the Javanese language, *song* means shelter or a place that covered something and *Luweng* means vertical cave or long and deep hole that is used for underground water. Tabuhan Cave has a 105 m passage and the first chamber is decorated by elongated stalactites that curve towards the entrance, while the second chamber has a lower roof at a clogged small hole. Small springs among small stalagmites called *belik* are formed by the percolation on water in the cave floor, as shown in Figures 19 to 22 below.

According to the Indonesian National Committee for Geoparks (2013), one of the caves in Pacitan, named *Gong Cave* is approximately 100 m long, 15 to 40 m wide, and 20 to 50 m high. This cave was formed by the dissolution process within the last 15 to 3 million years as part of the Wonosari formation. It is called *Gong* because the community once heard the sound of a *gong* (traditional Javanese musical instrument) from inside the cave. Several springs are formed inside Gong Cave, where underground water was used as one of the water supplies for the community particularly during the dry season.

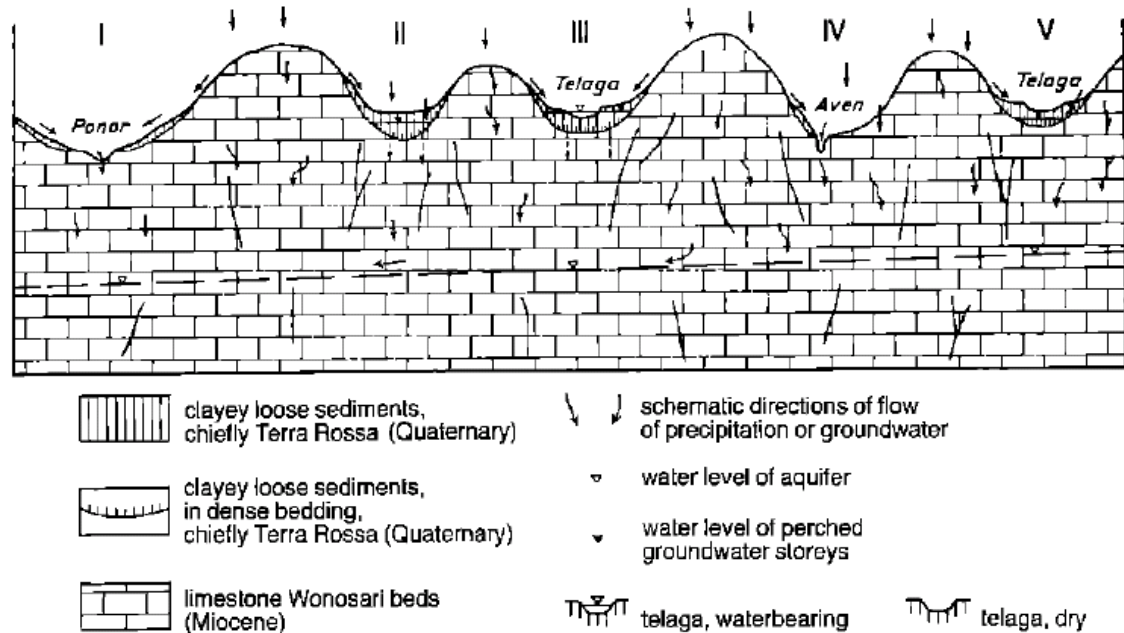


Figure 18. Types of surface- and groundwater in Gunung Sewu (Flathe and Pfeiffer, 1965 in Uhlig 1980:2)



Figure 19. *Luweng Ombo* or vertical cave in Donorojo (own photo 2013)





**Figure 20. Tabuhan Cave in Punung  
(own photo 2013)**



**Figure 21. Groundwater in Gong Cave Punung  
(own photo 2013)**



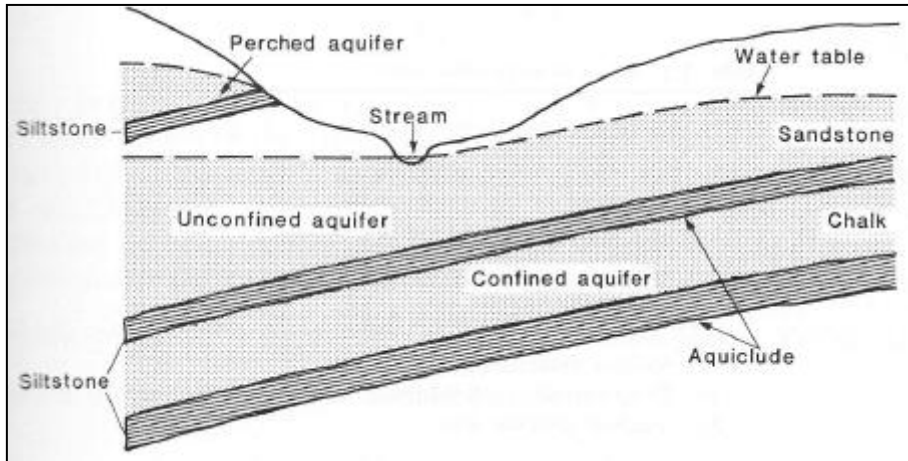
**Figure 22. Small spring or *belik* in Tabuhan Cave (own photo 2013)**

### **3.4. Hydrogeology of Gunung Sewu/Pacitan**

Kresic (2013) highlighted that a karst aquifer is characterised by the disappearance of an entire river into one large sink or cave, where on a volume basis, karst aquifers store and transmit more water than all surface streams within the karst water system. Haryono and Day (2004) added dissolution in karst systems create interconnected pores and forms secondary porosity features where the biggest dissolution occurs on the surface and progressively infiltrates downward because the dissolution of the rock matrix is decreasing as the carbonate concentration increases. As the water percolates downward under the force of gravity, it dissolves and enlarges any pore or fracture in the rock through which it flows and enlarges the fracture allowing it to carry more water, which increases the dissolution rate and its storage capacity.

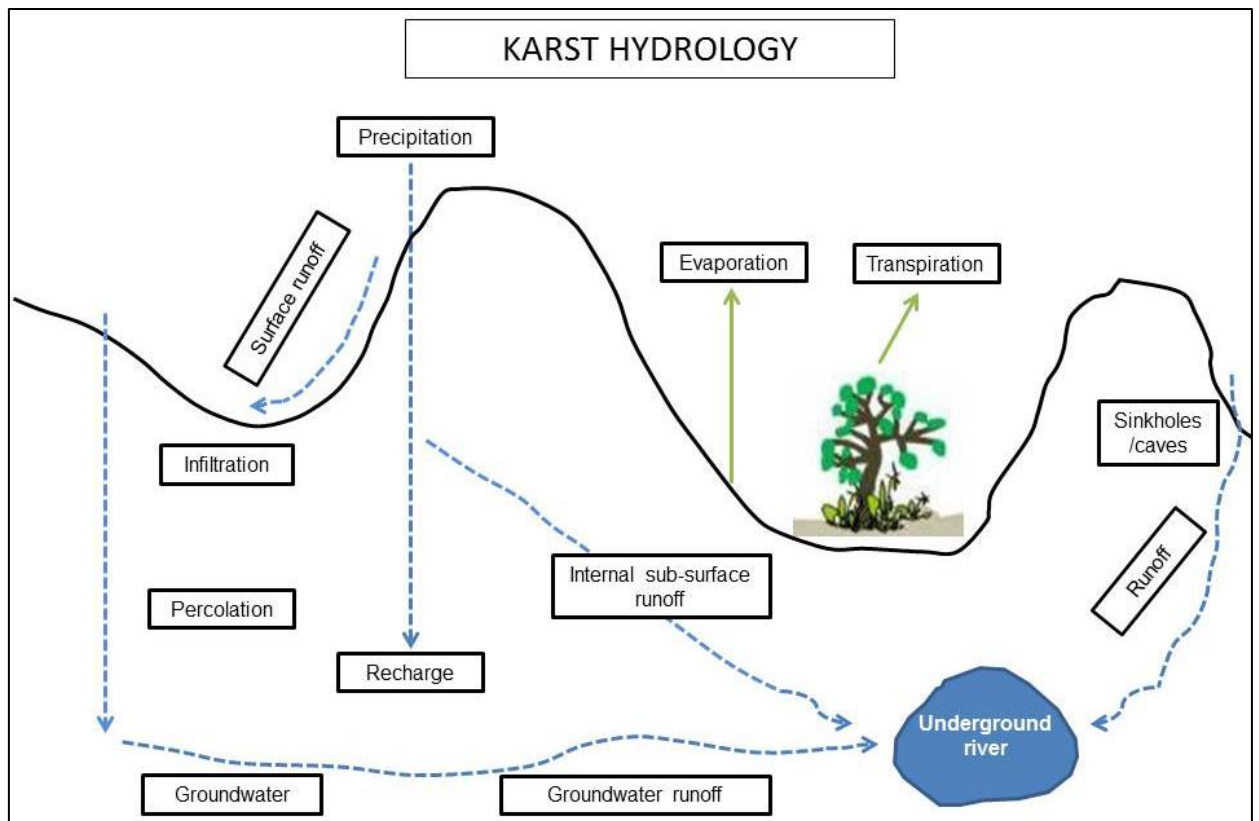
In addition, Ford (1989) mentioned karst aquifers like other rocks can be *confined, unconfined and perched*, as depicted in Figure 23 below. A confined aquifer is relatively impermeable rock that is incapable of absorbing or transmitting water, where the

water in a bore tapping the water-bearing formation usually rises up the bore hole to a level that is above the top of the aquifer. It is sometimes called as artesian well, where the water is said to be confined under artesian conditions. Meanwhile in unconfined aquifers, the upper boundary of the aquifer is the water table; it is an equilibrium surface at which fluid pressure in the voids is equal to the atmospheric pressure. A perched aquifer can be found on top of an impermeable layer rather close to the surface (20-100 m), where the impermeable layer separates the perched groundwater layer from the more deeply located groundwater table.



**Figure 23. Confined, unconfined, and perched aquifers (Dunne and Leopold, 1978 in Ford, D and Williams, P., 1989:127)**

The character of karst hydrology is associated by spring discharge, where in tropical karst areas there is high discharge shortly after heavy precipitation because of high porosity and poor storage of the karstic rock mass. Therefore due to its karst porosity, water will percolate downward until it reaches the water table and all pore space is occupied by water. At this point, the rock is saturated by water and water circulation is not as rapid and dissolution rates slow. Nevertheless, the water table fluctuates up and down as a result of seasonal change, drought condition and groundwater removal. Unconfined aquifers are also characterised by groundwater residence times, where the availability in the aquifers is susceptible to short and long term climatic fluctuations that influence the amount of recharge (ERDÉLYI and GÁLFI 1988; JONES and BANNER 2003).



**Figure 24. Karst hydrology in general (drawn from SOENARTO 2006: 74)**

Soenarto (2006) pointed out that karst hydrology generally differs from non-karst hydrology, due to the existence of sinkholes (*luweng*) and caves where rainfall generates sub-surface runoff and creates underground rivers: whereas surface rivers are common in non-karst hydrology systems as shown in Figure 24 above. Another characteristic of karst hydrology is the depressions formed by erosion of karst debris, where solid karst forms the baseline of the karst surface. In addition, besides the existence of perennial springs, seasonal springs are also scattered throughout the area, particularly during the rainy season.

The major water flow system in the Gunung Sewu karst area is through a conduit forming underground river network, where the aquifers in the karst areas are characterised by secondary porosities governed by enlarged fissures, bedding planes, and dissolution cavities. Nevertheless, local variations are distinguished as a result of geological structures and lithological variation (HARYONO 2008). In addition, allogenic recharge from surface rivers and point recharges are well spread in the area, where point recharges are mostly from ponors draining runoff from closed depressions during the rainy season. There is no surface runoff encountered during dry season. Recharge from ponors can be observed through the suspended load of spring water and underground rivers after rainfall has occurred (HARYONO and DAY 2004).



Haryono (2008) also added that there are five hydrogeologic units in the Gunung Sewu karst area, namely:

- (1) Panggang sub-system
- (2) Bribin-Baron-Seropan sub system
- (3) Ponjong sub-system
- (4) Pracimantoro and Giritontro sub-system
- (5) Donorojo-Pringkuku sub-system

Figure 25 below depicts these hydrogeology sub-systems and shows that Pacitan is included in the Donorojo-Pringkuku sub-system, where it exhibits a general southward groundwater flow, though in detail the flow is controlled by a North East-South West and North West-South East joint or fault system. Groundwater is shallow and is being utilized by local people from dug wells in the north district. Groundwater is gradually deeper to the south entering the core of the karstified area. In general, bed rocks of limestone beds in this sub system are shallower than in the middle part of Gunung Sewu, resulting in a shallower groundwater level, which in some localities emerges as springs feeding surface rivers. In addition, Adji (2010) mentioned that the components of groundwater in Gunung Sewu karst areas including Pacitan are as follows:

- (1) Allogenic recharge or surface runoff that flows into karst aquifers through ponor in this sub-system which mostly become seasonal surface river
- (2) Internal runoff that can be defined as the surface runoff that flows into enclosed depressions and then enter the karst aquifers through sinkholes or ponors (*luweng*)
- (3) Diffuse infiltration or precipitation that falls onto karst surfaces and infiltrates diffusely through soil pores

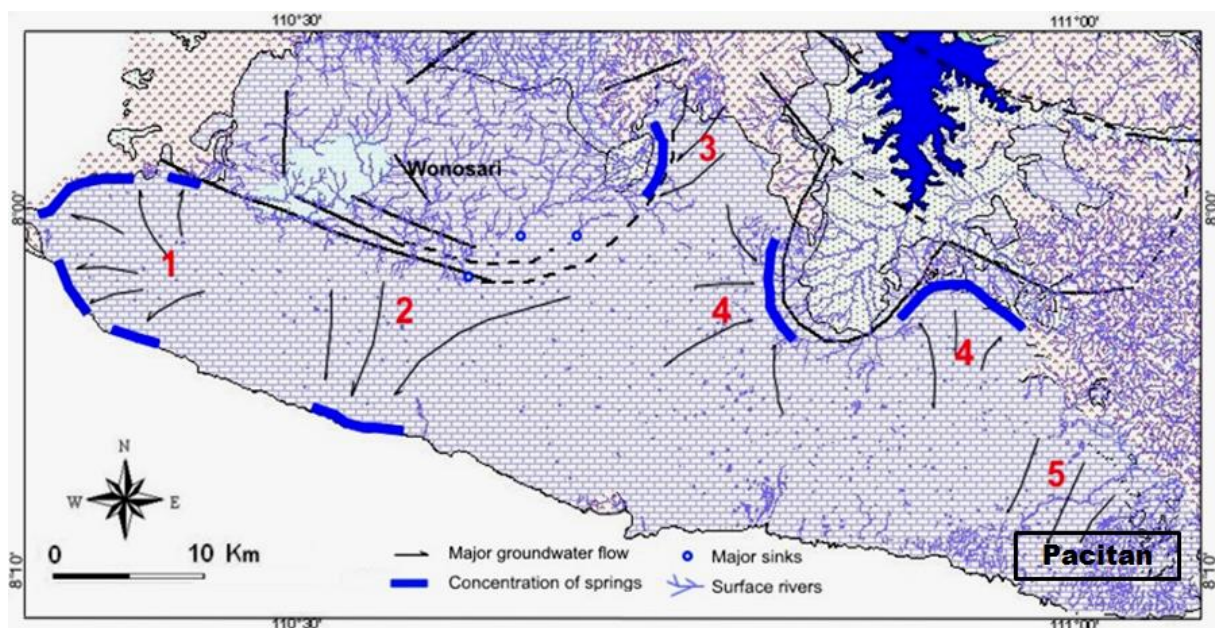
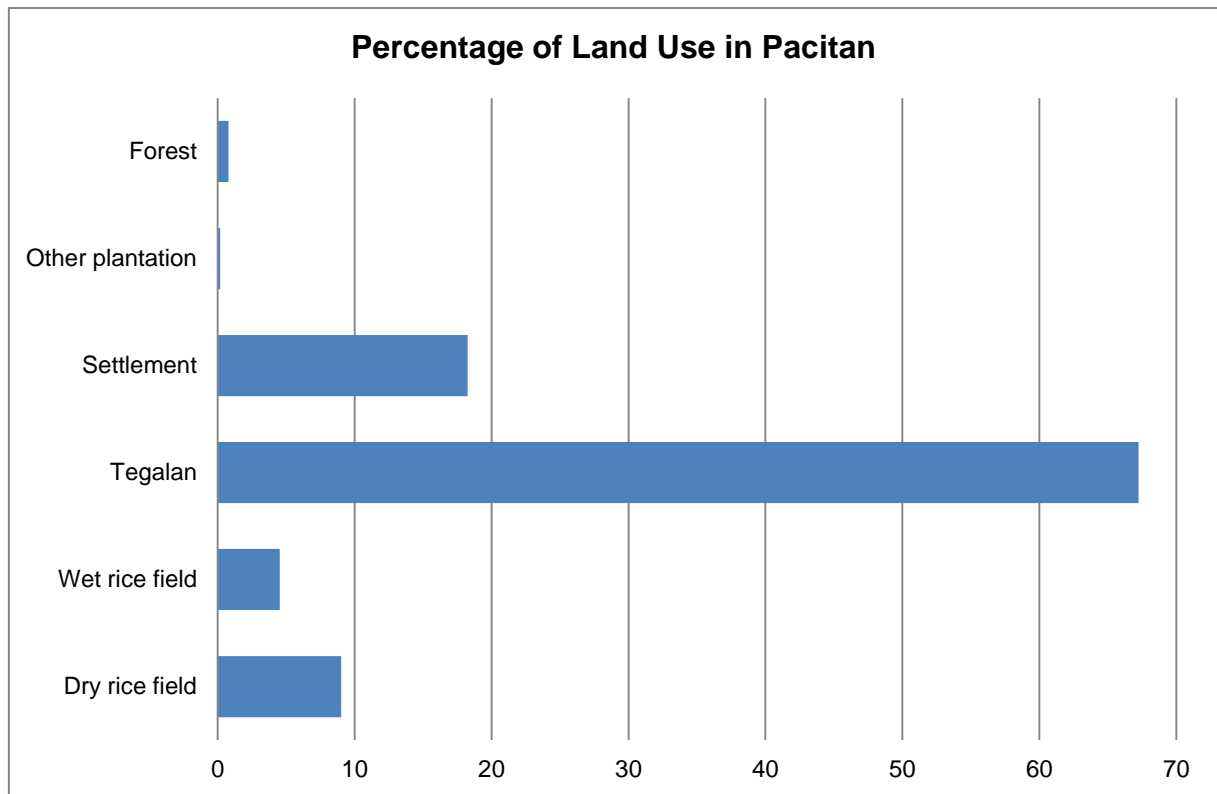


Figure 25. Hydrogeologic units of Gunung Sewu (HARYONO 2008:8)

### 3.5. Land Use of Pacitan

Uhlig (1980) mentioned that due to unfavourable conditions of the permeable substrate and the monsoonal rhythm of a distinct dry and rainy season, the soil moisture and nutrients rise to the surface during the dry season, thus intensive and continuous dry-field cultivation (*tegalan*) of the nutrient-rich soil occurs in the dry season. Therefore, the main crops in karst areas are the crops that are able to grow in reduced water conditions like cassava, maize and dry rice (*padi gogo*). Furthermore, according to the Directorate General of Water Resources (1979), rain fed fields and *tegalan* are based on the number of crops that can be produced. Rain fed fields can produce at best one dry rice crop and one *palawija* (secondary crop) per year, whilst *tegalan* produces not more than two *palawija* crops per year. *Tumpang sari* or multiple cropping is usually used in order to ensure staple food supply during the dry season. Soybeans, groundnuts, maize, soya bean, sorghum, chillies and cassava, where seedlings are planted between dry rice, are the rotated crops in *tumpang sari*. Multiple cropping of dry rice and tobacco usually occurs where slightly more favourable amounts of soil moisture are retained. However, during extreme dry seasons, there are no staple crops that can be grown, due to a very limited water supply. In general, land use in Pacitan mainly consists of *tegalan* (67%) that is dependent on rainfall and not irrigation. Meanwhile dry and wetland rice each comprise less than 10% of the land use in Pacitan, as shown in Figure 26 below.

Furthermore, Lukas and Steinhilper (2005) added that due to the porous texture of the karst underground, most of the rain water pours downward into the sinks and caves, resulting in water shortages for vegetation fairly soon after the rainy season finishes. Thus, only adapted species can grow in karst areas where water is a limiting factor. Due to permeable karst underground and a dry season that usually lasts from May to October/November, no irrigation can be found in the area. Therefore the agricultural fields remain idle during the dry season. Meanwhile, during the wet season there is enough water for intensive dry field cultivation (*tegalan*), and terraces are found not merely on the slope of hills but also in the relatively flat karst basins.



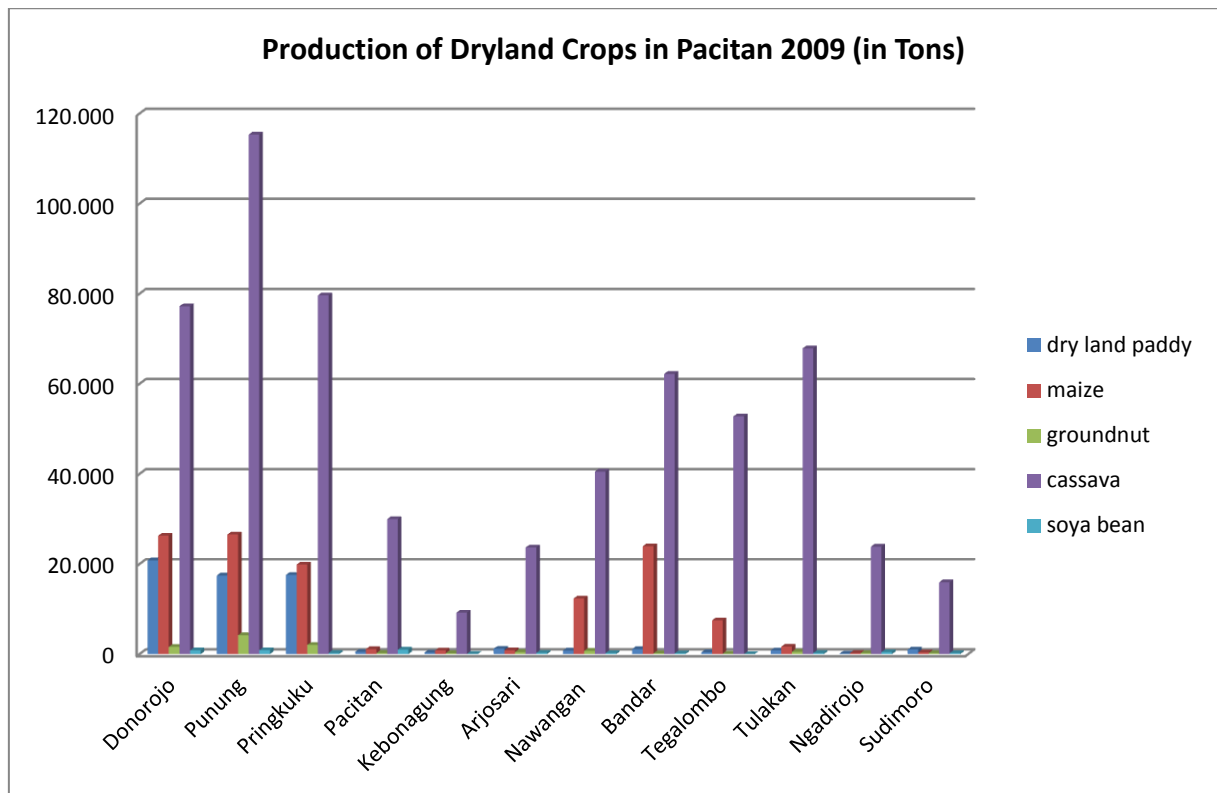
**Figure 26. Land use of Pacitan (drawn from *Badan Pusat Statistik* 2010)**

Nibbering (1991) mentioned that the pattern of land use is characterised by relatively large terraced fields in the basins and steep, narrow field terraces on the slopes. The karst basins are more favourable for crop production, where the valley floors are characterised by deep soils that are enriched with nutrients washed down from the slopes. Therefore, farmers can grow more than one crop during each rainy season. Meanwhile, on the slopes, the soils are shallower, less fertile and the water retention capacity is quite low as well.

Despite of the constraints in water sources due to karst topography, rice is still preferred staple food. Rice also takes precedence over other crops (*palawija* or secondary crop) where farmers include significant plantings of other crops in the rotation. Therefore, the farming system incorporates different cropping patterns that apply specifically to separate land parcels. For example, cassava or intercropped maize is planted in dry land after dry land paddy is harvested.

Most of the cultivated lands in Pacitan are marginally less suitable for perennial crops, where seasonal crops are grown in the bottom of dry valley by multiple cropping, for example cassava and groundnut, or cassava with maize as shown in Figure 27 below. Terraces are continually built to preserve the soil and more stones are dug up away from the carbonate rocks, where the small farmers use hammer to break off pieces of the walls and corners of the carbonate rocks in order to have additional cultivatable areas from the stony land in these spaces. Farmers also trap the soils transported by runoff during the

rainy season by constructing terraces on the hills slope so they can get more areas of soil covered land.



**Figure 27. Production of Dry land Crops in Pacitan year 2009 (drawn from *Badan Pusat Statistik Pacitan 2010*)**

However, according to *Badan Pusat Statistik Pacitan* (2010) in Figure 27, Donorojo, Punung and Pringkuku are the areas with the highest volume of dry land crops in Pacitan. Dry land paddy, maize, groundnut, cassava and soya bean are significant crops with dry land paddy accounting for about 20,000 tons in 2009, maize 28,000 tons, and cassava as the highest among at 115,000 tons. These dry crops are resistant to dry conditions with low water needs. Cassava is considered the perennial crop with the highest harvest return in April/May, after the harvest time for dry paddy. Meanwhile due to its high value in the market, the community plant soya bean as a cash crop and cassava as one of their staple food crops, as cassava leaves and roots can be used and it is relatively easy to plant.



**Figure 28. Multiple cropping cassava and groundnut in Punung (own figure 2013)**

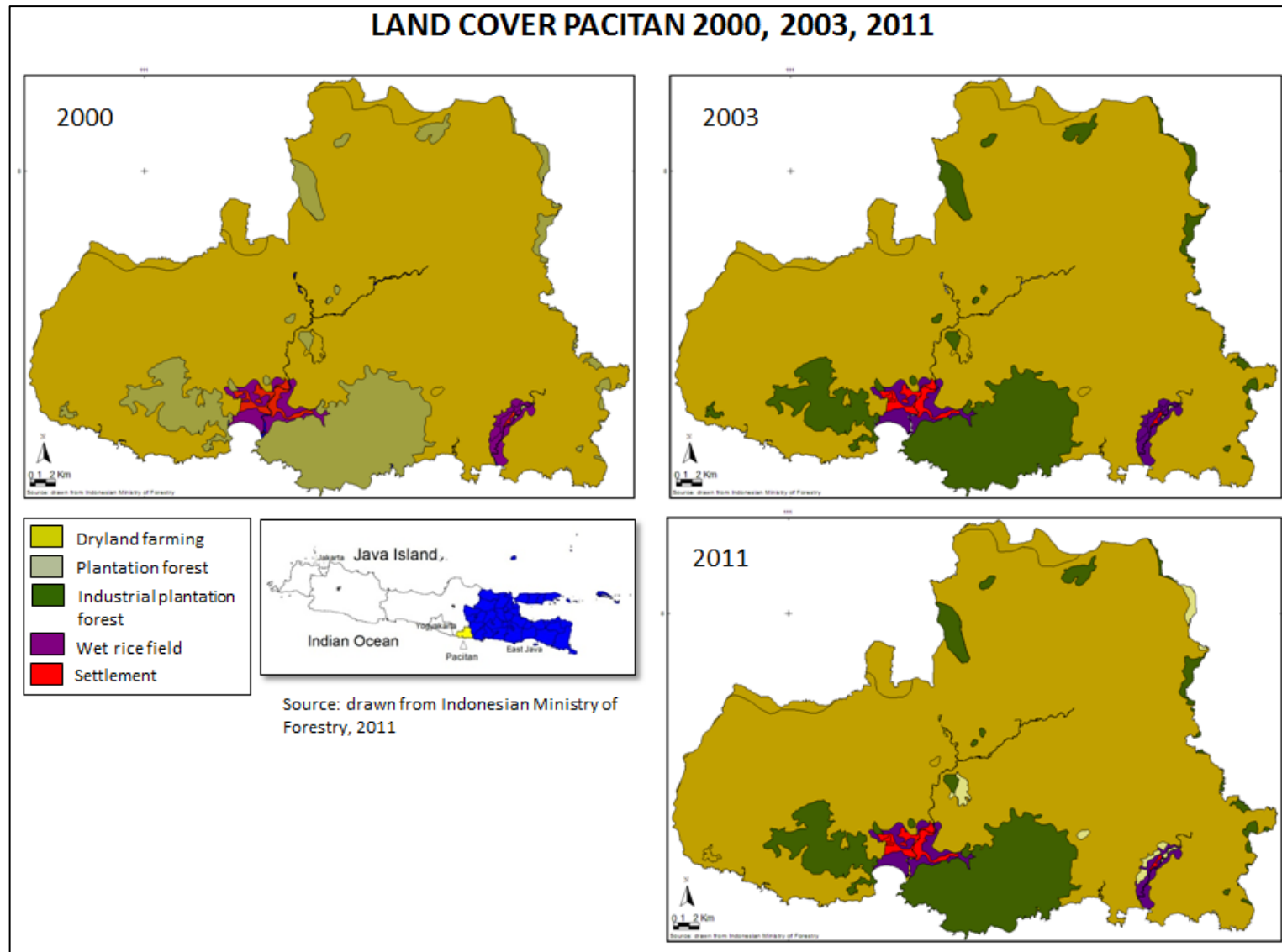


**Figure 29. Multiple cropping maize and cassava in Donorojo (own figure 2013)**

Based on interviews in 2013, multiple cropping occurs during the rainy season where groundnut or maize is grown as the second rotation after dry paddy is harvested. This type of land utilization occurs mostly in the bottom of closed depressions, dry valleys and the foot slope of karst hills, meanwhile mixed garden crops as shown in Figure 28 and 29 above are grown on the slopes of karst hills or on any land near settlements where the crops can also include timber plantations, fruit crops or other industrial crops. The two types of land utilization are related to the self reliant living of local farmers. Multiple seasonal crops are intended to fulfil daily needs, whereas multiple perennial crops function as savings for extra expenditures such as paying tuition fees for their children and other accidental expenses.

Map 7 below shows the change in land cover from 2000 to 2011, where dry land farming dominates almost the whole area in Pacitan including Donorojo, Punung and Pringkuku. Settlements are concentrated in the capital district, adjacent to Pacitan Bay and the eastern part of Pacitan where wet rice fields are located. In small parts of the west and east of Pacitan, there is a significant change of land cover from plantation forest into industrial plantation forest in 2000, 2003 and 2011.





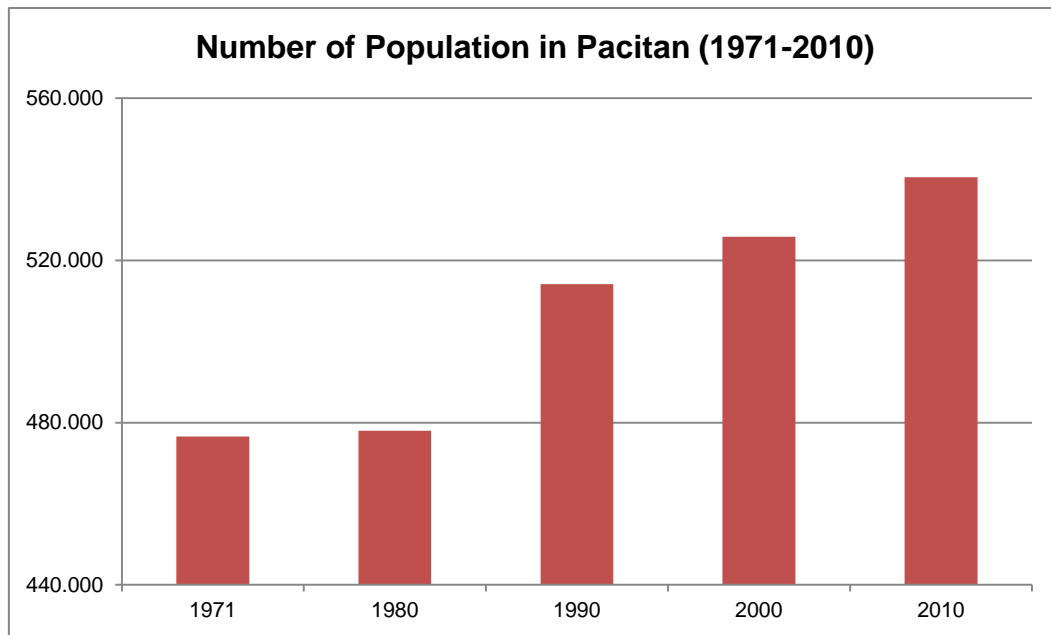
**Map 7. Land cover Pacitan in 2000, 2003 and 2011 (drawn from the Indonesian Ministry of Forestry 2011)**

Siswoyo (2007) emphasized that home yard and *tegalan* dominate community planted forest in Pacitan, where teak (*tectona grandis*) is the most suitable timber in western and northern parts of Pacitan including Donorojo, Punung and Pringkuku, for its capability to retain less water and its high value in the market. Community planted forest comprises 97.1% of the forest cover in Pacitan and produces 250 m<sup>3</sup> of timber per day with teak, *sengon* (*albizia chinensis*), acacia, mahogany (*swietenia macrophylla*) and pine as the main timber. Timber is also considered a long-term investment for the community for big expenditures due to its high value in the market. Nonetheless, Siswoyo also added that there is an escalation of early logging timber in order to have quick cash for the community. There is a trend away from mixed plantation forest and into industrial plantation forests from 2000 to 2011, which focus on specifically for industrial timber with high value in the market. The community prefers to have timber with short growing times of four to five years in order to have quick cash. In the long term this trend may cause soil erosion. Therefore, *Perum Perhutani* as a state-owned company for forestry, together with local stakeholders and Non-Governmental Organizations are assessing the potential forest land in Pacitan to reduce the impact of early logging timber.

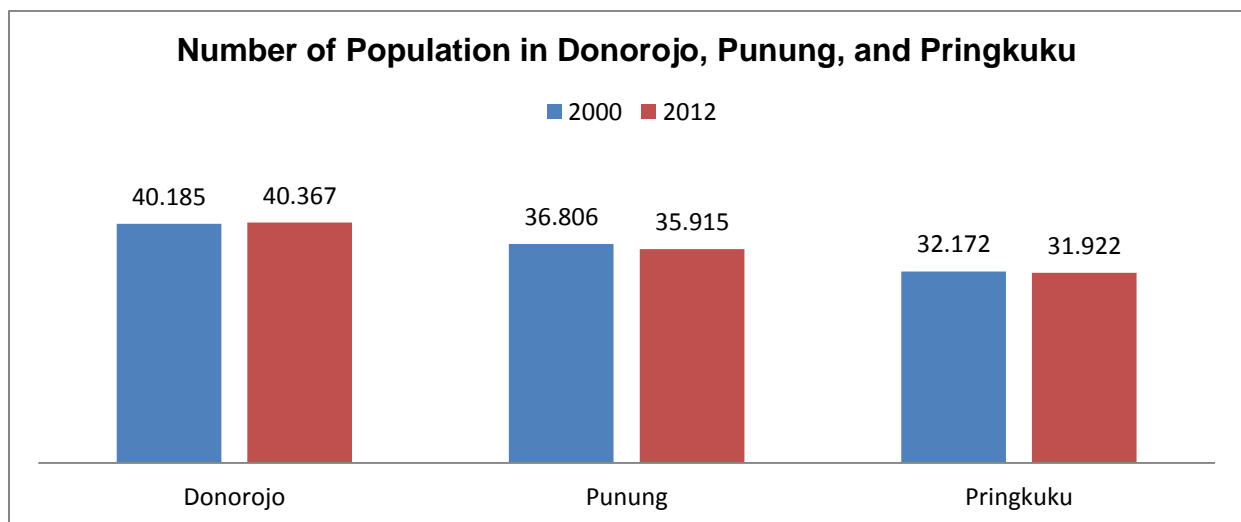
### **3.6. Social-Economy Condition**

Generally, the population in Pacitan including Donorojo, Punung and Pringkuku has increased by 13% between 1971 and 2010 as it shown in Figure 30 below. However as Lukas and Steihlper (2005) mentioned the karst topography in the Gunung Sewu area includes Pacitan has less surface water supplies for agricultural and domestic use. This ensures the population in Donorojo, Punung and Pringkuku tends to be stagnant and has slightly decreased from 2000 to 2012 as shown in Figure 31.

Despite the constraints in terms of water availability, the agricultural and forestry sectors play an important role in Pacitan as primary subsistence, where most of the communities are working as dry land farmers and have cattle around their home for unexpected expenses or as supplementary income particularly during long dry seasons when there is a poor result from the agricultural harvest. Some communities even use their cattle as an investment to purchase water tanks during longer dry seasons when local water sources cannot fulfil their daily water needs. As secondary subsistence, most of the farmers also migrate for seasonal work associated with agriculture part of the year and short-term employment work opportunities outside the area.



**Figure 30. Population in Pacitan from 1971 to 2010 (drawn from *Badan Pusat Statistik Pacitan 2010*)**



**Figure 31. Population in Donorojo, Punung and Pringkuku (drawn from *Badan Pusat Statistik Pacitan 2012*)**

Based on interview results and own observation (2013), the tourism sector is also considered essential for secondary subsistence in Gunung Sewu karst areas. Coastal tourism in Donorojo and Pringkuku is well known, as well as cave tourism in Punung. Pantai Klayar and Pantai Srau (*Pantai* in Indonesian means beach or coast) are famous touristic sites for local and international tourists, whereas Pantai Watukarung is well known as a surfing site. Moreover Goa Gong and Goa Tabuhan (Goa in Indonesian means cave) in Punung are also landmarks in Pacitan that are famous for local tourism. The maintenance and operational costs of tourist sites are managed by local government and local community groups, where the profit goes partially to local government. For



example, the entrance ticket to Pantai Klayar, Pantai Srau and Goa Tabuhan that is manage by the local government of Pacitan and the local community group costs Rp 3000 (around 20 cents Euro) for adults as shown in Figure 32 below. However not all coastal tourist sites are manage by the local government. Several coastal sites are still managed by local community groups where the supporting infrastructure such as entrance roads do not yet fulfill the requirements of tourist sites and the entrance ticket is paid voluntarily by the tourists.



**Figure 32. Entrance ticket for coastal tourism (Pantai Klayar, Pantai Srau) and cave tourism (Goa Tabuhan) (own figure 2013)**

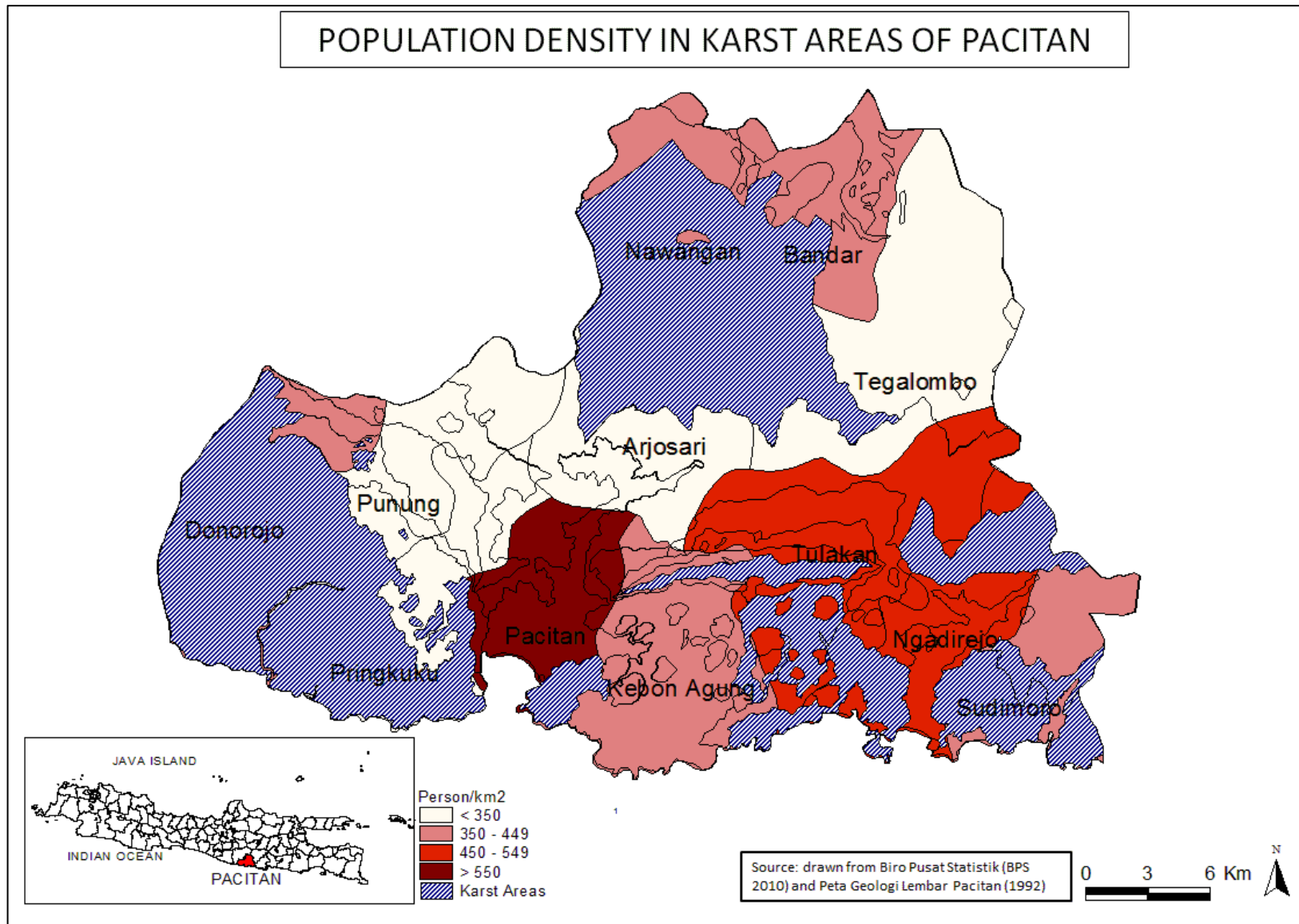
Based on interview result (2013), the community particularly those in their most age, choose to migrate seasonally to the capital district of Pacitan or neighbouring cities such as Solo in Central Java Province, Yogyakarta Province or even to other countries such as Malaysia to do labouring work. During the dry season when the land is dry and bare (from June to August/September), the head of the household is usually the one who undertakes seasonal migration to do labour work in the neighbouring cities and the rest of the family remain working on the field, fallowing the land to prepare for the next planting season (October). However, there are some communities who prefer to stay and work either as local government officers or do local business in the area. In the southern part of Donorojo and Pringkuku that are adjacent to Indian Ocean, fisheries are also essential for the subsistence of the community and coastal tourism is one of the main attractions for local and international tourists. Two villages in Donorojo are known as the producers of molasses from coconut (called *Nira*). Two molasses is extracted from the coconut tree by using buckets and is cooked, resulting in brown sugar cane that is finally formed into cubes or round shapes and transported to other areas as a home industry product. In addition, one village in Pringkuku is known for coir, made into floor mats, brooms and

mattresses as home industry products and transported to neighbouring cities and provinces.

Map 8 illustrates the distribution of karst areas and population density in Pacitan. Map 8 shows that the population in Pacitan is generally concentrated in the non-karst areas like the capital district of Pacitan and Tulakan with 849 persons/km<sup>2</sup> and 484 persons/km<sup>2</sup> respectively. Meanwhile population density in the karst areas of Gunung Sewu varies from 244 to 373 persons/km<sup>2</sup>, where Donorojo has the highest population density among the three sub-districts. Some parts of Nawangan and Bandar in the northern part of Pacitan, which are also karst areas, have population densities that are also below 350 persons/km<sup>2</sup>. Due to karst topography, the karst areas are considered non-favourable areas for residence by the community, who know the water sources particularly during the dry season are depleted. Based on the interview results, generally the communities reside in groups scattered at different altitudes and distances from water sources, where the access to water sources is limited by groundwater location and high water permeation resulting in less surface water. Therefore the communities prefer to reside either beside the main road for easy access to the capital district or close to public service areas. Table 3 summarizes the primary and secondary subsistence in Donorojo, Pringkuku and Punung.

**Table 3. Primary and secondary subsistence in Donorojo, Pringkuku and Punung (own interview results 2013)**

	Subsistence		
	Donorojo	Pringkuku	Punung
Primary	Dry land crops, cattle	Dry land crops, cattle, fisheries	Dry land crops, cattle
Secondary	Government officer, timber, home industry (Nira), coastal tourism, seasonal migration	Government officer, timber, home industry (coir), coastal tourism, seasonal migration	Government officer, cave tourism, seasonal migration



Map 8. Population density in karst areas of Pacitan (own figure drawn from *Badan Pusat Statistik* 2010 and *Peta Geologi Lembar Pacitan* 1992)

### 3.7. Piped Water Supply (*Perusahaan Daerah Air Minum*/PDAM)

This sub chapter provides general information on PDAM, whereas the next chapter will detail the distribution of PDAM in every *Kecamatan*. As the main state-owned water supplier, the existence of PDAM is essential in Indonesia, especially in the areas where water sources are scarce. However, PDAM faces numerous constraints in terms of financing operational costs; infrastructure and efficiency issues that make it unable to serve the public optimally. Furthermore, most of the water supplies in East Java Province use groundwater with electricity as the main power source for pumped distribution. The distribution networks faces leaking pipes, increasing financial operational costs and population pressure. In 2002, PDAM in East Java Province lost 36% of its water due to leaking pipes; meanwhile there are 5000 additional units of pipe demanded annually to PDAM (BRONTOWIJONO 2008).

Despite of the constraints, the number of PDAM customers in Pacitan is increased 10% each year from 2004 to 2009, as shown in Figure 33. The figure shows that the community still need PDAM as the water supplier for their daily needs, especially during the dry season where other water source like *telaga* and dug wells are depleted. Nevertheless, in 2010, PDAM Pacitan covered only 16% of the service area, where 94% of the water supplied was for domestic use, and the rest are for industry and government. Perennial springs, surface waters and deep wells are the main water sources for PDAM in Pacitan, where surface waters in non-karst areas contribute the most water (137.5 L/sec) (PERPAMSI/*Persatuan Perusahaan Air Minum Seluruh Indonesia* 2010).

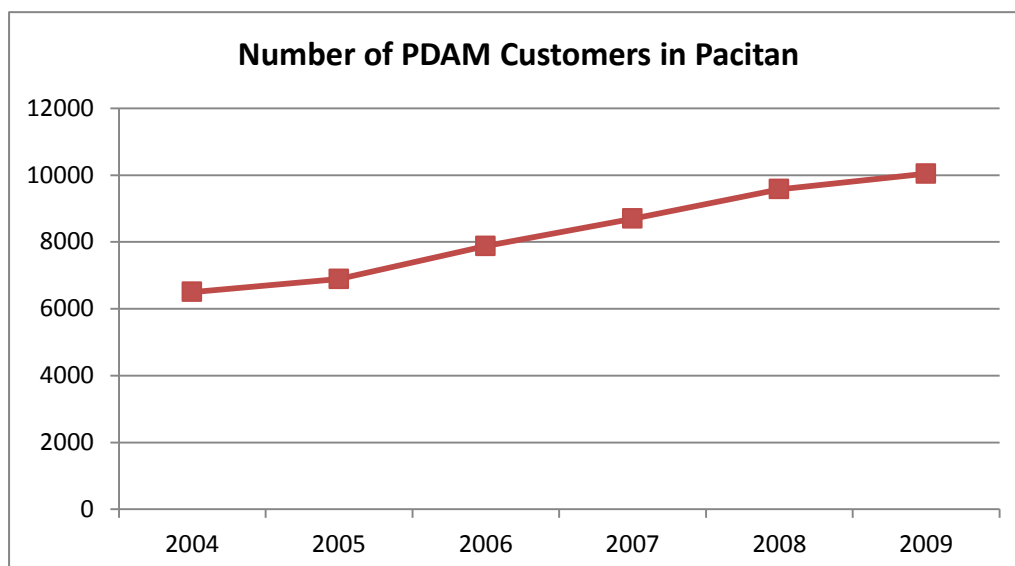


Figure 33. Number of PDAM Customers in Pacitan (drawn from *Badan Pusat Statistik* 2010)

According to the Ministry of Public Work, some parts of Donorojo, Punung and Pringkuku experienced water drinking problems, especially in the Karst areas during the dry season. During the dry season in 2009, many villages in these three *Kecamatan*

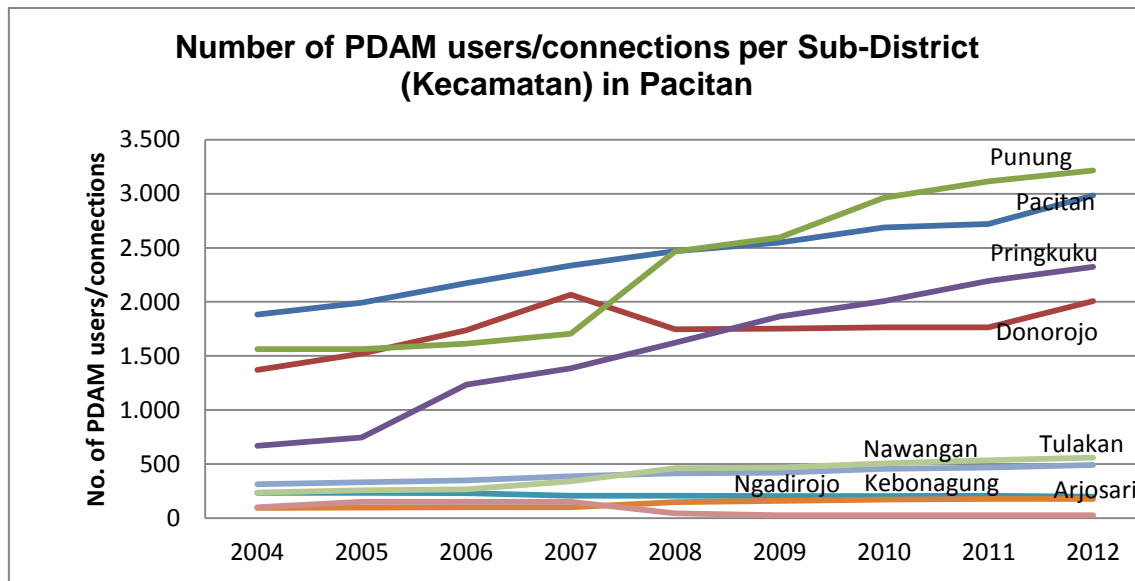
suffered drinking water problems. Water sources, including *telaga* that are drying up and depleted provide water that needs to be boiled first, due to its quality and yellowish colour. In order to take water from other sources, the local community needs to walk up to several kilometres, for their domestic and agricultural water uses (Antara News 2009).

According to PERDA<sup>2</sup>(*Peraturan Daerah*) Pacitan (1992), PDAM Pacitan was built by the local government of Pacitan in 1992 to manage water supplies and its use in the community. However, it was not until 2005 that PDAM covered most of the water-scarce areas in Pacitan, particularly in the karst areas and developed their service in terms of water quality. PDAM had built 9 units in 9 out of 12 *Kecamatan* in Pacitan, and are still developing new units in water-scarce areas. In karst areas of Gunung Sewu, PDAM built three water installations or IPA (*Instalasi Pengolahan Air*) and ground reservoirs in Punung, namely one installation in Desa Sekar Donorojo and two installations in Desa Candi and Desa Sugihwaras Pringkuku, where the latter serves for most areas in the south of Punung and some parts of Pringkuku. PDAM is working together with the Ministry of Public Work, where technical operation is provided by PDAM and the Ministry of Public Work supports the funding in terms of supplying tanks and other operational costs. For the community that has connected with PDAM through IPA, they do not receive water 24 hours in a day; water rotation is done based on time division where the PDAM users in the northern part of IPA Pringkuku receive water for 14-15 hours in a day and those in the southern part for 17-18 hours per day; therefore water storage is necessary to have for each PDAM user in order to store water while the water is still running from IPA (interview result with an officer of IPA Pringkuku 2013).

Regardless of the constraints that PDAM experiences, the number of PDAM users in Donorojo, Pringkuku and Pacitan as well as the capital district of Pacitan, significantly increased by 16% from 2004 to 2012, as shown in Figure 34 below. Based on the results of interviews and FGD (2013), the communities in these three sub-districts are relying mostly on PDAM connection as their primary source of water supply, particularly in dry seasons where other sources such as dug wells and seasonal springs are depleted. However, due to the location of several villages in the hilly areas, PDAM has difficulties in covering the whole area by withdrawing water from the perennial springs and transporting the water to their houses. Some houses are even using only one PDAM connection and sharing the cost based on their needs. Figure 34 below also shows that Donorojo, Pringkuku and Punung have the highest number of PDAM users outside the capital district of Pacitan, which means that the communities there are dependent on PDAM as the primary source of water, particularly during the dry season when water is limited.

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<sup>2</sup> PERDA is regional regulation that is issued by DPRD (*Dewan Perwakilan Rakyat Daerah*) or the Provincial Legislative Council for provinces and approved by the head of province or sub-division of province (*Kabupaten*).



**Figure 34. Number of PDAM users/connections per Sub-District (*Kecamatan*) in Pacitan (drawn from *Badan Pusat Statistik* 2012)**

Water sources in the form of perennial and seasonal springs, include drilled wells are spread in most areas of Donorojo, Punung, and Pringkuku as shown in the Map 9 below. However, due to the karst topography, seasonal springs are generally depleted during the dry season and thus they cannot fulfil the water needs where water discharge in seasonal springs varies from one to 13 L/second in the dry season and two to 20 L/second in the rainy season respectively; meanwhile water discharge of perennial springs range from 10 L/second in the dry season to 40 L/second in the rainy season. Thus PDAM has been using three perennial springs in Donorojo, Punung, and Pringkuku as their water sources to fulfil the needs of the community. Furthermore, drilled wells in Punung and Donorojo were built by PDAM together with community groups as an additional water supply particularly during the dry season. These figures are summarized in Table 4 below.

**Table 4. Water discharge in Donorojo, Punung and Pringkuku (collected from PDAM 2011, interview with mechanical officer in IPA Pringkuku and the communities 2013)**

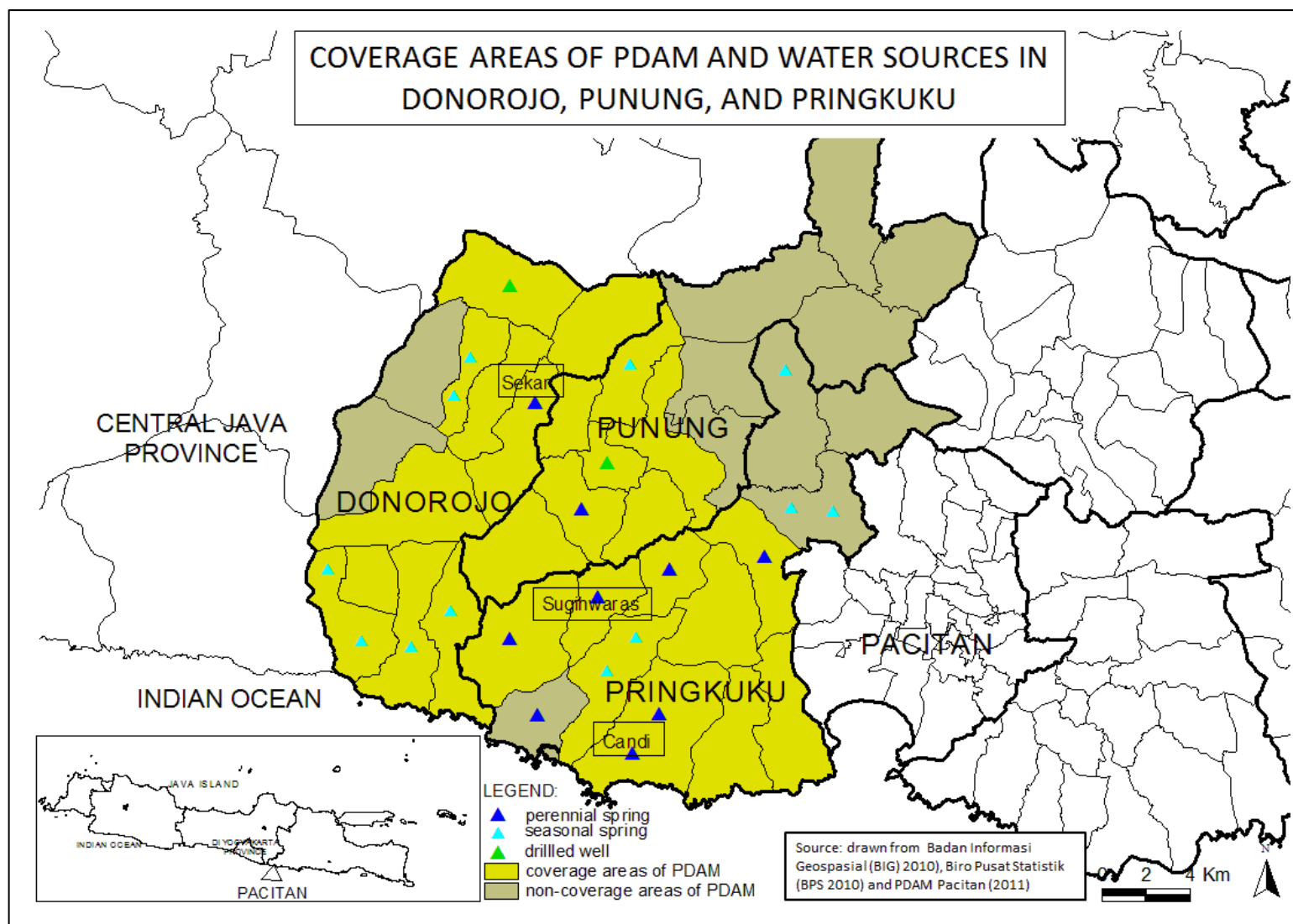
<i>Kecamatan</i>	Number of water sources	Type of water sources	Water discharge (L/second)	
			Rainy season	Dry season
Donorojo	7	6 seasonal springs, 1 perennial springs, 1 drilled well	2-40	1-21
Pringkuku	11	4 seasonal springs, 7 perennial springs	2.5 – 20	1-10

Punung	3	1 seasonal spring, 1 perennial spring, 1 drilled well	7.5 – 20	2-10
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According to PDAM (2011), for both residential and industrial use, the customer needs to pay the first instalment. The cost for residential use is lower than industrial use as shown in Table 5 below. After the first instalment, the community needs to pay for every 10 m<sup>3</sup> used. Thus if the customers use less than 10 m<sup>3</sup>, then they still need to pay the same amount of money for 10 m<sup>3</sup> water use. Based on the interviews with the communities (2013), they generally use around 10 m<sup>3</sup> water from PDAM per month for one family that consists of four to six persons in one household. Some households even share water with others and share the costs based on their needs. The water from PDAM is used for domestic use and not for cattle or watering the plants, which are watered from the rainfall.

**Table 5. PDAM costs for residential and industrial customer (PDAM 2011)**

	Residential	Industrial
1 <sup>st</sup> instalment	Rp.650,000 (€ 42)	Rp.650,000 (€ 42)
Monthly payment (per 10 m <sup>3</sup> )	Rp.31,400 (€ 2)	Rp.71,000 (€ 5)
If more than 10 m <sup>3</sup> (per 1 m <sup>3</sup> )	Rp.2640 (2 cents)	Rp.3840 (3 cents)



**Map 9. Coverage areas of PDAM and water sources in Donorojo, Punung, and Pringkuku (own figure drawn from *Badan Pusat Statistik* 2010 and PDAM Pacitan 2011)**



## 4. DATA ANALYSIS AND DISCUSSIONS

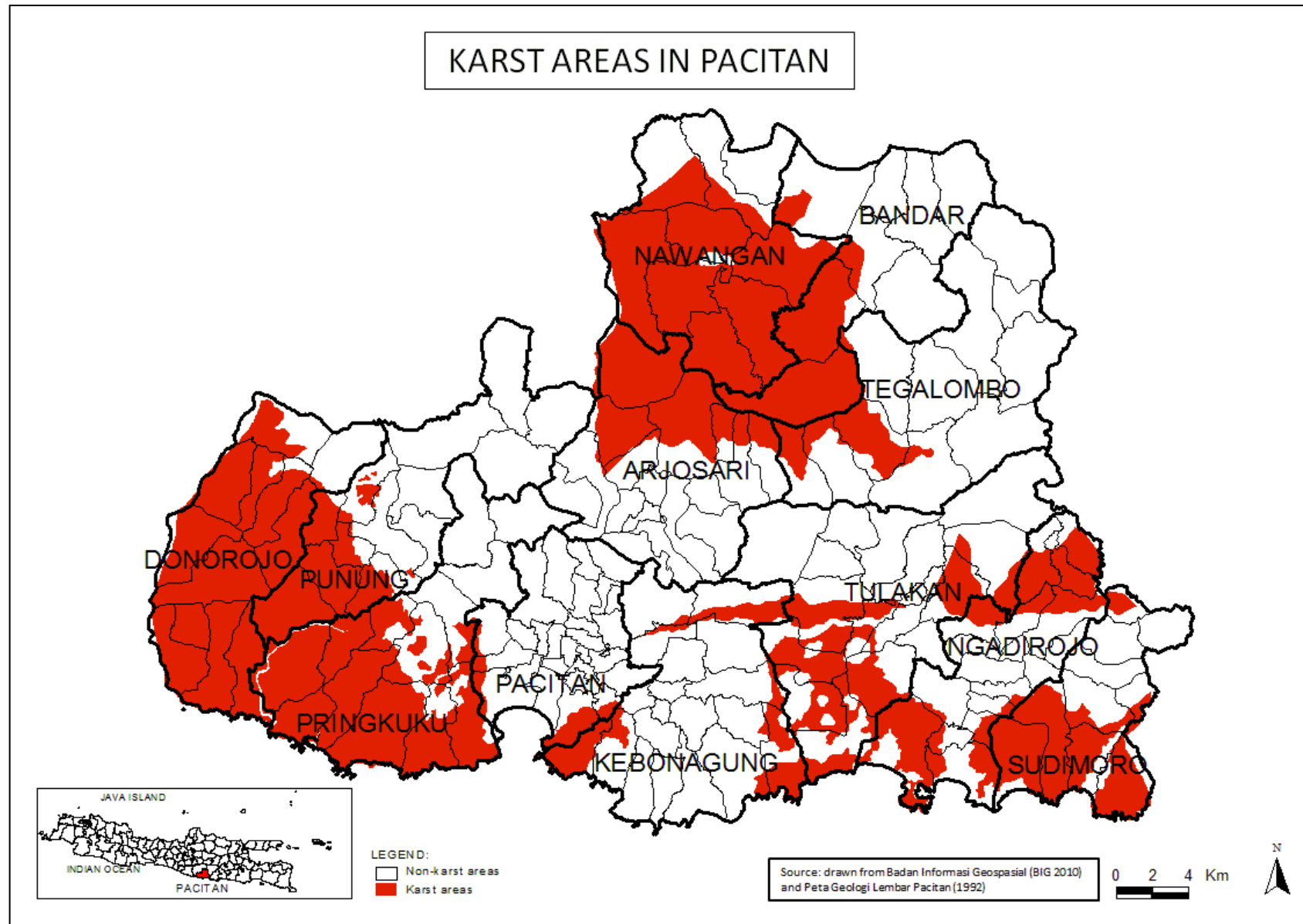
The distribution of karst areas in Pacitan, climate parameters, rainfall and temperature, including extreme climate events, the distribution of PDAM and the relation of water scarcity with water use have been described and analyzed in this chapter.

### 4.1. Distribution of Karst Areas in Pacitan

The hydrology of the karst system in Gunung Sewu region has resulted water issues particularly during the dry season where rain water infiltrates into the ground and the porosity of karst structures reduces the capability of the soil in water filtering (NESTMANN, OBERLE, IKHWAN, LUX, SCHOLZ 2009; DITTMANN, FACH, FUCHS, HOSSU, NESTMANN and OBERLE 2011). Pacitan, as the most western part of Gunung Sewu has the typical karst system of Gunung Sewu where kegelkarst generates seasonal water source with limited water discharge particularly during the dry season; while underground rivers are filled with abundant water discharge (HARYONO 2008). The coverage of the Gunung Sewu karst areas in Pacitan, as described in chapter III, are located in the most western part of Pacitan that encompasses three *Kecamatan*, namely: Kecamatan Donorojo, Kecamatan Punung, and Kecamatan Pringkuku.

The coverage of karst areas in Pacitan within the Gunung Sewu region must be determined, as there are also karst areas in the northern part and sparse amounts in the eastern part of Pacitan as shown in Map 10 below. In addition, several studies regarding Gunung Sewu (LUKAS and STEINHILPER 2005; SUNKAR 2008; NESTMANN 2012) have described the karst area most prominently in Gunungkidul as a Special Region of Yogyakarta Province; therefore the research emphasizes Pacitan as the most eastern part of the Gunung Sewu karst region.

Gunung Sewu consists of three different administrative areas, namely the Special Region of Yogyakarta Province, Central Java Province and East Java Province. In order to acquire the distribution of karst areas in Pacitan, particularly in the Gunung Sewu karst region, topography map (*Peta Rupa Bumi*) from *Badan Informasi Geospasial* (BIG) in 2010 and the geological map of Pacitan in 1992 are collected and overlaid as shown in Map 10 below. The spatial distribution of chalky limestone in Pacitan can be seen in most of the areas except the middle of Pacitan, where the red color in the map shows the content of limestone that has formed the Wonosari formation that dominates the Gunung Sewu karst areas. The research focuses on three *Kecamatan* in Pacitan that include Gunung Sewu karst areas in the western part, namely Donorojo, Punung and Pringkuku. However, the limestone does not cover the whole area. Only around 70% of these three *Kecamatan* consists of karstification or kegelkarst as shown in Table 6 below.



**Map 10. Karst areas in Pacitan (own figure drawn from BIG 2010 and *Peta Geologi Lembar Pacitan* 1992)**

**Table 6. List of the *Desa* in Donorojo, Pringkuku and Punung that are include in Karst of *Gunung Sewu* ( collected from BIG 2010 and *Peta Geologi Lembar Pacitan* (1992)**

<b>Kecamatan</b>	<b>Desa</b>	<b>Karst Areas</b>	<b>Kecamatan</b>	<b>Desa</b>	<b>Karst Areas</b>
Donorojo	Belah	√	Punung	Mantren	√
	Donorojo	x		Punung	√
	Cemeng	√		Wareng	√
	Gendaran	√		Kendal	√
	Sukodono	√		Piton	√
	Sekar	√		Sooko	√
	Geodmpol	√		Bomo	√
	Klepu	√		Mendolo Kidul	x
	Sawahan	√		Mendolo Lor	x
	Kalak	√		Tinatar	x
	Sendang	√		Gondosari	x
	Widoro	√		Ploso	x
				Kebonsari	x
Pringkuku	Pelem	x			
	Tamansari	x			
	Glinggangan	x			
	Ngadirejan	√			
	Sobo	√			
	Pringkuku	√			
	Sugihwaras	√			
	Dersono	√			
	Jlubang	√			
	Dadapan	√			
	Candi	√			
	Poko	√			
	Watukarung	√			

The sign “√” in the table shows areas that are included in the karst areas of Gunung Sewu and located in west, south and eastern part of Donorojo, Pringkuku and Punung; meanwhile the sign of “x” indicates the areas that are not included and these are located in the northern part of these three *Kecamatan*, particularly Punung, that has the most areas of non karst. According to Van Bemmelen (1970), the northern part of Pacitan is marked by a distinct escarpment from pre-quaternary peneplain, called the Gunung Gembes with a height of 1243 meters. The southern part is covered by limestone with steep abrasion cliffs along the Indian Ocean. The mountainous areas in the north of Punung where the slope ranges from 40 to 60% are used by the communities and the local government as conservation areas and potential sites for agro-tourism.

## 4.1. Climate Parameters

This sub chapter briefly describes climate parameters that are used in the research, namely temperature and rainfall, as the long-term average annual rainfall and temperature are the indices that determine the wetness of the climate. Linacre (1992) pointed out that predicting rainfall during the remainder of a crop's growth and fluctuation of average temperature in various seasons is useful to farmers, where the year-to-year variation of a particular month's rainfall is often considerable particularly for the months in the dry season. These parameters are used in this research to distinguish the period of the dry and rainy season within the area and to observe whether extreme climate events occur by referring to list of historical El Niño and La Nina episodes in 31 years of climate data collected between 1981 and 2012.

The climate parameters that are used in the research are taken from a weather station in Pacitan where the measurements are done at the airport station of Pacitan working together with *Badan Klimatologi dan Geofisika* (BMKG) the Indonesian Agency for Meteorology, Climatology and Geophysics. Due to a lack of archive data in Pacitan, full data collection from the weather station can only be assembled from 1981 to 2012. The term full data collection refers to no missing data in monthly average rainfall and temperature observation as well as annual rainfall in Pacitan. The weather station in Pacitan covers climatological observation in the area of Pacitan, where the instruments are used to measure climate parameters in temporal and spatial scale and considered representative for the surrounding areas although the size of the areas vary. In addition, a map of general rainfall types in Indonesia from BMKG is also being taken into consideration in this research to observe the type of rainfall in Pacitan. It shows that Pacitan is classified as a monsoon area that receives the rainfall normally during the rainy season from October to March and experiences a dry season from May to August.

The research combines secondary data from climatic parameters from BMKG and an in-depth interview to complement the periods where extreme climate events occurred by conducting interviews and Focus Group Discussions (FGD). The accuracy from both results are verified by using data series of ENSO years from the Climate Prediction Centre of National Oceanic and Atmospheric Administration<sup>3</sup> (NOAA).

### 4.1.1. Rainfall

Rainfall data that is collected comprises the monthly average and annual value from January to December starting from 1981 to 2012. The value of monthly rainfall is calculated by accumulating daily rainfall for thirty consecutive days and it is measured to

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<sup>3</sup> [http://www.cpc.ncep.noaa.gov/products/analysis\\_monitoring/ensostuff/ensoyears.shtml](http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml)

observe the difference between the rainy and dry season, BMKG uses criteria that determines a rainy season is any 10-day period that has more than 50 mm rainfall in consecutive days and a dry season as 10-day period that has less than 50 mm rainfall in consecutive days (MAKMUR 2009). The 10-day period of rainfall variation can be used in the agricultural sector since such units of time are also used in planning field operations and for measuring crop development. The observation of the onset of rainy and dry seasons is necessary in order to analyze whether there is a shifting of season that is caused by extreme climate events, like the ENSO phenomenon. In general, the basic calculation of rainfall data is conducted by accumulating rainfall that is received per day within the area and sums it into per month or annual data; meanwhile rainfall average data is calculated by dividing the amount of rainfall by days in the month or the year (LINACRE 1992).

**Table 7. Mean monthly rainfall from 1981 to 2012 in Pacitan (BMKG Pacitan 2013)**

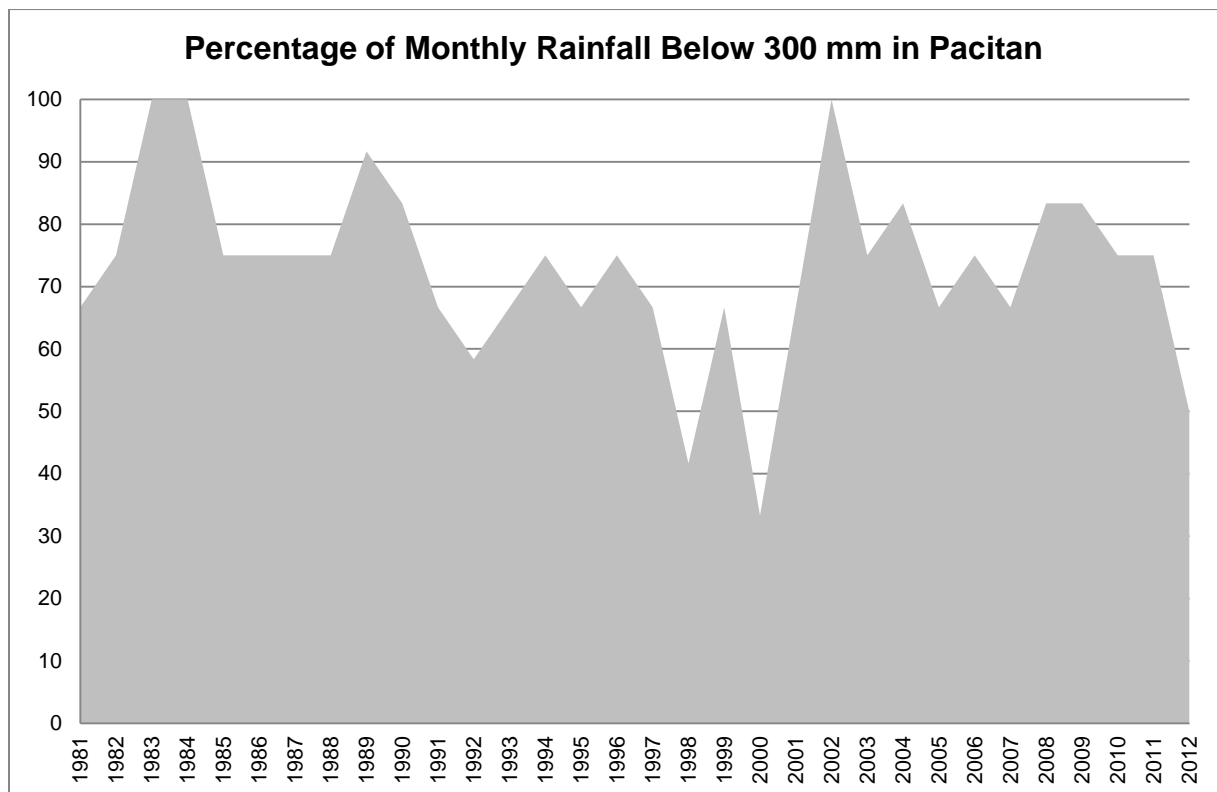
Month	Mean monthly rainfall (mm <sup>3</sup> )
January	318,6
February	341,7
March	279,4
April	178,2
May	120,5
June	61,6
July	41,9
August	51,9
September	79,3
October	202,4
November	313,4
December	318,4

The table shows the distinction between the rainy and dry season in Pacitan, where the highest rainfall from 1981 to 2012 is in December to January with more than 318 mm<sup>3</sup>; meanwhile the lowest rainfall is in July with 41 mm<sup>3</sup>. Based on interview result (2013), the communities in Donorojo mentioned that there have been some periods where there was no rain from April in the past decade. Between 2002 and 2004 they needed to store water in advance for water needs in the dry season.

A region that depends on rainfall, particularly for agriculture purposes or rain fed agriculture like Pacitan makes rainfall as crucial parameter for their planting season and to determine the planting calendar. The 10-day measurement for rainfall is also applied in Pacitan, where generally the planting season is divided into two periods; the dryland paddy and the dryland secondary crops. Rainfall inventory is also necessary to determine the characteristics of rainfall based on climate zones in the area and the determination of the onset of the planting season.

Makmur (2009) highlighted that BMKG determines the criteria for monthly rainfall distribution; where anything below 300 mm of rainfall is considered as low rainfall and vice versa. Figure 35 below shows that the percentage of monthly rainfall below 300 mm in

Pacitan from 1981 to 2012. The lowest percentage occurs in 1998 and 2000 with 42% and 33%, meanwhile the highest percentage occurs in 1983, 1984 and 2002 with each year having a 100% value. This means that in the year 1998 and 2000, the rainy season had more than 300 mm almost every month throughout the year that would be termed as wet periods. In the years 1983, 1984 and 2002, rainfall less than 300 mm occurred in the particular months associated with the rainy season throughout the year, and could be termed as dry periods. These years are associated with extreme climate events like ENSO and will be discussed in the following sub chapter.



**Figure 35. Percentage of monthly rainfall below 300 mm in Pacitan (drawn from BMKG, 2012)**

One of the constraints using climatological data from weather stations is the lack of full data, where missing data is quite common, particularly data with short term measurement, such as daily climate parameters. The research is also using monthly climate parameters to reduce the possibility of total error, whereas tolerable error for rainfall data at the weather station is 2% from the measurement. The weather station in Pacitan has recorded climate parameters manually since the 1950s, however there are many gaps in the data for each of the climate parameters that could not be well archived. Therefore, the consistency of the full data needs to be considered in order to avoid total error.

The dispersion of monthly rainfall in Pacitan, as shown in Figure 36 below, illustrates where rainfall from 1981 to 2012 was concentrated. In parallel with Figure 2, the

periods where rainfall was more than 300 mm are shown dispersed in Figure below, particularly during wet periods that start from October, signed by purple color. Those in February or March are signed by red and green colors in the Figure. In the 31 years of data that are used in this research, there are three years where monthly rainfall in the rainy seasons exceed at 500 mm (1981, 1986, and 1987) or around 9% of the total monthly rainfall data; whereas there are 25 years where monthly rainfall in the dry season was less than 100 mm or around 80% of the total monthly rainfall data. There are months when no rainfall occurs particularly at the beginning of dry season or in the end of rainy season, where it is the time to harvest dryland paddy and plant the secondary crop or *palawija* crop. Based on the interview results (2013), it is quite common to have no rain, particularly between June and August, which is considered the peak of dry season; however there are years where rainfall stops in February and it continues dry until October, when it is the time to plant the dryland paddy so they can harvest it at the end of the next rainy season.

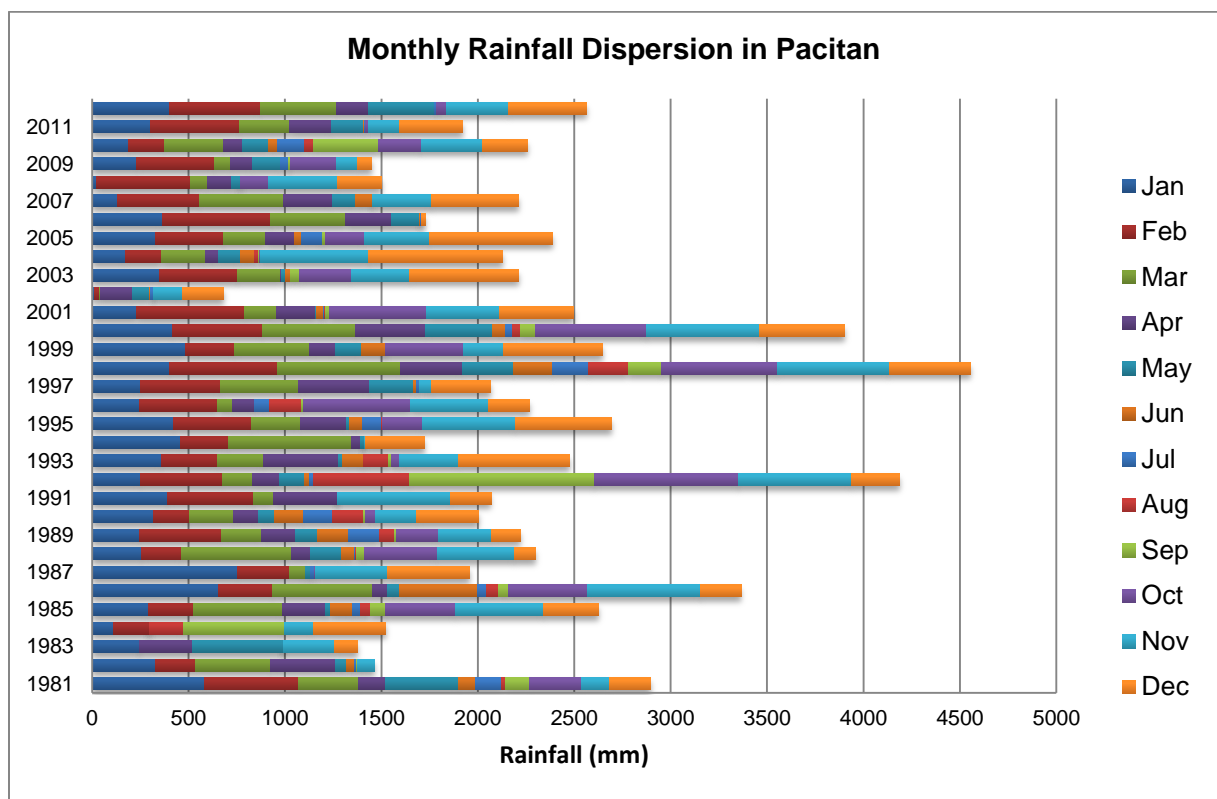


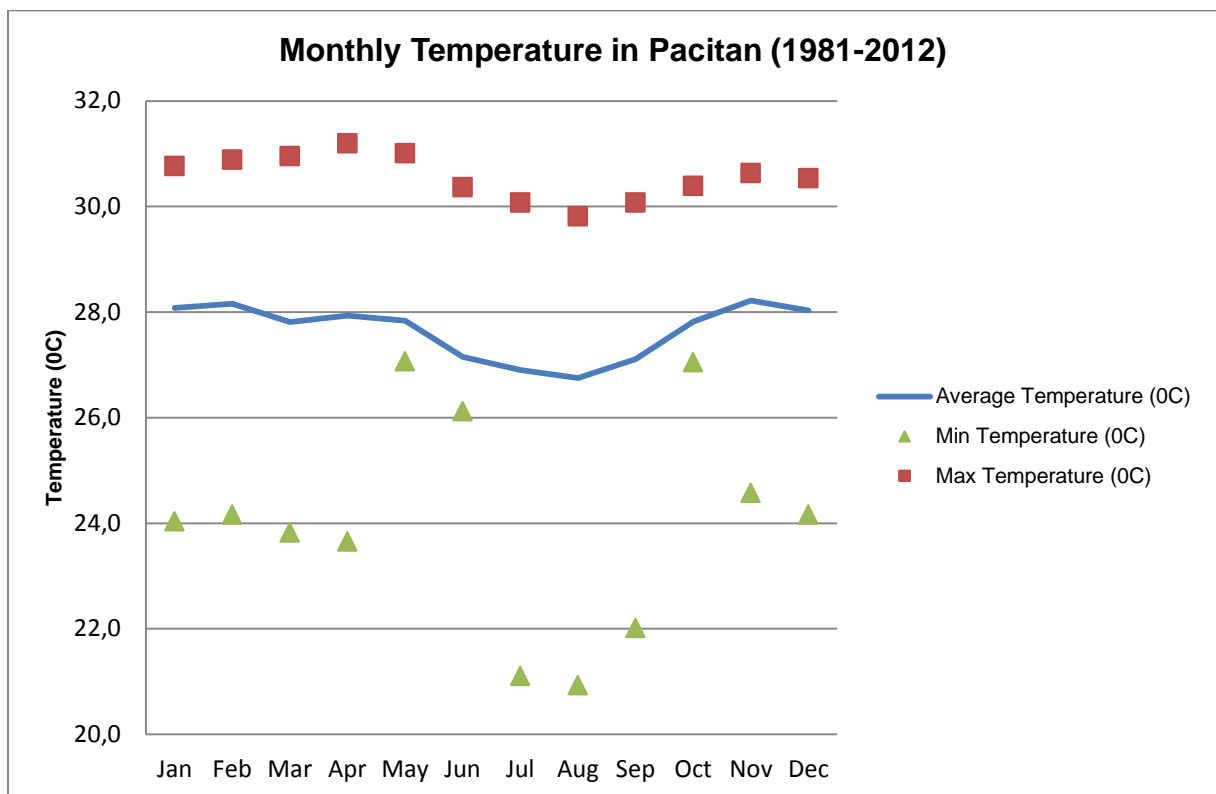
Figure 36. Monthly rainfall dispersion in Pacitan from 1981 to 2012 (drawn from BMKG 2012)

#### 4.1.2. Temperature

Temperature data that is collected in this research comprises monthly average data, maximum and minimum temperature from 1981 to 2012. The value of temperature is acquired from the air temperature near the ground and unlike rainfall; average monthly

temperature is measured by taking the average value of temperature in thirty days. Maximum temperature is needed to see the highest value of temperature occurring throughout the year and vice versa. As Pacitan is strongly influenced by Northwest and Southeast monsoons, the fluctuation of average monthly and annual temperature tends to be constant in comparison with daily (variation between day and night) temperature value that varies throughout the day, where the highest value of daily temperature occurs at 14.00 local time due to the continuity of maximum radiation that occurs and the time lag between maximum radiation and maximum temperature (HANDOKO 1995).

Figure 37 below shows the difference between average, maximum and minimum monthly temperature in Pacitan from 1981 to 2012. The highest value of maximum temperature is 31°C, which generally occurs in March and April throughout the year at the beginning of the dry season. However, during the peak of the dry season in July and August, the average monthly temperature drops to 26°C due to the low rainfall that occurs during these months, where there is low humidity and little water vapor in the air resulting in less cloud cover to produce rainfall.



**Figure 37. Monthly temperature in Pacitan from 1981 to 2012 (drawn from BMKG 2012)**

Furthermore, based on the observation of maximum monthly temperature, there is a tendency of values more than 30°C to occur generally in March and April throughout the year, meanwhile the lowest values less than 20°C, usually occur in August and September respectively. The years where there is the tendency of high maximum monthly temperature can be referred to the periods where the extreme climate events occur,



where delay in the onset of rainy season occurs and where prolonged dry seasons occur. The list of extreme climate events is described in the next sub chapter.

#### **4.1.3. Extreme Climate Events**

The anomalous appearance of sea surface temperature (SST) and precipitation in the Pacific basin has been investigated particularly for the impacts in the equatorial Pacific or the Niño 3,4 region, where the anomaly has caused climate phenomenon that refers to extreme climate events, henceforth termed as ENSO (QUINN et al 1978, HENDON 2002). Furthermore, Rasmusson (1987) added that rainfall and SST are the most influential climate parameters for ENSO. When the temperature in the equatorial Pacific increases, latent heat in the “warm pool” will be released and moves eastward resulting in heavy rain in the eastern equatorial Pacific and a contrary shift of dry air in the western Pacific, including Indonesian archipelago islands, results in less rain from June to November as shown in Figure 38 below. The rhythm of ENSO that is not periodic but oscillatory regulates anomaly events in the particular times where the distinct warm events occur at irregular intervals from two to seven years.

The sign of “O” in the Figure shows the period of initial warming in the ocean’s surface and the sign “+” illustrates the following years of the warming events. Indonesia, particularly Java Island, in the western equatorial Pacific is influenced by these warming events starting June to November where the initial warming shifts from westward Indonesia to the Australian continent, including the eastern Indonesian archipelago carrying dry air in the following year. In addition, Naylor et al (2006) and Haryono (2008) highlighted that Indonesia is also influenced by the Austral – Asia Monsoon that consistently brings dry climatic conditions and droughts during ENSO events.

Map 11 shows the regional pattern of monsoon movement from Sumatera Island eastward through Java Island with the onset of monsoon and termination dates. The Northwest monsoon starts from north Sumatera in September to June and shifts to central and west Sumatera in October and to west/central Java at the end of October as well as east Java/Bali including Pacitan in November; whereas the termination dates in the latter region occurs at the end of April. This event causes Pacitan in the eastern part of Java Island to experience rainy season from November to April which affects the onset of the rainy season and eventually water availability. Thus, when anomalies occur and affect the onset of the rainy season, then water availability in a given area has the possibility of being hampered by having less rain and a prolonged dry season.

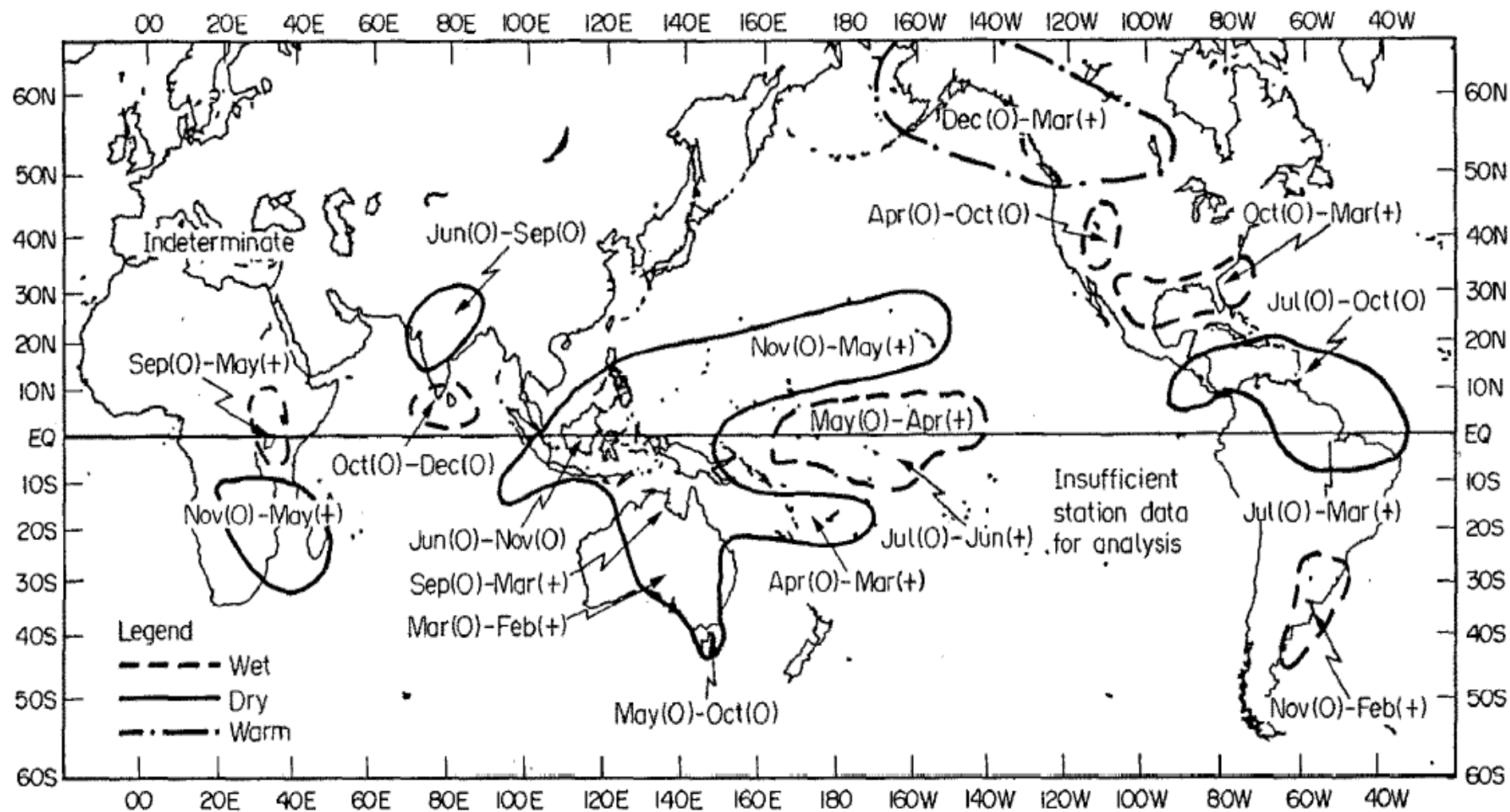
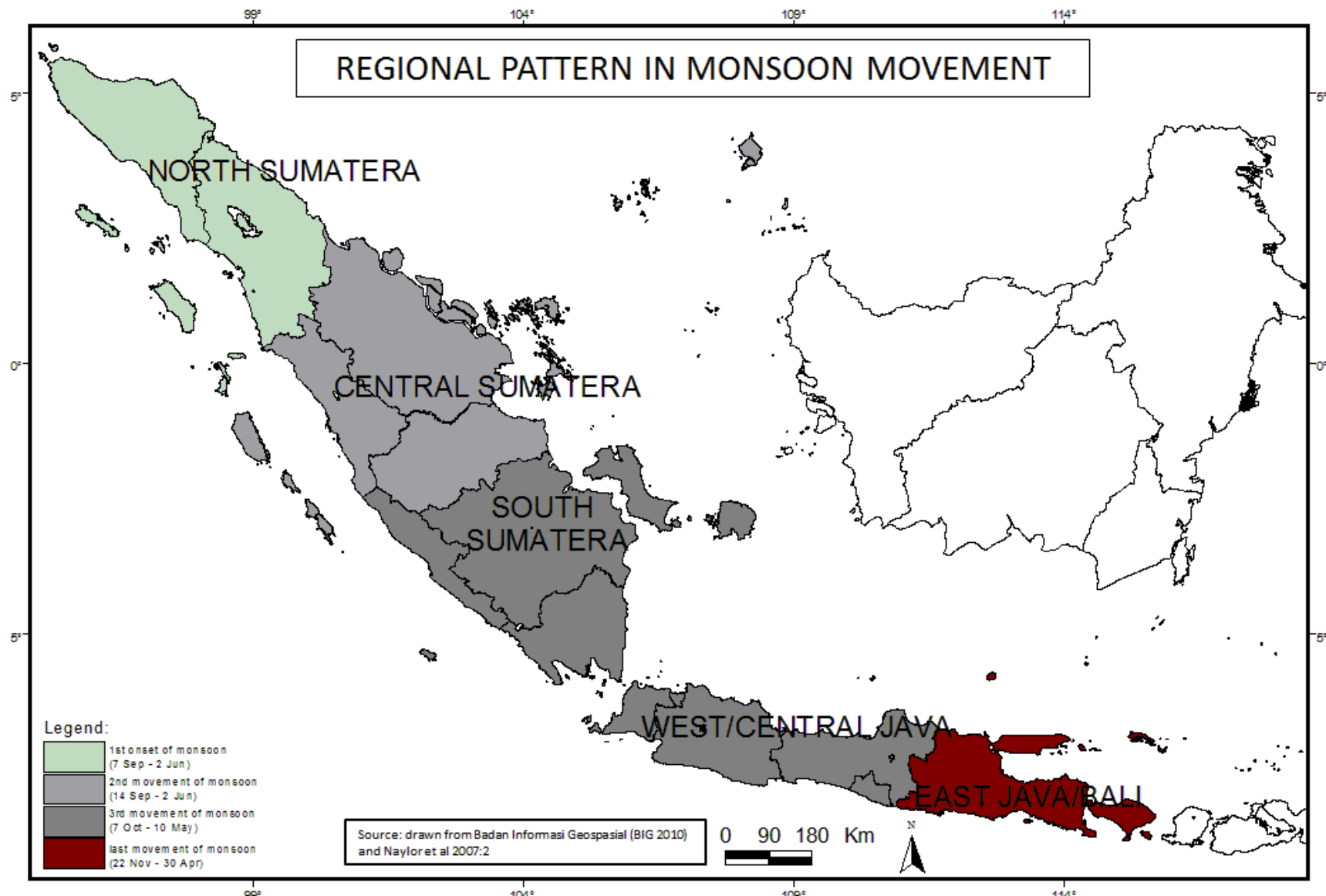


Figure 38. Schematic areas with ENSO phenomenon (Rasmusson 1987: 178)



Map 11. Regional pattern in monsoon movement (drawn from *Badan Informasi Geospasial*/BIG 2012 and Naylor et al 2012:2)

The research combines the data record of historical ENSO and extreme climate events that are experienced by communities through in-depth interview and FGDs. The descriptions from the communities may differ depending on the age of the respondents and the ability to remember whether they have experienced those events or not. The time length of memory for the historical events may also differ. There are some respondents who can only remember the last ten years although their age is more than 40 years old, whereas others are able to remember thirty to forty years back. However, there is a distinct pattern based on events that they have experienced, namely the irregular intervals of extreme climate events that occur, as shown in Table 8 below. Communities memorize significant events by associating those events with important historical events that occur, therefore the communities are able to memorize whether they have experienced extreme climate events or not.

**Table 8. List of historical ENSO events from three references**

<i>NOAA (2014)</i>	<i>Makmur (2009)</i>	<i>In-depth interview and FGD results (2013)</i>
1964/65		1963/64
1968/69		
1982/83	1982	1982
1986/87	1986	1985/86
1991/92	1991	1988
1997/98	1997	1997/98
2002	2002	2002
2009/2010	2006	

The research also uses the Oceanic Niño Index (ONI), a standard calculation by NOAA, to observe the oscillation of ENSO in Niño 3,4 region ( $5^{\circ}$  N –  $5^{\circ}$  S and  $120^{\circ}$  –  $170^{\circ}$  W). NOAA uses ONI to identify El Niño (warm) and La Nina (cool) events in the tropical Pacific<sup>4</sup>. The anomalies are derived from 1950 to the present time and represent the average equatorial SSTs across the Pacific. The period of years shown in the list above is periods where there were five consecutive overlapping 3-month periods at or above  $+0.5^{\circ}$ . These are considered as El Niño or anomalous for warm events. Meanwhile, La Nina occurs when there are five consecutive overlapping 3-month periods at or below  $-0.5^{\circ}$ .

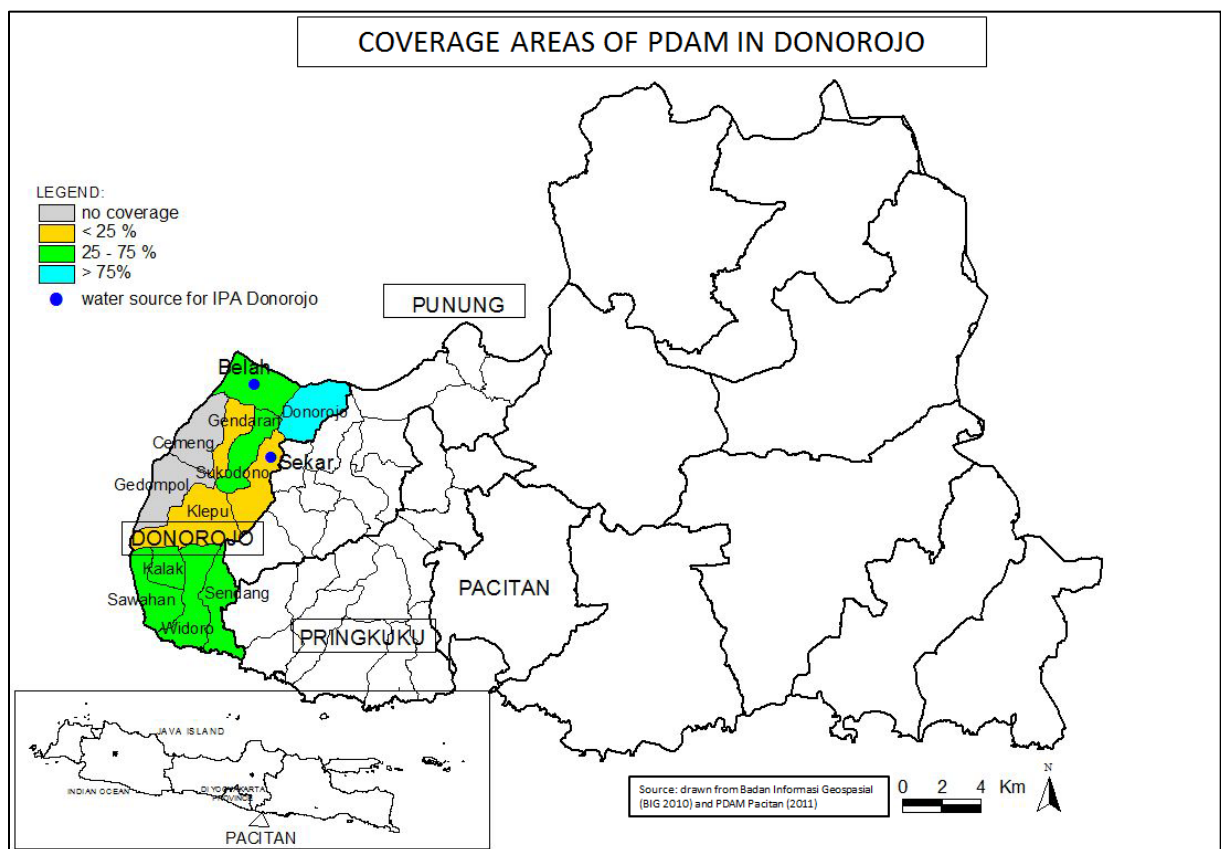
<sup>4</sup> The full list of historical ENSO events is available at [http://www.cpc.ncep.noaa.gov/products/analysis\\_monitoring/ensostuff/ensoyears.shtml](http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml)

## 4.2. Distribution of Piped Water Supply (*Perusahaan Daerah Air Minum/PDAM*)

This sub chapter briefly specifies the distribution of piped water supply (PDAM) in every *Kecamatan* where the data is taken from PDAM Pacitan and based on the interviews with officers of IPA as well as the interview results from the communities in Donorojo, Punung and Pringkuku. The percentage of coverage areas is calculated by dividing the number of population that is covered by PDAM with the total number of the population in the respective areas.

### 4.2.1. Donorojo

Out of three *Kecamatan* in Gunung Sewu karst areas of Pacitan, Donorojo has the most population in comparison with other *Kecamatan*. According to *Badan Pusat Statistik* (2012), the total population of Donorojo is 40,367 and comprises 12 *desa* where the PDAM connections in the bordered regions are connected with Kecamatan Punung. The coverage area of PDAM in Donorojo is around 35% where the capital of *Kecamatan* is the most covered areas. There are still two *desa* that are not yet covered, Desa Gedompol and Desa Cemeng, located in the most western part of *Kecamatan* Donorojo, as shown in Map 12 below.



Map 12. Coverage areas of PDAM in Donorojo (drawn from *Badan Informasi Geospasial/BIG* 2010 and PDAM Pacitan 2011)

A perennial spring in Desa Sekar is used as the source for IPA Donorojo. The spring has water discharge 40 L/sec in the rainy season; however, Desa Sekar has less than 25% coverage because instead of paying to PDAM, the communities prefer to take water directly from the water sources, as they have other several sources, either by installing long pipes from water sources to their houses or by fetching water using buckets (interview results 2013). Areas that are covered by PDAM in Donorojo are mostly located in the south and northern part of Donorojo, where four *Desa* in the south mostly use water from seasonal springs with water discharge from 2-20 L/sec during the rainy season. Furthermore, PDAM and the Ministry of Public Work have built well or P2AT (*Proyek Pengembangan Air Tanah*) by drilling for ground water to fulfil water needs in the northern part of Donorojo.

The scheme of water distribution in Donorojo is illustrated in Figure 39 below, where the water is taken from perennial springs in Desa Sekar, pumped into IPA Donorojo and distributed to most areas in the centre and northern part by using pumps and gravity; whereas areas in the southern part are covered by using water sources in Punung like Sumber Maron. In addition, drilled well in Desa Belah is used to cover the northern part of Donorojo, including the capital sub district. Due to its mountainous location, Desa Cemeng and Desa Gedompol are not yet covered by PDAM. However, based on the interview results (2013), the main pipes are already installed in those two areas as PDAM is planning to encompass the whole area in the coming years.

#### **4.2.2. Punung**

Located in the north of Pacitan, *Kecamatan* Punung has two water sources that are used by PDAM, Maron and a drilled well in Desa Kendal. Maron with a 20L/s water discharge during the rainy season is located in the border area between Desa Bomo in *Kecamatan* Punung and Desa Sugihwaras in *Kecamatan* Pringkuku and considered the main water source in Punung. It is also fulfil the water needs in the southern part of Donorojo. The coverage areas of PDAM varies from 25 to 75% and is concentrated in southern part of Punung, whereas in the north, the connection is not yet installed as shown in Map 13 below. The biggest coverage in Punung is located in Desa Punung and Desa Kendal in centre of Punung with more than 70% coverage. Meanwhile the least coverage areas are located in Desa Sooko and Desa Mantren with around 30% coverage. However, due to its mountainous location, the whole coverage of PDAM in Punung is less than 30% where other communities still depend on other water sources than PDAM.

As illustrated in Figure 39 below, the scheme of water distribution in Punung shows that water is taken from Maron by using pumps to fill a ground reservoir to cover

the southern part of Pringkuku, including Desa Sugihwara, Desa Dersono and Desa Jlubang. Another ground reservoir is also used to cover Desa Bomo in Punung and areas in the southern part of Donorojo, including Desa Kalak, Desa Sendang, Desa Sawahan and Desa Widoro. Another water source in Punung is a drilled well that is located in Desa Kendal with 7.5 L/s water discharge during the rainy season. By using a pump, the water intake is taken from the drilled well to cover most areas in the centre of Punung, except areas in the north. Its mountainous location is also an obstacle for PDAM to connect pipes to these areas in the north part of Punung. Nevertheless, seasonal spring and dug wells are the options that they use to fulfil their water needs as no *telaga* is found in these areas. Based on the interview results (2013), the seasonal spring and dug wells are around 500 meters walking distance, where the communities in the north need to fetch water by using available tools.



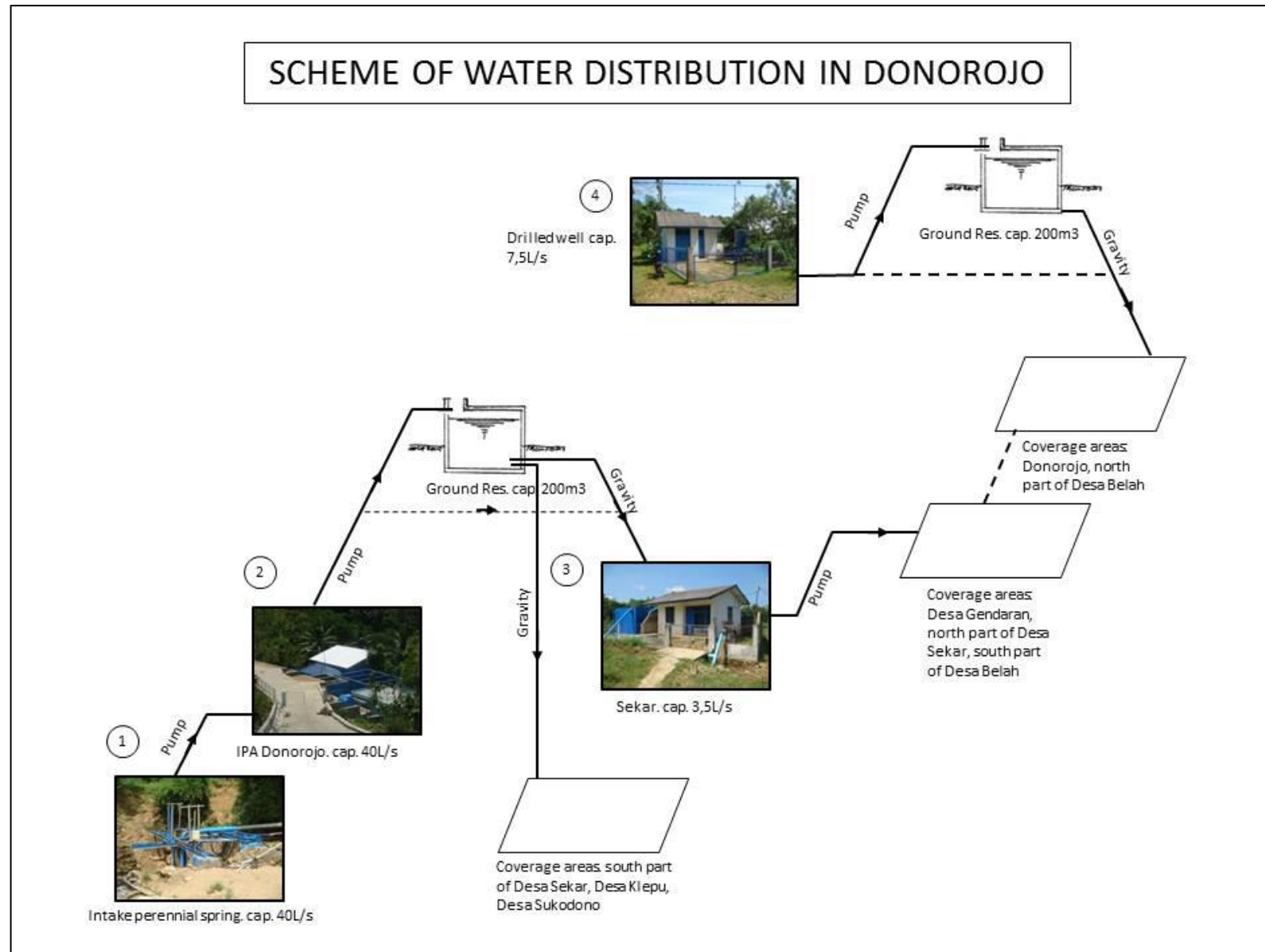
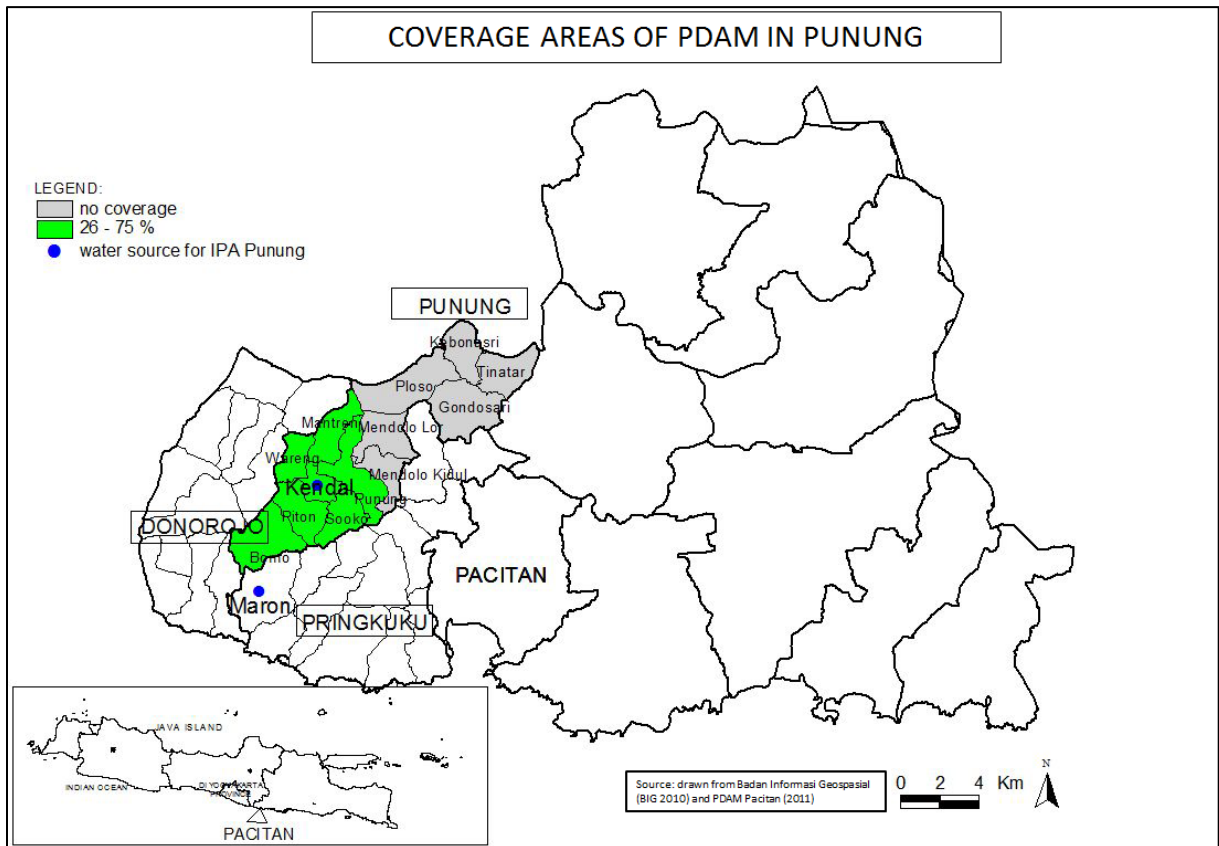


Figure 39. Scheme of water distribution in Donorojo including the coverage areas (drawn from PDAM 2011)





**Map 13. Coverage areas of PDAM in Punung (drawn from *Badan Informasi Geospasial*/BIG 2010 and PDAM Pacitan 2011)**

#### 4.2.3. Pringkuku

There are two water sources that are used by IPA Pringkuku, namely IPA Barong in Desa Candi, and IPA Sugihwaras in Desa Sugihwaras. Based on the interview with the officer of IPA Barong (2013), the primary water source of IPA Pringkuku is the perennial spring named *Barong* in Desa Candi that is located in the southern part of Pringkuku. IPA Barong covers most areas in the centre of Pringkuku, including some parts of the capital district Pacitan where water discharge the in rainy season is 20 L/second and 10 L/second in the dry season. Meanwhile IPA in Sugihwaras, with water discharge varying from 15 L/second in the rainy season and 10 L/second in the dry season, covers the southern part of Pringkuku and Punung.

Coverage areas of PDAM are not based on administrative regions or *Kecamatan* but rather are based on the location of *desa* or *dusun*<sup>5</sup> in relation to IPA. This explains why southern parts of Punung are connected with IPA Pringkuku while the northern part has not yet been connected due to its location closer to the nearest IPA in Desa Sugihwaras Pringkuku. Although the authority will make the community in their own *Kecamatan* the

<sup>5</sup> *Dusun* in Indonesian language refers to a form of municipal hierarchy where administratively works as sub-village and the head of *dusun* is called *kepala dusun*.

priority and then transport the remaining water to the neighbouring *desa* or *dusun* (interview with head of *Kecamatan* Pringkuku 2013). The highest coverage in IPA Pringkuku as shown in Figure 40 below is Desa Dadapan with more than 90% coverage; whereas most parts in the south are around 25 to 75%, where the southwest has the least coverage. In comparison with other *Kecamatan*, Pringkuku has more water sources from perennial and seasonal springs. This explains why the total coverage of PDAM in Pringkuku is only 32%, because other areas depend mostly on other perennial and seasonal springs during the rainy season.

Below are the figures of IPA Barong where the water is treated for domestic and industry use by using calcium hypochlorite and tawas (aluminium potassium sulphate) to clear and to remove germs from the water. The water treatment is conducted in an open storage area and then transported through pipes to the users (officer of IPA Barong 2013). Based on the interview with the PDAM users (2013), the calcium hypochlorite and *tawas* produce a distinct scent in the water and due to the limestone concentration, the water needs to be boiled two or three times before it can be used. A deposition of limestone forms on the base of pots and other kitchen utensils that are used to boil the water. According to interview results and FGD (2013), the communities still use the water from PDAM despite the distinct taste due to the limestone content, chlorine and alum that are infused in the treatment process which dominates the taste in the water.

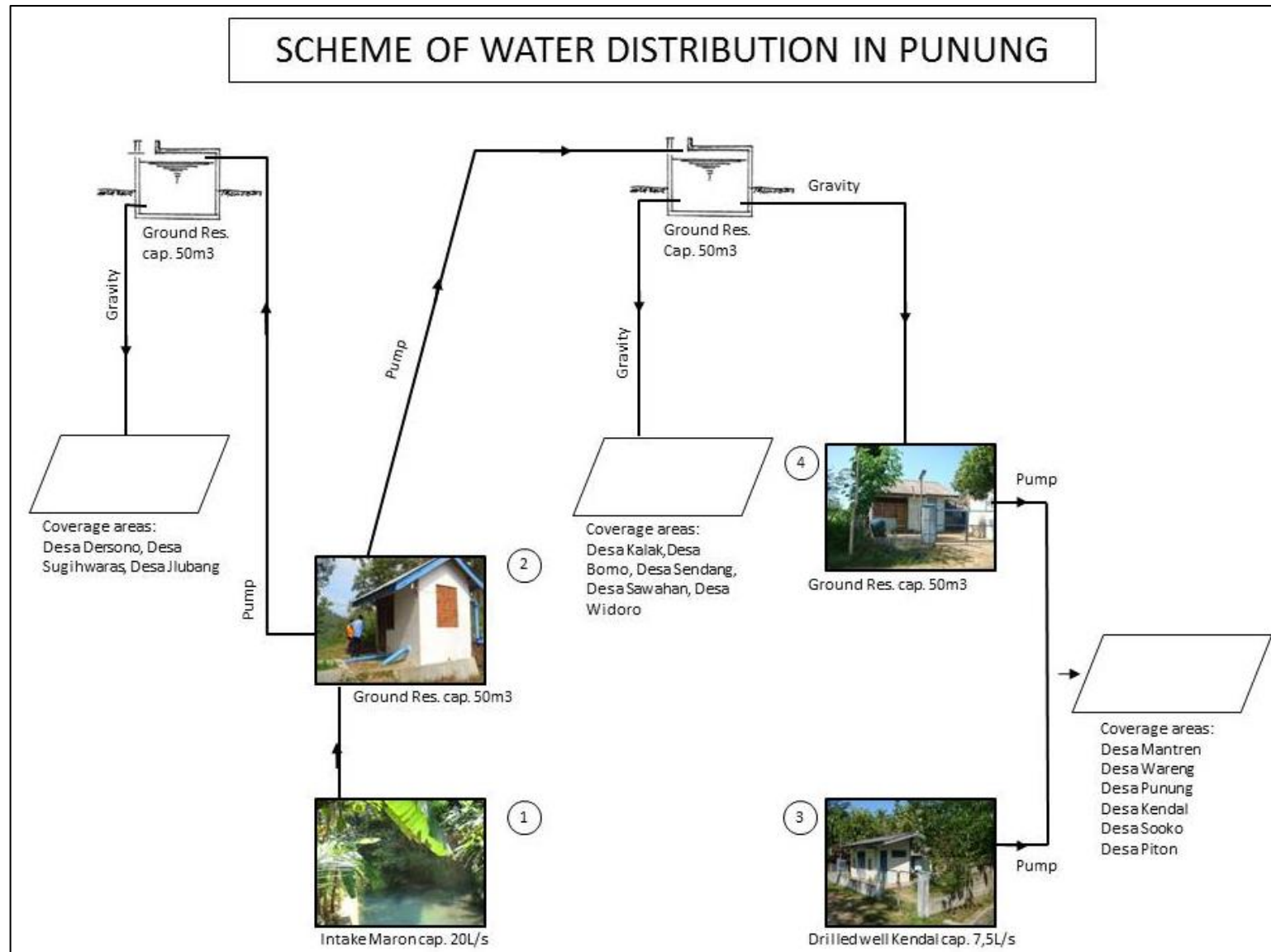
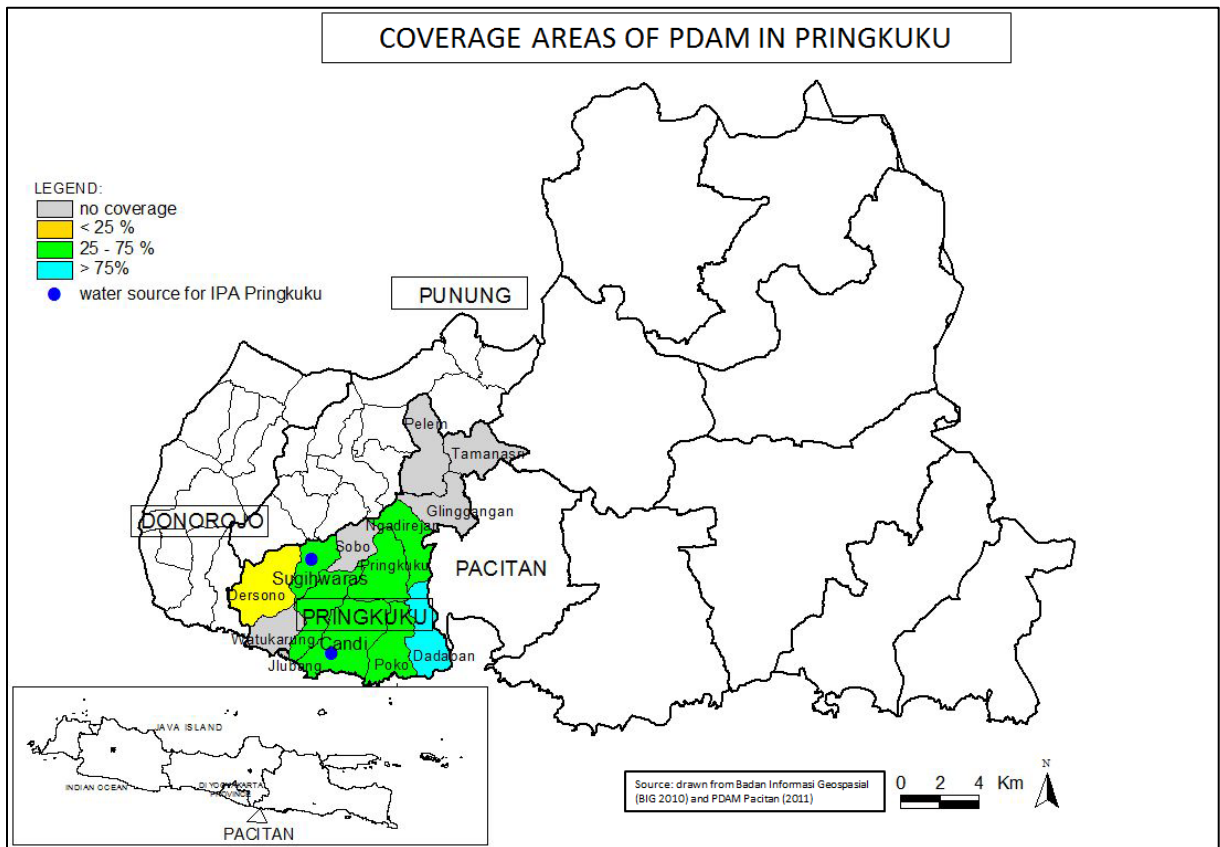


Figure 40. Scheme of water distribution in Punung (drawn from PDAM Pacitan 2011)



**Map 14. Coverage areas of PDAM in Pringkuku (drawn from *Badan Informasi Geospasial/BIG 2010 and PDAM Pacitan 2011*)**

The scheme of IPA Pringkuku, as illustrated in Figure 43 below, shows how water is being circulated from the intake at *Barong* with water discharge of 20L/s, pumped to IPA and processed in the panel pump. Next the water is delivered to several ground reservoirs before it enters the distribution system in the areas of Pringkuku, including other villages (*desa*) and sub-village (*dusun*) in the area of Pringkuku, as well as to capital district. There are six *desa* in centre of Pringkuku that are covered, whereas one *desa* in capital district (Desa Sedeng) is covered by one ground reservoir.



**Figure 41. IPA in Kec. Pringkuku  
(own figure 2013)**



**Figure 42. Water installation inside IPA  
Kec.Pringkuku (own figure 2013)**

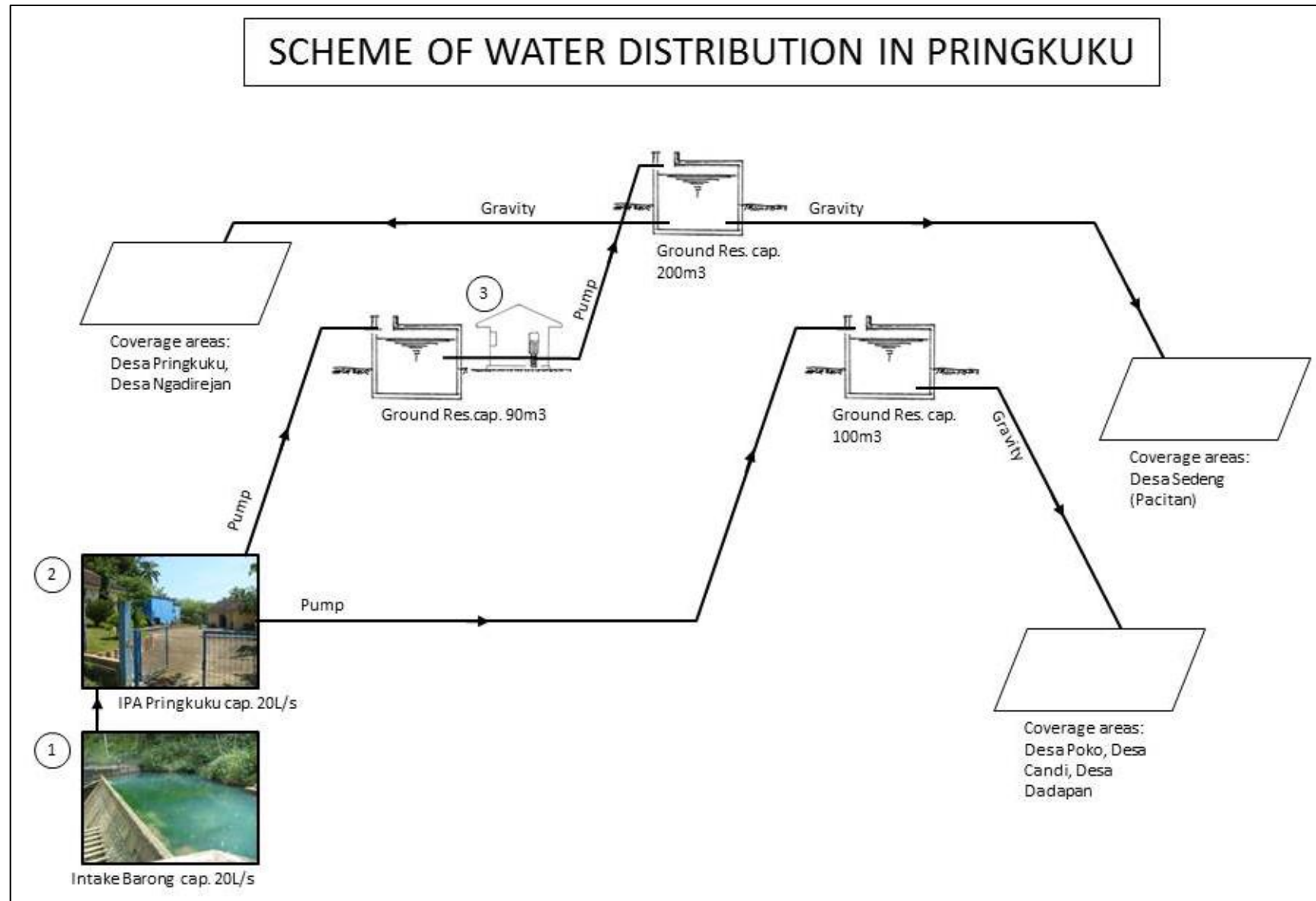


Figure 43. Scheme of water distribution in Pringkuku (drawn from PDAM Pacitan 2011)

### 4.3. Water Scarcity in Relation with Water Use

Basically, water scarcity occurs when water supplies cannot fulfil water demand in the given area. As highlighted by FAO (2008), the growth rate of the population and the pattern of consumption are the factors that affect water demand, including the associated goods and services that include water in the process. Falkenmark (1989) mentioned that water scarcity occurs when a society in a given place has between 500 to 1000m<sup>3</sup> or between 500,000 to 1 million liters<sup>6</sup> of water per person per capita. Anything below 500 m<sup>3</sup> is considered as absolute scarcity, where the cause may come from varying natural and anthropogenic activities that require specific responses. The Falkenmark indicator has been used widely to measure water scarcity as a function of available water resources and its relation with human population. Rijsberman (2006) added that the Falkenmark indicator is used to know and measure the amount of water that is needed to meet human demands and illustrates this mostly at a national scale.

Correspondingly, Ohlsson (1999) pointed out standard water use at the local scale per person per day for drinking water is two to five litres. Household use in general is around 25 to 100 litres. These two categories of water use are considered important at the local level to distinguish between the needs and demand for water. Whereas, Gleick (1996) and the World Health Organization (2005) highlighted the amount of water use in a society include all of the activities, where some of the activities use more water than others. Therefore, the WHO sets up standard quantities based on how much a person needs, particularly for household uses as shown in Figure 44 below. For short-term survival, drinking and cooking purposes, the amount of water is 30 litres. For medium-term use, washing clothes, sanitation and other domestic uses the water requirement is around 70 litres. Livestock, the business sector and gardens and recreation are considered part of long-term water use, as the amount of water required is more than 70 litres.

Meanwhile, the total of population, culture/lifestyle and the climate of the given area are the factors affecting basic water requirements from the Ministry of Public Area (IQBAL 2012). Furthermore, the amount of water use can be determined by taking the population numbers into consideration, as shown in Table 9 below. According to *Badan Pusat Statistik* (2012) Donorojo, Punung, and Pringkuku each have around 50.000 inhabitants which make the amount of water use per capita in the respective areas around 90 litres. Table 9 also shows that the minimum water requirement in the least populated regions is 60 litres per person per day, which means this volume of water, must be provided in the local level in order to meet the basic needs of water use.

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<sup>6</sup> 1 m<sup>3</sup> is equal to 1000L



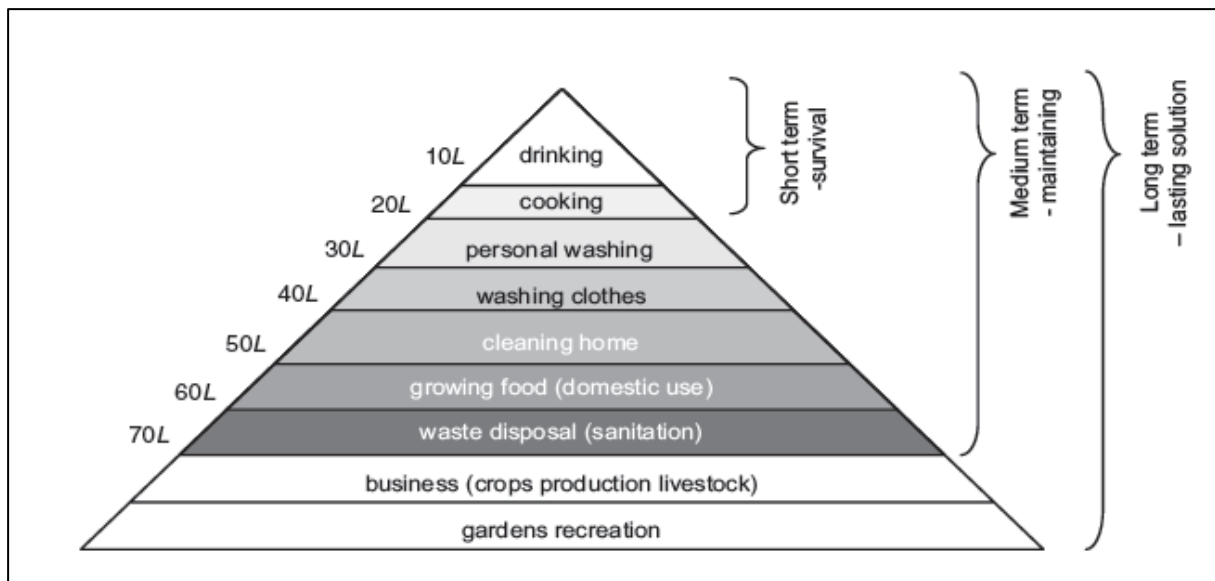


Figure 44. Hierarchy of water requirements (WHO 2005: 2)

Table 9. Amount of water use based on the number of population (IQBAL 2012 and *PERATURAN KEMENTERIAN PEKERJAAN UMUM 2012*)

Population	Amount of water use (litres per capita per day)
Desa (< 20.000)	60 – 80
Small City (20.000 – 50.000)	90
Medium City (50.000 – 100.000)	110
Big City (100.000 – 1 million)	130
Metropolitan City (> 1 million)	150

Based on the regulation of the Ministry of Home Affairs (*PERATURAN MENTERI DALAM NEGERI 2006*), basic water requirements for a household is 10 m<sup>3</sup> per month or around 60 litres per capita per day, with the assumption there are five members in one household at a local scale. However, Iqbal (2012) highlighted the minimum water requirements are around 80 litres per capita per day, which breaks down into 10-15 litres for drinking and cooking purposes, 20-40 litres for personal washing, 15-20 litres for washing clothes and 30 litres for sanitation. Therefore, based on this regulation, PDAM generates basic water requirements for its customers to have per 10 m<sup>3</sup> for one household per month and calculate every one m<sup>3</sup> after the initial 10 m<sup>3</sup> of water use (PDAM 2011).

According to interview results (2013), the initial 10 m<sup>3</sup> of water use is not always sufficient to fulfil water needs in one household, particularly for those with other subsistence activities beside livestock and agriculture, such as grocery shops, room renting and tourism. Hence, the communities with these additional activities use more water and pay more costs for every one m<sup>3</sup> after 10 m<sup>3</sup> of water use. Communities not yet



connected with PDAM, are quite careful when it comes to water use particularly during dry season, as they need to fetch water and/or buy water tank from private groups. The communities are used to living with limited water availability where they consider water as a significant resource. There are even some communities with communal allocation of their livestock as an investment to purchase water from private groups during the dry season and other important needs like paying school tuition for their children. Below is a quote from one of the communities in *Kecamatan Donorojo*<sup>7</sup>.

“We intentionally grow cow with other people to buy water tank, of course with other livestock, you know, just in case we do not have money during dry season, but we do it together with other households, so you see, having livestock for us is important.”

Based on the type of water source, the communities differentiate their water use, as shown in Table 10 below, due to their needs as well as the water quality from PDAM that has a distinct taste and scent from water treatment. Those who are not yet connected with PDAM also differentiate their water use based on water sources, where water from springs and PAH are not use for cooking and drinking purposes but rather for personal washing and watering plants. Meanwhile, there are only a few people who still use *telaga* for personal washing; however the existence of *telaga* is still significant for several communities who use it in the fisheries sector. In terms of drinking, there are some communities who prefer to buy water from the drinking water company and use around 30 litres per household per day only for drinking and not for other purposes.

**Table 10. Water use based on water source (Interview, FGD and observation results 2013)**

<i>Water Source</i>	<i>Water use</i>
PDAM and water tank	Drinking, cooking, personal washing, washing clothes, watering plants
Spring and dug/drilled well	Personal washing, washing clothes and watering plants
PAH	Washing clothes and watering plants
Telaga	Personal washing, watering plant, fisheries

Although there is not much difference in water use between the dry and rainy seasons, there is a tendency for the communities to use more water in the dry season (interview results 2013). Several PDAM customers mentioned that they spend more on water in the dry season, because generally they do not experience any water issues during the rainy season. Meanwhile those who are not PDAM customers do see the

<sup>7</sup> The interview was conducted in Desa Belah, Kecamatan Donorojo on 15<sup>th</sup> May 2013

difference in water use between the dry and rainy seasons, where they experience a lack of water only in the dry season.

## 5. ADAPTATION STRATEGIES OF WATER SCARCITY

### 5.1. Basic Concept of Adaptive Capacity to Climate Change and Water Scarcity

Before the concept of adaptation strategies to water scarcity will be described, it is necessary to describe how the basic concept of adaptive capacity includes mitigation response, vulnerability and resilience in terms of climate change.

#### 5.1.1. Adaptation to and Mitigation of Climate Change

The concept of adaptation and mitigation as a response to environmental change has been developed in the communities and regions to adjust their activities in the context of climate change, where mitigation refers to actions that abate impacts or exposure to climate variability through regulation, location and technological shifts. Meanwhile, adaptation refers to the adjustments in response to actual or potential impacts that are caused by the change of climate variability; hence, there has been a correlation in documented effort to reduce risk through adaptation processes in response to the increased awareness of change (NELSON et al 2007). Engle (2011) also mentioned there is an understanding that develops toward sustainability implications regarding how the ecosystems and societies adapt to climatic change while the issues of mitigation or the acts to prevent the impacts of climatic change have been extensively discussed. Füssel (2007) argued both mitigation and adaptation are not alternatives but rather as complementary responses due to their time-scales characteristics and the actors as one of the components. The characteristic of both responses are described in Table 11 below where it is shown mitigation has been accepted first and received more attention than adaptation in scientific investigation and from a policy perspective. The focus on mitigation is more concerned on the ability to reduce the impacts of all climate-sensitive systems whereas adaptation is limited to particular systems.

**Table 11. Characteristics of mitigation and adaptation (Füssel 2007: 266)**

	<i>Mitigation of climate change</i>	<i>Adaptation to climate change</i>
Target system	All system	Selected system
Scale of effect	Global	Local to regional
Lifetime	Centuries	Years to centuries
Lead time	Decades	Immediate to decades
Effectiveness	Certain	Generally less certain
Ancillary benefits	Sometimes	Often
Polluter pays	Typically	Not necessarily

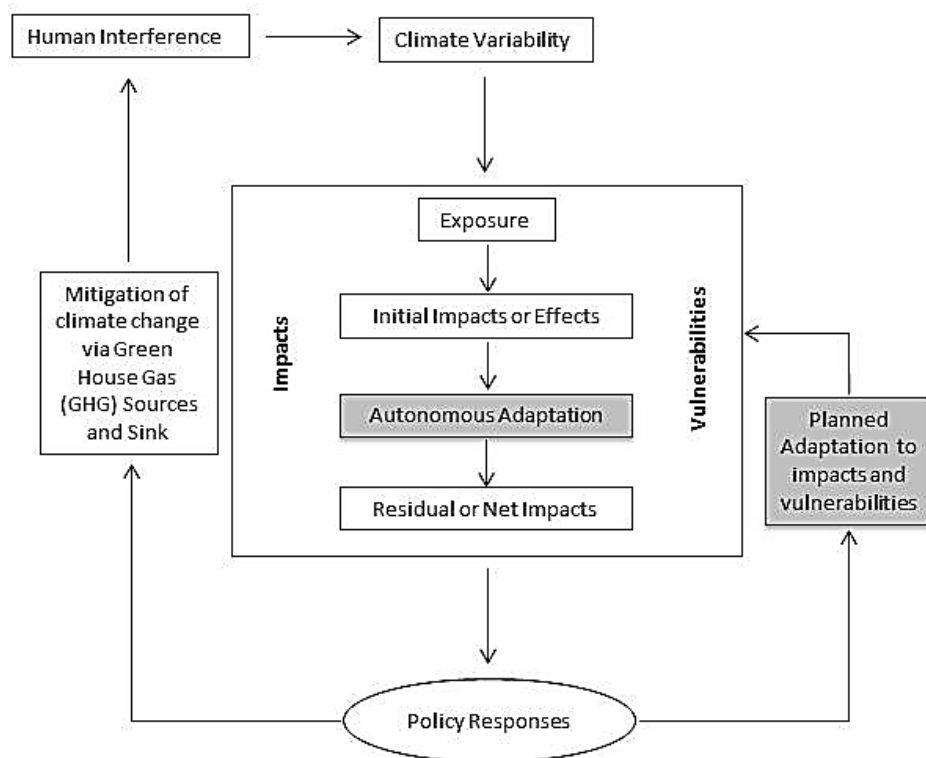
Actor benefits	Only a little	Almost fully
Monitoring	Relatively easy	More difficult

The descriptions of adaptive capacity related to the climate challenge in general have been formulated in many researchers (FANKHAUSER 1998; SMIT, BURTON, KLEIN, and STREET 1999; GROTHMANN and PATT 2005; SMIT and WANDEL 2006; GALLOPIN 2007; ENGLE 2011), where adaptive capacity can be described as a concrete expression of adaptation. Based on policy responses, adaptation and adaptive capacity are associated with *planned adaptation*, whereas *autonomous adaptation* is related to the distribution and quality of the habitats and the level of additional anthropogenic pressure (e.g. pollution) that are largely determined by the forms and intensity of human and land use (CARTER, JONES, LU, BHADWAL, CONDE, MEARNS, O'NEILL, ROUNSWELL, and ZUREK. 2007). Therefore autonomous adaptation performs as a response mechanism from land management and natural resources allocation towards keystone ecosystem services, such as climate and runoff regulation and the maintenance of genetic resources. As seen in Figure 45 below, the term of adaptation refers to changes in processes, practices or structures to moderate potential damage or impacts that are associated with the change of climate and involves the vulnerability of community, regions or activities to climatic change and variability; therefore it is important to understand the autonomous ecological adaptation in developing comprehensive socio-economic adaptation strategies (SMIT, BURTON, KLEIN and STREET 1999).

Smit and Pilifosova (2001) in an IPCC Report formulated that both autonomous and planned adaptation encompasses actions from coping to deeper change of systems, where these types of adaptation are differentiated based on how the adaptation occurs. Autonomous adaptation derives from an action that takes place separately from planning or outside involvement, without the directed intervention of public institutions or the initiation of private sector factors usually triggered by market or welfare changes rather than action induced by actual or anticipated climate change; meanwhile planned adaptation can be both reactive or part of vulnerability assessment where the actions are taken before impacts are visible, occur at any organizational level, as well as policy decisions that are deliberately formulated on the part of a public agency based on an awareness that conditions are about to change or have changed to minimize the losses.

Furthermore, Gallopin (2007) added that adaptation also includes changing the sensitivity of the system to perturbation, reducing the exposure of the system to perturbation and increasing the resilience of the system; thus the cycle of adaptation can be referred to as the resilience of a community or a region in a given location. In addition,

Nelson, Adger and Brown (2007) pointed out that due to external undesirable change, adaptation is often imposed on localities where the efforts to respond to adaptation involves changes that reduce vulnerability and enhance the capacity to adapt, in this sense, to enhance the resilience of the communities and their way of life. Adaptation responses utilize demographic changes, technological shifts and land use changes away from those that are creating risks. Nonetheless, adaptation to the environment does not take place in isolation. It is inevitably the result of actions from multiple actors and usually in response to multiple stresses and stimuli.

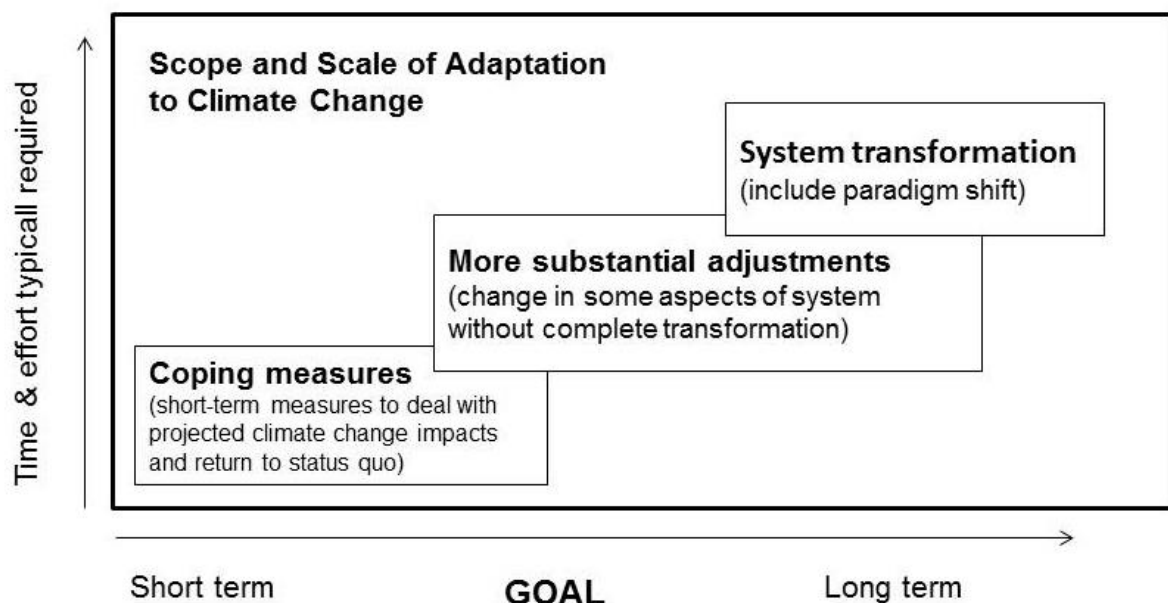


**Figure 45. Adaptation in IPCC Assessment (Smit et al 1999: 4)**

In terms of climate change, adaptation as an element of impact assessment and policy response is not limited to changes in long-term of climate variables, where the variability of climate changes from time to time; thus the change in mean climate variability is experienced through changes in nature that include extreme conditions (e.g. ENSO) and therefore the adaptation to this change is made (SMIT, BURTON, KLEIN, and WANDEL 2000). Smit *et al* (2000) also grouped actions into three general temporal categories, namely, actions that deal with long term trends, variability from the norm over relatively short trends, and actions that deal with extreme events. However, the common assumptions of adaptation by the IPCC are criticized by Pielke, Grins, Rayner, and Sarewitz (2007), because marginal adaptation is considered as a local issue, whereas mitigation is a global issue that requires global coordination. Pielke *et al* (2007) pointed

out that while the ongoing greenhouse gas emission reduction is progressing, the mitigation actions have developed in a vastly diffuse way at the local scale, particularly in developing countries. Hence it is essential to have understanding at a national or global scale for policy makers in terms of distinctions to limit the mitigation actions for reducing vulnerabilities and emphasize more the adaptation policies for natural resources like water resources that empower societal resilience to future climate impacts regardless of the cause of the climate challenge.

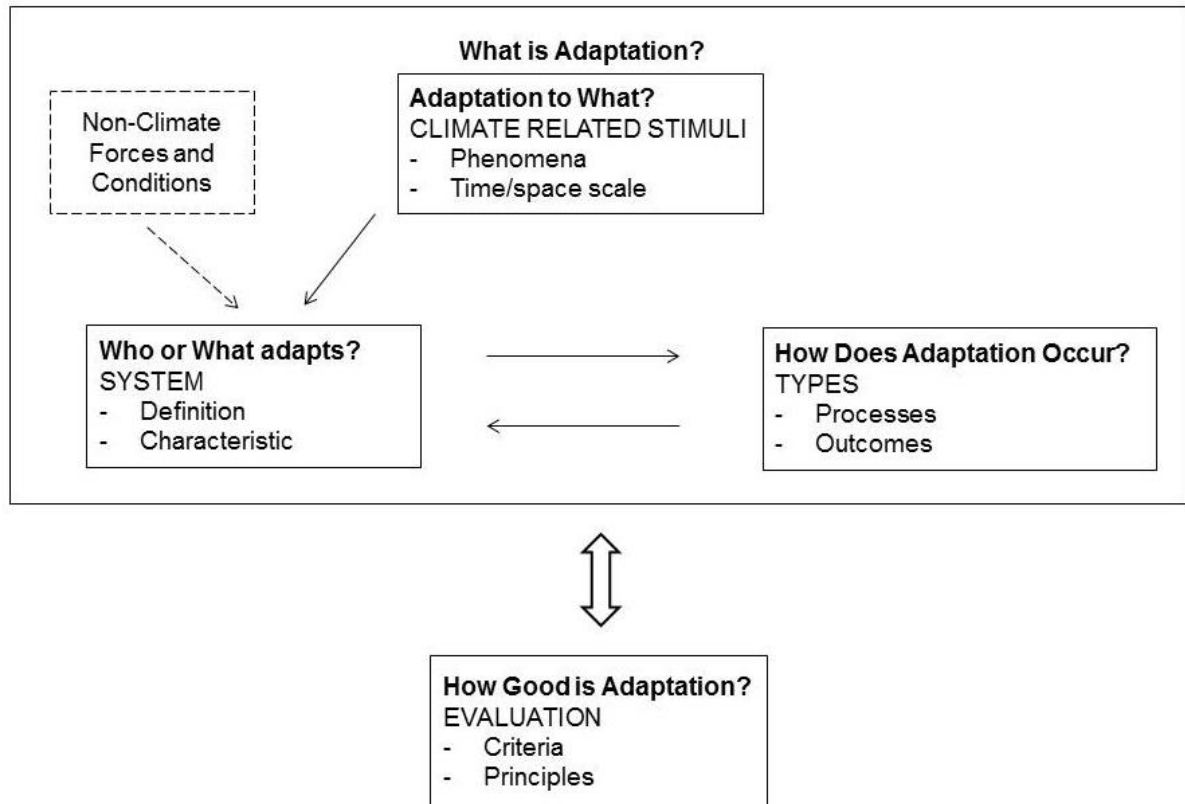
Adaptation actions that need to be taken into account should consider the changes in social-ecological systems in response to the actual and expected impacts of the climate variabilities in the context of interrelating to the change of non-climatic factors. In terms of scope and scale of strategies, adaptation actions can range from short term to long term coping, where the coping measures cover deeper transformation and diffuse into more substantial adjustment and system transformation including the shift of paradigm in order to meet the goals of climate change as shown in Figure 46 below (MOSER and EKSTROM 2010).



**Figure 46. Scope and scale of adaptation to climate change (Moser and Ekstrom 2010: 2)**

Smit *et al* (1999) and Füssel (2007) emphasized, due to delimitation of activities, the diversity of human adaptation covers what, when and how to adapt to the change of climate variability, because adaptation can be a response not only to adverse effects or vulnerabilities, but also a response to opportunities, as well as to current and potential conditions. Thus, the analysis needs to be specific to the stimuli to which adaptive response refers, or "adapt to what?". The adaptation response also needs to be specified in terms of which ecological system it refers to, as the system can be individual, societies or any systems that can be differentiated based on its characteristic or "who or

what adapts?”. Other diversity of human adaptation can be “how to adapt”, referring to the adaptation process and the outcome of the process, where the definition involves change to new condition as it shown in Figure 47 below.



**Figure 47. Adaptation to climate change (Smit *et al* 1999: 204)**

In terms of coping range or how adaptation occurs, Füssel (2007) hypothesized time planned adaptation and took precipitation as an example. Figure 48 below illustrates T as the time series and E as an exceedance of “coping range” or vulnerability in a given region. In the area that covers  $T_1$ , the change of climate variability is still in the coping range, where the minor damage caused by slight exceedance are still accepted by the community. The  $T_2$  area shows where the climate event considerably increases up to  $E_2$  and causes substantial damage. It is assumed that the community will bear costs during such an event although it is still within the coping range area and even extends until  $T_3$ , because the community is willing to accept the damage. However, when the “unusual” climatic event increases up to  $E_3$ , where it is already outside the coping range area and causes more substantial damage than the previous one, the community has to deal with the foreseen risk and consider further costly adaptation. This is where accurate information regarding future climate change is considered essential to minimize the costs of adaptation responses.

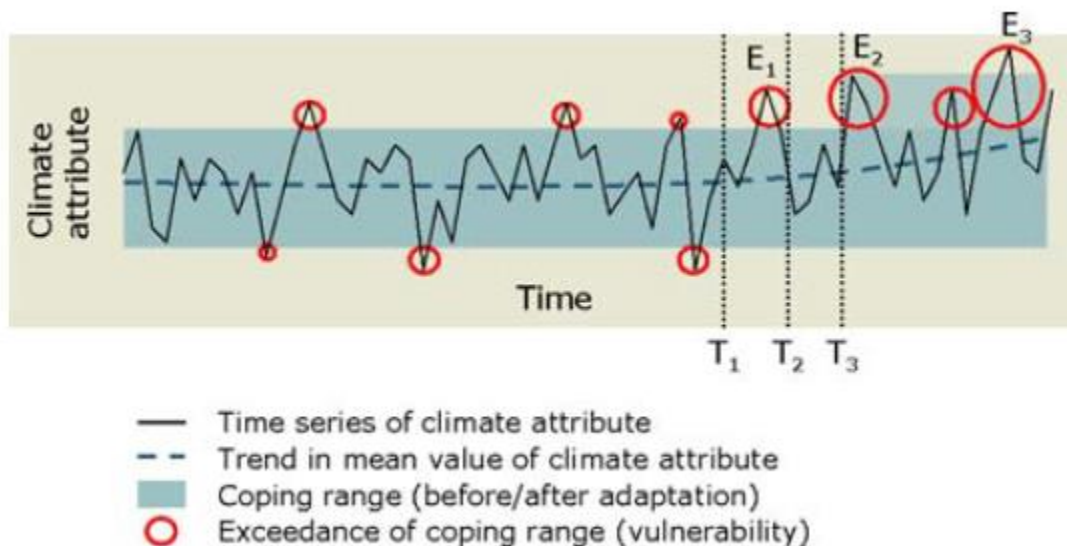


Figure 48. Hypothetical example of time planned adaptation (Füssel 2007: 267)

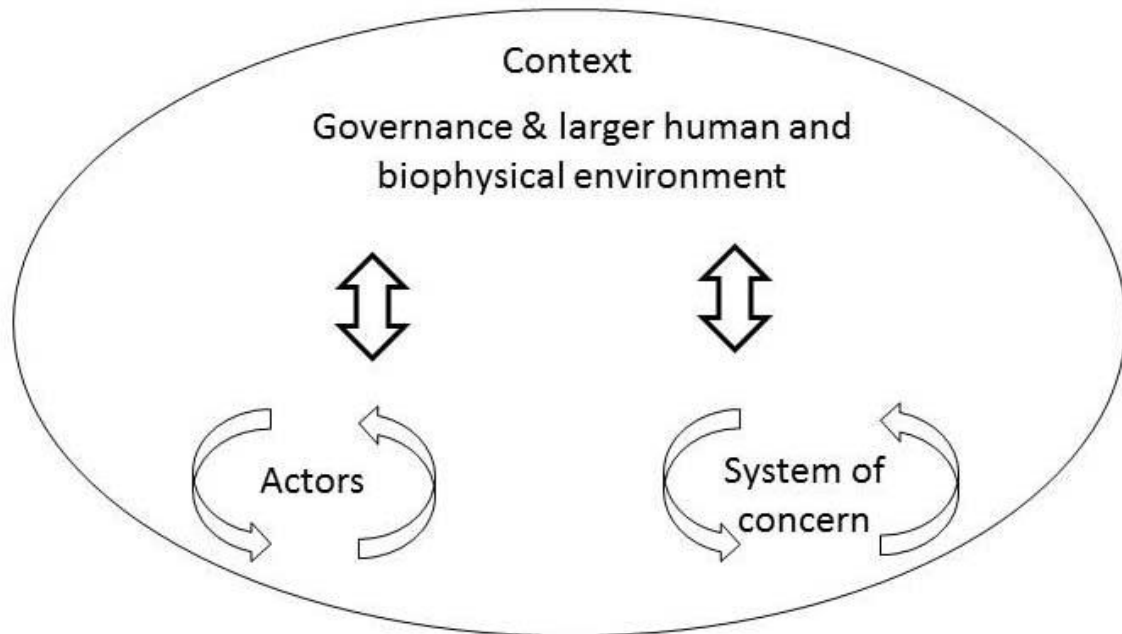
### 5.1.3. Components of Adaptation

In order to have an understanding of how the adaptation process is analyzed, it is essential to recognize what are the components within the process. Smit and Pilifosova (2001) and Moser and Ekstrom (2010) hypothesized three interconnected components of adaptation as follows:

- (1) A set of actors, government as decision makers, as well as private actors including individuals, institutions and public interest that are served by governments at all levels.
- (2) The system where the adaptation takes place, the larger context in which the actors act.
- (3) The object upon which the actors act that can be also identified as the exposure unit, the specific interrelation between the human and natural system to be managed or altered.

The three components are depicted in Figure 49 that describes the context in which both the actor and the system of interest are integrated. It accommodates the enabling and constraining contextual conditions that shape adaptive responses.





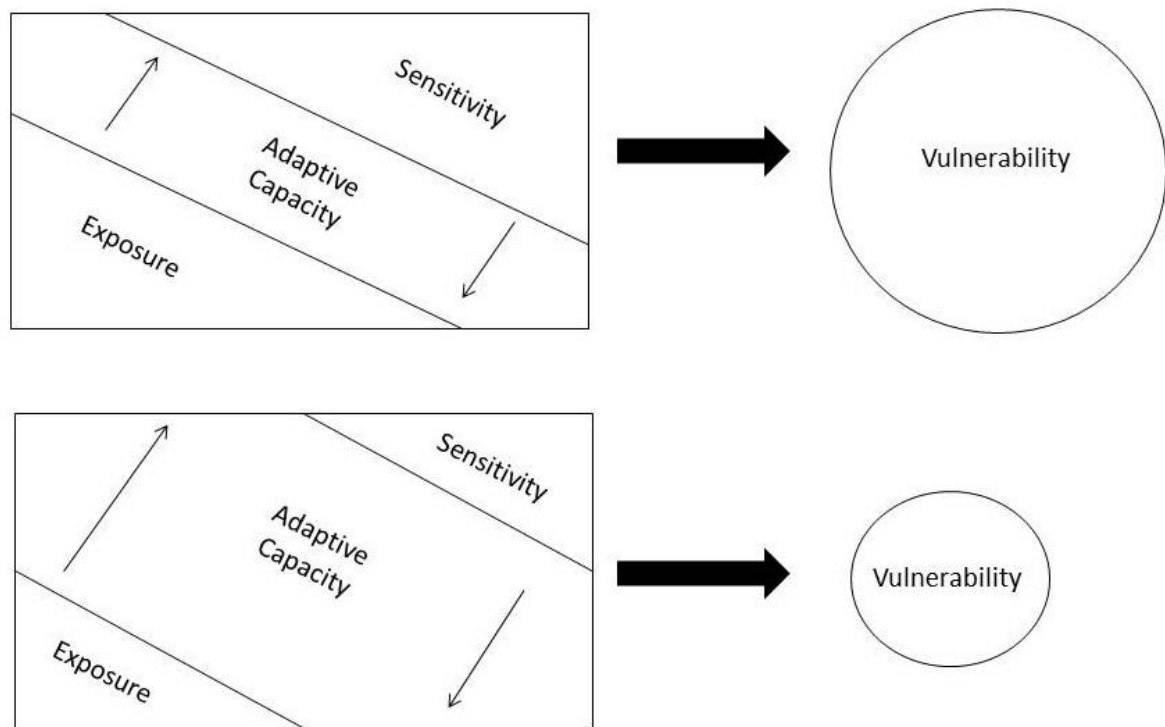
**Figure 49. The structural components of adaptation (Moser and Ekstrom 2010: 3)**

### **5.1.3. Vulnerability and Resilience**

In the context of climate change, the framework of vulnerability has frequently been identified as a function of the exposure of a system and also its sensitivity to stress, as well as the capacity to absorb or cope with the impact of climate change; nevertheless, neither the attributes nor the connection between both is well defined (EAKIN and LUERS 2006). In the social-ecological system, Adger (1999) argued “social” vulnerability is an exposure of individuals or communities in a given location to livelihood stress as a result of the impacts of environmental alteration. Metzger, Leemans, and Schröter (2005) also added that the assessment of vulnerability is a function of exposure to climatic forcing, the inherent sensitivity of the exposure units, and their capacity of adaptation. Hence, it is essential to identify what is the most vulnerable group that will suffer the potential impact of climate-induced events, where social-economic factors such as seasonal migration and population growth play an important role. It is also necessary to take into consideration the level of vulnerability that determines whether a community can adapt to the change of climate variability or needs to move in anticipation of climate events.

Smit *et al* (2001), Adger *et al* (2007) in the IPCC Report and Engle (2011) have described three basic concepts of vulnerability in the context of climate change, namely: (1) exposure that describes how far an ecological system is damaged (2) sensitivity represents to what extent a system is affected after being exposed to the stress, and (3) adaptive capacity depicts the system’s ability to prepare and cope with the stress. Hence, if a system has developed bigger adaptive capacity, then less damage

would be caused from vulnerability and *vice versa*. Figure 50 below shows how adaptive capacity plays an important role in determining vulnerability by moderating exposure and sensitivity.



**Figure 50. The relationship between adaptive capacity, vulnerability, exposure and sensitivity (Engle 2011: 650)**

Adger (2000) has defined a concept of ecosystem resilience that accommodates an understanding of the role of biological diversity in ecosystem dynamics, as well as social resilience that is associated with the ability of a community to resist external shocks or “unusual” exceedance to their social infrastructure, such as environmental variability or social and economic disturbance. However, Smit and Wandel (2006) argued that resilience can also be related to opportunities where disturbance opens up the recombination of evolved structures and processes, renewal of the system and the emergence of new trajectories, in this sense, adaptive capacity. Furthermore, Gallopín (2006) discussed how resilience is interrelated with the capacity of the response component of vulnerability and also can be considered as a form of preservation of a behavior of the system that is conveyed by its state; while vulnerability refers to transformations that may go beyond a single domain.

As ecological and social resilience act as integrated components in which individuals and communities adapt to environmental change, both components also refer to the inter-dependence on ecosystems of the communities and their socio-economic activities. Furthermore, it is also important to consider whether the communities are already less resilient by depending on resources and ecosystems (ADGER 2000).

Meanwhile, social resilience can also refer to an institution that plays an important role to incorporate modes of socialized behavior as well as more formal structures of governance, such as mainstream climate policies that enable the communities to cope with the stress. Therefore, resilience is essential in terms of human-environmental interaction as it is not only refers to economic, but to social stability and its relation with natural resources (O'RIORDAN, COOPER, JORDAN, RAYNER, RICHARD, RUNCI, and YOFFE 1998).

In addition, Vanclay, Leith and Fleming (2009) have formulated three basic mechanisms of ecological resilience particularly to climate change, as follows:

- (1) Ecosystem resilience; where habitat occurrences in natural conditions are more likely to be more resilient to climate stress
- (2) Refuge-based resilience adaptation; the condition where the refugees are withdrawn from unfavorable environment into local microclimates that are considered more favorable.
- (3) Migration-based adaptation; it is a condition where there is large scale movement of species following macroclimatic changes

In terms of climate change, Vanclay *et al* (2009) also described the relation between adaptive capacity, vulnerability and resilience within a socio-ecological system, where in order to reduce vulnerability by increasing resilience in the community, a participatory approach is considered necessary. Meanwhile, the narratives of uncertainty and consensus related to climate series and the impacts in the communities are obtained through story telling that are established within the communities. In such participatory knowledge-making, applied research conveys the “experience” from the communities by which the people consider and manage the variability and change throughout the time. Although debate among researchers appears, this approach accepts interdisciplinary and collaborative research will make the knowledge more visible and significant.

#### **5.1.4. Adaptive Capacity to Water Scarcity**

Ohlsson (1999), Turton (1999) and Mohieldeen (1999) defined adaptive capacity as the ability to make necessary adjustments to cope with natural resource scarcity. It can be also termed as the ability of a society to develop alternative coping options with natural resource scarcity, and to accept these alternatives as legitimate. There are two elements of adaptive capacity, namely:

- (1) Structural; where institutional, intellectual and technical capacity involved in alternative solutions, such as the formation of water strategies

- (2) Social; where the society has the willingness and ability to accept the above solutions as being both reasonable and legitimate.

In terms of social resources for managing water scarcity, Ohlsson (1999) also formulated three indices to create new social institutions that were necessitated by the imperative to find a sufficient amount of adaptive capacity,

- (1) A reliability index, capturing the uncertainty in water supply due to climate, precipitation and import deficiency (rivers and aquifers that flow within the region)
- (2) A use-to-resource index, which is a general index to measure water stress
- (3) A coping capacity index, which is recognition of inter-independent not only to physical conditions, but also to respond and manage the conditions.

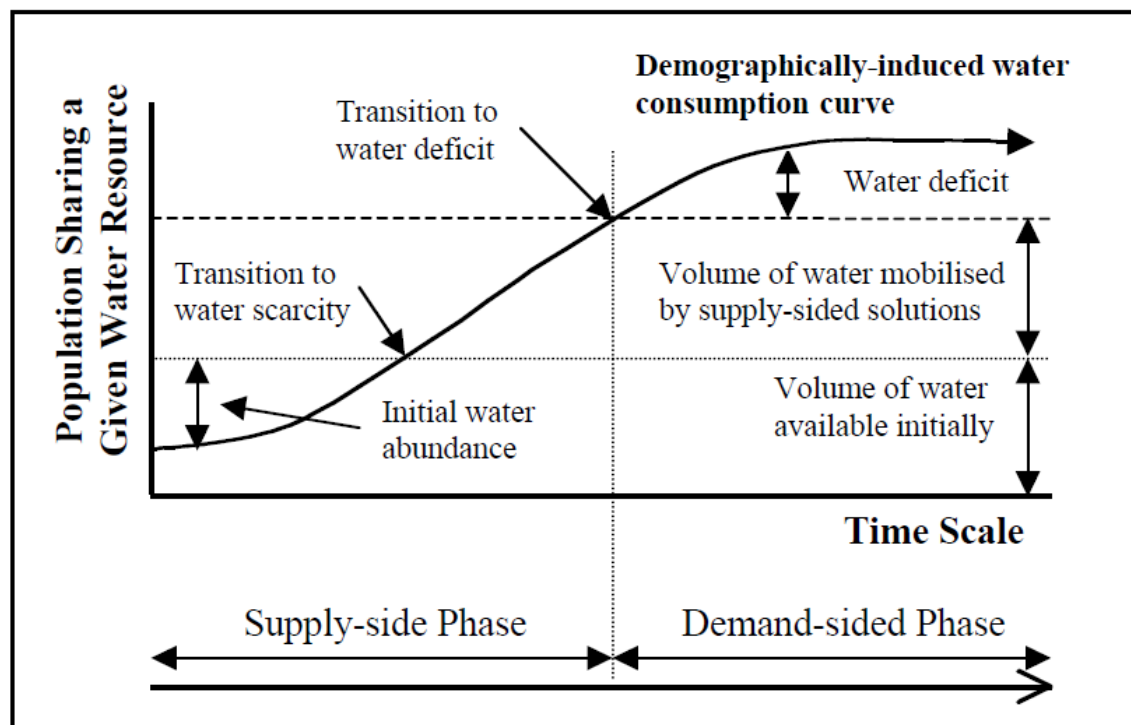
Still according to Ohlsson (1999), in terms of water adaptation scheme, there are three stages, where each stage requires a degree of social effort and the involvement of organization,

- (1) Attempts to increase the available amount of water by getting more water through supply regulation that involves water infrastructure and water extraction from the sources
- (2) Attempts to increase the available amount of water by saving water and re-using it, including demand regulation by using efficiency measures that involve both employment of social resources and the establishment new institution (administrative bodies and economic incentives)
- (3) Redirecting water users within the society towards production yielding higher economic value that involves large-scale structural change and affects the local subsistence on jobs in cities and industries, rather than agriculture in rural areas

Ohlsson (1999) also added that the existence of natural resource scarcity is regarded as “first-order scarcity”, where the solution can be mobilizing more water and increasing further large-scale engineering efforts, building dams, pipelines and aqueducts diverting river water, rainwater harvesting and the drilling of boreholes to extract groundwater. These solutions are examples of supply-side management. Meanwhile, the lack of adaptive capacity of a given society is called “second-order scarcity” or social resource scarcity, where this stage appears as conflict within “first-order scarcity” over blue water, between users at the local and areal level within countries, and between countries sharing a common resource of blue water, such as river. At this stage, the community, societies and states fail to find the social tools to deal with first- and second-order scarcity conflicts caused by supply-side management efforts.

In addition, Turton (1999) added that when supply-side phase fails or is unable to mobilise more water by the application of traditional supply-sided solutions, then there is another phase of water management, namely demand-side management, where there

is more disparity between the water resource and water consumption, leading to greater water deficits as illustrated in Figure 51 below. Figure 51 also depicts how the transition changes from water scarcity in the supply-side phase to a water deficit if supply is decreasing; whereas the demand-side phase is determined by the volume of water that is consumed increasing and exceeding the water available, resulting in water deficit.



**Figure 51. Simplistic model showing transition from Supply-Side Phase to Demand-Management Phase within political economy (Turton 1999:13).**

In addition, Arnell *et al* (2001) emphasized that supply-side adaptation can change structures, operating rules and institutional arrangements, as well as modifying water collection infrastructure and distribution; whereas demand-side adaptation aims to reduce water consumption and protect against the risk that is caused by the stress which also includes water demand management and changing water allocation. The IPCC (2007) has summarized the example of supply-side and demand side adaptive options particularly in municipal water supply as shown in Table 12 below, where increasing supply can be done by improving or adding water infrastructure, as well as modifying water demand by regulating water pricing and developing new techniques sanitation. These responses derive from water use policies and demand management, where in order to enhance appropriate policies or program alternatives, the decision makers, both government agencies and private organizations, need to establish and enforce water management within the region and municipal areas. Nevertheless, there are also values, perceptions, and traditions that are developed traditionally within the societies to

mainstream water management and levels of cognitions that affect the capability to cope with the risk caused by climate stress.

**Table 12. Supply and demand side examples (IPCC 2012)**

<i>Supply Side</i>	<i>Demand Side</i>
Increase reservoir capacity	Less incentive to use (e.g. pricing)
Extract more from rivers or groundwater	Legally enforceable water use standard
Alter system operating rules	Increase use of grey water
Inter-basin transfer	Reduce leakage
Desalination	Development of non-water-based sanitation system
Seasonal forecasting	

According to Vickers (2010), the term “capacity” in water savings can be achieved through conservation programs that are tangible and as valid as the same unit of water supply and can also be produced by conventional supply-side projects. The project may encompass community participation and consideration of social and environmental factors related to water supply management which include least-cost analysis of demand-management and supply-management options, as well as an open participatory decision-making process, the construction of alternative planning scenarios and recognition of the multiple institutions concerned with water resources.

Mohieldeen (1999) alluded that to a strong correlation between adaptive capacity and coping strategy. Social entities with a high level of adaptive capacity have more ability to generate coping strategies than social entities with limited adaptive capacity. In addition, a society will be more vulnerable if it is more exposed and sensitive to resource scarcity and climate stimulus, *ceteris paribus*; a society that has more adaptive capacity will tend to be less vulnerable (SMIT 2006). Adding to that, Sonka (1987) mentioned there are three types of mechanism that will reduce the consequences of drought when it occurs:

- (1) New technologies
- (2) Societal policies
- (3) New management practices

Furthermore, the IPCC (2012) described how the cause of vulnerability in a freshwater system may derive from an increase in reliance on specific sources of supply or alteration in the availability of other alternatives. The indicators of hydrological and water resource drought impacts encompass lost production of crops, the cost of alternatives or replacement water resources and the change in community well-being within the freshwater ecosystem. Moreover, sustainable adaptation in the context of a water system requires the integration of water infrastructure, policy and economic

instruments, as well as the change in behavior towards national development strategies, particularly strategies that are known traditionally and related to indigenous know-how that could enhance scientific knowledge (UN WATER 2010).

Vickers also added that in regions where drought is an issue, native plants that grow naturally are able to adapt to lower amounts of water and high temperatures. The native vegetation can be thwarted by such factors as poor soil quality and unusual microclimate conditions. In addition, to save more water, indigenous plants help to restore the natural environment and invite the return of native birds, butterflies, insects and animals. In terms of water-efficient landscapes, slow-growing and drought-resistant perennials or shrubs can be naturally adapted, as an indigenous plant typically has deep root systems and leaves whose top surfaces retard evapotranspiration and have low maintenance requirements. According to Dregne (1987), the decision about which crops to plant in dry regions is important. If rains come early, long-season cultivars are planted to take advantage of their greater yield producing potential. If rains are late or if dry periods kill crops planted early, then short-season cultivars are a normal response to temporal variability in rainfall, whether or not the season turns out to be drought-affected.

## **5.1. Existing Adaptive Capacity in Pacitan**

Smit and Wandel (2006) mentioned that the adaptive capacity of a system is flexible and responds to changes in economic, social, political and institutional conditions over time. Meanwhile the external socio-economic and political factors may lead to a narrower ability to cope with resource scarcity. As mentioned by Bohle (2001), Burton and May (2004), many cases of local-level adaptive actions are described as reactive and short-term, unlike the higher-level national or regional plans that are considered anticipatory and involve information, policies and programs. This study observed Pacitan's agricultural and water sector, as both sectors play an important role in the social economic system and are described in this part of the chapter as one of the substantial sectors in the community.

### **5.1.1. Agriculture Sector**

Nabhan (2013) stated the characteristics of perennial plants which can adapt to climate uncertainty are described as having roots, trunks, branches and foliage that can sequester more carbon per year than most crops do, as well as tall and bushier trees, shrubs and palms can reduce heat on understory plants. In the agricultural sector, the making of terraces in sloping lands is considered the oldest and widest practice that has been implemented by farmers to reduce erosion, retain moisture and sustain soil

resilience. A well-constructed and maintained terrace can reduce runoff by 25% and minimize soil loss to one-twentieth of their former rates on erosion-prone slopes, keeping moisture so that the nutrients are available to the crops planted upon them. One of the examples of perennial plants that can adapt to climate stress is as follows:

- Cucumber (40-70 days to be harvested), which are heat tolerant and also resistant to diseases and pests
- Maize (60-90 days to be harvested), is considered drought evading for late planting with delayed rains and hardy to all kinds of weather, as well as tolerant to heat

Planting cultivars which are drought resistant can be one of the adaptive capacities in agricultural systems facing water shortages, as well as cultivation systems. The cultivation of rice in the karst area in Gunung Sewu is limited to fertile basins due to its high demand for nutrients and water, especially in the rainy season. Meanwhile, other dry crops, which are resistant to drought, like cassava and maize, are planted with soybeans and groundnuts, and these crops can be planted in the dry season as well (Lukas 2005).

In addition, Boer (2008) added that in dry land, maize, groundnuts and cassava with multiple cropping systems (first, second and third crop) are the kind of crops which can survive during the dry season. In the monsoon type areas, drought normally affects second crops when the rainy season ends earlier or rainfall in the dry season is below normal. Drought can also occur during late planting for the second crop due to a delay in the onset of the rainy season. These conditions commonly occur during extreme climate events like El Niño.

Based on the observations and interview results in Pacitan (2013), dryland crops of dryland paddy, maize, groundnut and soya bean along with cassava in *tumpangsari* are the kind of crops which can survive during the dry season. In the monsoon areas, drought normally affects second crops when the rainy season ends earlier or when rainfall in the dry season was below normal. Therefore, it is important to plant the first crop at the beginning of rainy season, in October or November when water is available, so that the community knows when they will harvest the dryland paddy and plant the dryland crops (*palawija*) afterwards. During the dry season, in July to September, the community starts following the field to prepare the next planting season, as well as harvesting cassava as one of the main dryland crops. Thus, if the onset of rainy season shifts or there is a prolonged dry season, rice cannot be planted as rice needs plenty of water in the planting season. This is the situation when secondary crops play an important role as substitute plants, either for subsistence or as cash crops. During dry season some communities even prefer to leave the area bare as no water is available to do agricultural



activities. Below is Figure 52 which shows the planting season in Donorojo, Punung and Pringkuku.

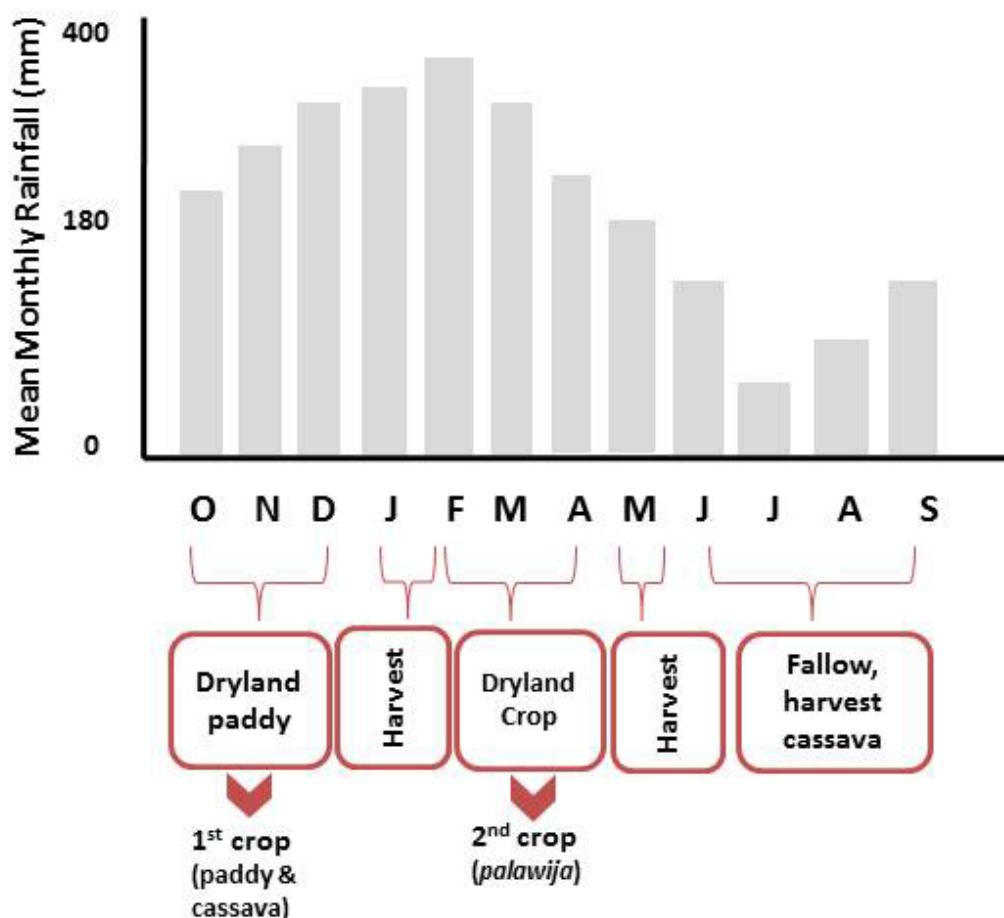


Figure 52. Planting season in karst areas in Donorojo, Punung and Pringkuku (drawn from BMKG and interview result 2013)

Due to karst conditions, there are no practices of irrigation founded in the area; therefore the communities are dependent on rainfall as one of the important water sources. This explains why rain-fed dryland paddy is the only paddy that can be planted in the area where they can generally harvest once a year, unless the community lives nearby the perennial water sources, like Sugihwaras and Candi then they can have more than one harvest per year. Some communities also plant secondary crops right after they finish harvesting dryland paddy in the same land that they used for planting dryland paddy, as the karst areas are dominated by more rocks than soil, which makes the availability of fertile soil limited.

Traditionally, the rural communities in Java and Bali believe in the traditional Javanese calendar, called *pranoto mongso* in the Javanese language, *pranata mangsa* in Sundanese and *Kerta Masa* in Balinese. The traditional calendar was made as a result of an observation and used as a practical guide not only for agricultural activities for rural communities, but also for integrated pest management that was based on climatological

phenomena. There are twelve seasons in the traditional calendar and these are divided into two big seasons, young *mangsa* that consist of *kaji*, *karo*, *katelu*, *kapat*, *kalima* and *kanem* (season 1, 2, 3, 4, 5, 6), and old *mangsa* that consist of *kawolu*, *kasanga*, *kasepuluh*, *desta*, and *sada* (season 7, 8, 9, 10, 11, 12) (DALDJOENI 1984;. SULTHON 1985; WIRIADIWANGSA 2005).

The two big seasons in the *pranata mangsa* can be roughly converted into Gregorian calendar which starts in July and runs until December for the young season where the term young refers to the early stage of planting, both first and secondary crop. January to June can be considered as the old season where the harvest season is ready to be implemented (DALDJOENI 1984). However, extreme climate events resulting from climate variability are causing the validity of *pranata mangsa* to be disputed, as the science of *pranata mangsa* is passed from generation to generation. The young generation are starting to be not as dependent on it as the senior generation are. Sarwanto, Budiharti and Fitriana (2010) debated whether the *Pranata Mangsa* system was an observation that was formed in the 16<sup>th</sup> century in the local communities of Java and Bali as a local calendar that was used particularly by the farmers. Despite the impact of alteration of climatological events, this local system also refers to the bio-climatological activities (the behavior of animals and plants), so the system still can be implemented.

Based on the results of interviews and field observations (2013), there are still some communities in Pacitan who still believe in this local calendar and use it. Timber industry is one such industry and is considered one the important sectors in Pacitan. In order to have a good quality of timber, particularly for housing, the community harvests timber from the ninth season or *mangsa kasanga* until the tenth season or *mangsa desta*, where the water content in the trunk is lower and considered sufficient to be harvested and resistant to woodboring pests. Nevertheless, there are also communities who think that this system is no longer applicable, as they observe there is a changing of climate variability in the last ten years, particularly the shifting of the rainy season that affects the planting season. Below is the quote from the Focus Group Discussion (FGD) in *Kecamatan Punung*<sup>8</sup>.

“25 years ago, Baksoko River was still running, but now it is not anymore, water discharge in the rivers is also decreasing. So, we think the season is changing. What do you call this? Global warming? Yes, so that is why mongso cannot be used anymore because the season is changing now. Although my parents still use it. Yes we still believe in it but I do not think it is still relevant”.

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<sup>8</sup> FGD was conducted in Kecamatan Punung on 8<sup>th</sup> April 2013 where it was attended by 11 out of 13 village representatives. The respondent was a representative from Desa Wareng.

### 5.1.2. Water Sector

Climate variability and its change have been a growing concern of water stakeholders, where the vulnerability of a system to climate change depends on that system's ability to adapt suitably, both in the long and short-term adaptation strategies (BROOKS, ADGER, and KELLY 2004; ENGLE, JOHNS, LEMOS and NELSON 2011). In terms of water management approaches, water stakeholders experience limitation as vulnerability and also as opportunities in response to change, such as decisions on allocation and water distribution, as well as the participatory approach from the community as water users.

Furthermore, Wurzel (1993) added that integrated approaches to the community in terms of water supply comprises not only the effective involvement from the community on the design and implementation, but also institutional and manpower development programs suitably corresponding to the needs of the planned water supply system. The examples of water supply technologies can be formed are rainwater harvesting where the ground surface is modified in some way to collect the water and then fed into a storage tank; other example can be a gravity flow system where the water is taken from springs from whence it flows under pressure through pipes to an outlets in the mountainous areas.

Many communities relied on karst springs that are interconnected to depressions in the ground surface, before PDAM covered most scarce areas in Pacitan. Some of the springs have large quantities of water moving through cavities or channels that developed in limestone, like *Kali Barong* in *Kecamatan* Pringkuku that has 180 L/sec water discharge rate in the rainy season and 80 L/sec in the dry season. *Kali Barong* has become one of the biggest water sources in the karst area in Pacitan that is currently being used by PDAM and transports the water to almost all villages in *Kecamatan* Pringkuku and parts of the capital district. Nevertheless, there are seasonal springs that have a small discharge and these are depleted during the dry season in several villages. This is the time when the communities that do not have connections with PDAM, rely on rainwater harvesting (*Penampungan Air Hujan/PAH*), *telaga* and water tanks from the local government. PAH is often used as an additional water source and only for washing clothes and not for drinking and cooking purposes. Water that is collected through pipes at the side of the roof will be transported to a water tank (it can be self-made tank or one purchased from the store) and impound it for washing purposes. In order to fulfill other domestic uses like drinking and cooking purposes, the community frequently buy water from private companies that are organized locally. The example of PAH in Pacitan is drawn in Figure 53 below.

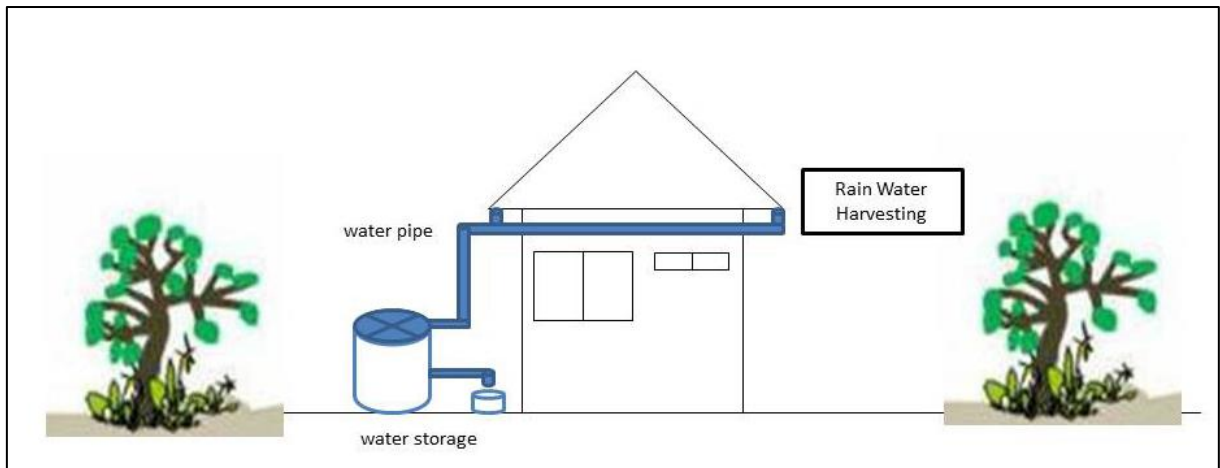


Figure 53. General example of PAH in *Kecamatan* Donorojo, Punung and Pringkuku (own figure based on the interview results 2013)



Figure 54. PAH in *Kecamatan* Donorojo (own figure 2013)

Besides PAH, other forms of local adaptive capacity in terms of water use have been used by the communities, such as springs, dug/drilled wells, water tanks that are organized privately, *telaga* and combinations of these. Table 13 below shows the combination between PDAM – springs and PDAM - dug/drilled wells which dominate water sources in these areas. Water tanks organized privately by some people who need access to water are normally arranged by communities who have more money to purchase the water, for those who do not, they use dug wells and springs. However, dug wells are not always available in every area due to karst characteristics, therefore small springs or *belik* and water tanks are becoming their options. Although the water discharge of *belik* is relatively small, some villages still use *belik* as additional water source particularly when there is pipe leak in PDAM. Based on the result of interviews (2013), many *telaga* have been depleted over the last five to ten years ago. Currently the

communities are using *telaga* for their temporary agricultural fields, particularly at the end of the rainy season and at the beginning of dry season as mentioned in chapter 3.

**Table 13. Water Sources in Kecamatan Donorojo, Punung, and Pringkuku (based on interview results and FGD 2013)**

Kecamatan	Desa (village)	(1) PDAM	(2) Spring	(3) Dug/drilled Well	(4) PAH	(5) Water Tank	(6) Telaga
Donorojo	Sendang	√	√				
	Sukodono	√				√	
	Gedompol	√	√				
	Gendaran			√		√	
	Klepu	√	√				
	Cemeng	√		√			
	Donorojo	√		√			
	Belah	√	√				
	Sawahan	√	√				
	Kalak	√			√		
	Widoro	√		√			
	Sekar	√	√				
Punung	Punung	√					
	Mendolo Lor			√		√	
	Mantren	√					
	Wareng	√	√				
	Mendolo Kidul		√	√			
	Kendal	√	√				
	Piton	√	√				
	Gondosari			√			
	Sooko	√		√			
	Ploso			√		√	
	Bomo	√				√	
	Tinatar	√	√				
	Kebonsari	√	√				
Pringkuku	Candi	√	√				
	Watukarung	√	√				
	Dersono	√	√				
	Dadapan	√	√				
	Poko	√	√				
	Glinggangan		√				
	Ngadirejan	√		√			
	Sobo		√			√	

	Jlubang	√					√
	Tamansari		√				
	Pelem		√			√	
	Pringkuku	√	√				
	Sugihwaras	√	√				

As we can see from Table 13, the community relies greatly on PDAM as it covers most of the areas, and the combination between PDAM and dug/drilled wells dominates in these three *Kecamatan*. Meanwhile, some areas which are not covered by PDAM depend on seasonal springs and dug/drilled wells, whereas water tanks are also an important additional water source, particularly during the dry season. Some respondents even expressed that although they already have PDAM connections, they still purchase gallons of water from a well-known brand in the shops for drinking purposes, as the limestone content in the water from PDAM is quite noticeable; thus for drinking purposes, the community needs to boil water from PDAM two to three times in order to remove the limestone contents from the taste. Nevertheless, the existence of PAH and *telaga* are also important although they are not dominating the areas and become substitute water sources for the communities.

In order to acquire water, several communities that live far from springs and do not have PDAM connections, build long pipes to connect springs to their houses. Even before PDAM was established, some communities had to walk up to 10 km to *Sumber Barong* in Donorojo during the dry season. Although they have seasonal springs close by but due to the long queue, they prefer to fetch water from a distant spring by bringing buckets that contain 10 to 30 L per day as shown in Figure 55 and 56 below, depending on who brings the water. Usually there is a “responsible division” of labour in the family, such as who fetches the water, who works in the field and who take care of the cattle. After PDAM is built, the communities mentioned and even those who still do not have PDAM connections can share the connection with their neighbors who are PDAM customers and share the cost. This shows how important the communal inter-relation is within the communities, which makes social capital one of the essential factors in water resource management in Pacitan.



**Figure 55. Pipes that are built by the communities to connect from water sources to their houses (own figure 2013)**



**Figure 56. Buckets to fetch water that contain 10 to 30 L (own figure 2013)**

The addition of Water Treatment Plants or IPA in 2011 by the Ministry of Public Work in Donorojo through PDAM connected three ground reservoirs in order to deliver water to communities in the surrounding areas of Donorojo (GAPENSI 2011). In addition, based on PERDA Pacitan No. 3/2010, Section (6) Article (28) on the Plan of Water Resources Development System, the local government of Pacitan is currently developing 89 reservoirs that include five river basins in the whole district, including Baksoka River Basin that is located in Sub District Donorojo (PERATURAN DAERAH PEMERINTAH PACITAN 2010).

During the dry season when water is limited, those who do not yet have connections from PDAM, use water either from the nearest perennial springs that are still running or buy water from water tankers that are run by private company which costs around IDR 350.000 (€ 23) for 50.000m<sup>3</sup> (5000 liters). One water tank capacity can be used by one household with six members for one month (interview with the communities 2013). In addition, the local government of Pacitan together with PDAM are transporting water for free to support areas that are listed as being low on water by *Kecamatan* during the dry season; however the water tanks from the local government are limited and cannot fulfill the water needs of all the communities, therefore they still need to provide water by themselves from other sources (interview with the heads of *Kecamatan* 2013).

Besides PDAM, some areas of Donorojo, Punung and Pringkuku also have community-based water groups, called HIPPAM (*Himpunan Penduduk Pengguna Air Minum*) that organize water from the water sources and circulates it to the communities. HIPPAM charges Rp. 3000 (€ 3 cents) for every bucket or storage utensil that contains 20 liters of water. Nonetheless, the existence of HIPPAM has decreased since PDAM was established, because the communities prefer to have connections from PDAM so they do not need to bring water with buckets; meanwhile by having connections with PDAM, they

just need to install pipes and the water will come directly to their house although they need to pay more than they did to HIPPAM. Therefore, HIPPAM is gradually losing their customers and it only exists in several *desa*, two villages in *Kecamatan* Donorojo, one village in *Kecamatan* Punung and two villages in *Kecamatan* Pringkuku (interview results and FGD 2013). One of the respondents expressed that the existence of HIPPAM is still considered significant for those who are still not yet connected with PDAM to fulfill the water needs for the communities. HIPPAM is still needed particularly during the dry season where water is limited.

Another local practice that applies in the communities is having the assumption that water sources are holy places. The term holy is associated with sacred and does not necessarily carry mystic connections. For example, the existence of *luweng* or sinkholes is considered sacred, where the communities believe that it is guarded by their ancestors to keep the place safe. One of the physical appearances indicating a place is sacred is the existence of a big tree and roots in the surrounding areas (interview results 2013). The idea of having this assumption associated with keeping water sources safe from disturbance, such as human's disturbance; ensures the water source can be used by the communities as groundwater river.



## 6. NATIONAL AND LOCAL POLICIES ON WATER MANAGEMENT AND CLIMATE CHANGE

This chapter reviews the legal basis related to water management and its correlation with climate issues at the national and local level, particularly policies that regulate the national and regional development plan in East Java Province include Kabupaten Pacitan. This chapter also reviews the strategy and how these policies correlate in terms of decision planning and the challenges in correlation with the implementation of the policies.

### 1.1. National and Local Policies

The legal basis of law in Indonesia is the 1945 Constitution (*Undang Undang Dasar 1945*) that regulates the general legal framework. It is subjected to broad interpretation, following by the Decree of the People's Representative Assembly (*Ketetapan Majelis Permusyawaratan Rakyat/TAP MPR*) where the Decrees are made by MPR as the representative of people in the assembly board. The next line in the hierarchy is Law (*Undang Undang*) made by joint agreement between the House of Representatives (*Dewan Perwakilan Rakyat/DPR*) and the President, Government Regulation/GR (*Peraturan Pemerintah/PP*) and Presidential Decree/PD (*Peraturan Presiden/Perpres*) which are made by the executive offices of the President and its related Ministries. The last legal system is the Regional Regulation/RR (*Peraturan Daerah/Perda*) that are made by shared agreement between the Head of the Regional or Local Government and the Regional House of Representatives (*Dewan Perwakilan Rakyat Daerah/DPRD*). In terms of policies and planning, the national government that comprises the legislative and executive is responsible for formulating policies, whereas the regional government or municipalities and authorities implement the policies as depicted in Figure 57 below (KEMENTRIAN SEKRETARIAT NEGARA REPUBLIK INDONESIA 2010; RAJENTHRAN 2002).

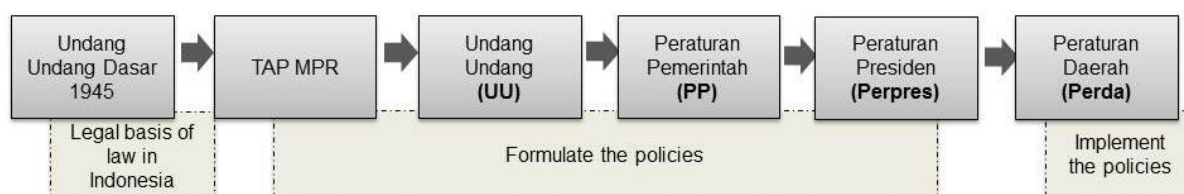


Figure 57. Hierarchy line of Indonesian Law (compiled from *Kementrian Sekretariat Negara Republik Indonesia 2010; Rajenthiran 2002*)

Tejalaksana (2012) pointed out that the policy on water resource management should aim to support the availability of water resources, which should be done by

focusing on multiple functions including ecological, economic and social function. Water management should be integrated and cross sectored, while taking the population growth projections into account.

Moreover, Brontowijono (2008) mentioned that development of water is not merely an effort to give every individual free access to water, but also aims to control the damaging capacity of water for the life of society. Below are the general targets of water resource development that are formulated by the national government:

- (1) Attaining an integrated and continual management pattern on water resources
- (2) Establishing good control over potential conflicts on water
- (3) Establishing good control over the exploitation of groundwater
- (4) Increasing the ability to satisfy water demand for domestic, agricultural and industrial needs with the priority on households and farmland
- (5) Decreasing the impact of flood and drought disasters
- (6) Establishing good control of water contamination
- (7) Protecting the coastal area from seawater abrasion, especially in small islands, boundary areas and strategic areas
- (8) Increasing the active participation of the society
- (9) Increasing the quality of coordination and cooperation among institutions
- (10) Emerging the continual pattern
- (11) Providing an actual, accurate and accessible data and information system
- (12) Improving the condition of water resources and infrastructure, the availability of water resources for the society, and preventing floods in the urban areas

In the context of climate change adaptation, the Government of Indonesia with its line ministries formulates the national policy to cope with the impact of climate change. The sectoral adaptation plans that are implemented by the regional government or municipalities authorities are called RAN-API (*Rancangan Aksi Nasional-Adaptasi Perubahan Iklim*) or National Action Plans for Climate Change Adaptation. RAN-API is formed by involving stake holders in government and civil society to coordinate between them in terms of adaptation and priority sectors and cross-sectors in the short (one year) and long term (five years) (MINISTRY OF NATIONAL DEVELOPMENT PLANNING/BAPPENAS 2012).

Based on issues related to water management and climate change adaptation policies at the national, provincial and regional scale, there are several issues described which include the division of roles and accountability in national and local government and the community; water conservation; water use; water penalties as well as the National Action Plan for Climate Change Adaptation. The important issues that are described in the

national, provincial and regional policies, including the policies that are formulated by related ministries as the executive board in the context of water management and climate change adaptation are depicted in Table 14 below.

**Table 14. Issues of water management and climate change adaptation in the national, provincial and regional level (compiled from different sources 2014)**

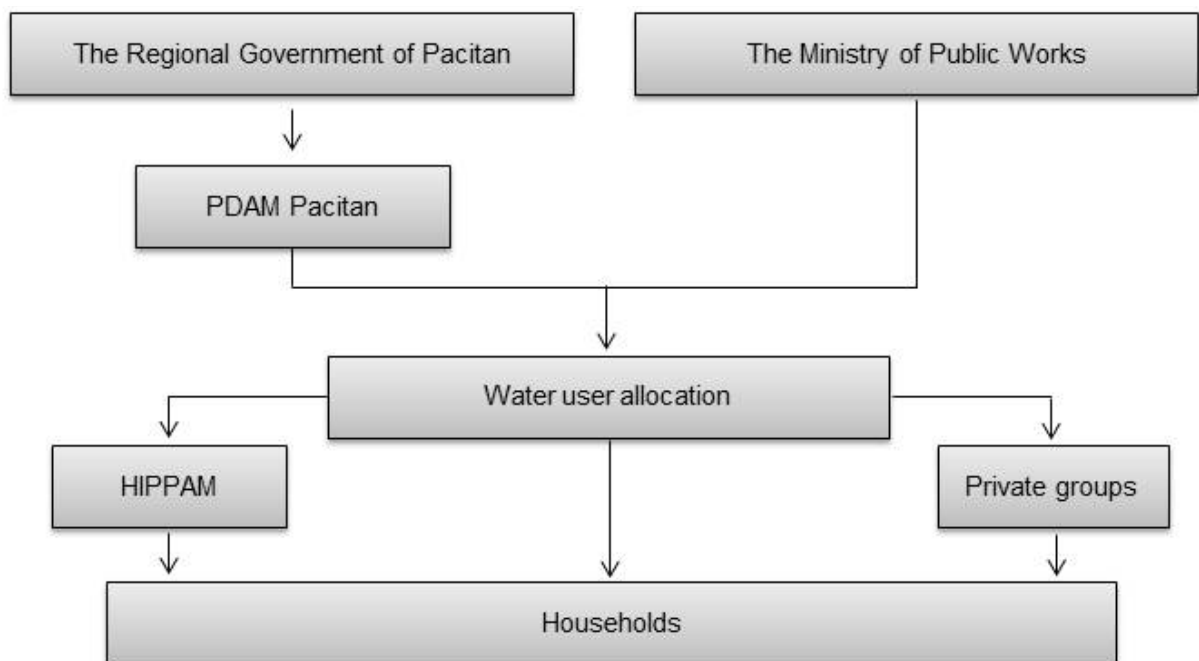
Issues	National	Provincial	Regional
Water Management			
Division of roles and accountability regarding water management between national, local government/municipalities and the community, and the establishment of Water Resources Council ( <i>Dewan Sumber Daya Air</i> ) at the national level	Law No. 7/2004 Article 6, 14, 16, 17, 45, 64	RR East Java Prov. No. 5/2011 Article 3, 5, 25, 26, 27	RR No. 2/1992 Article 2, 3, 4
	GR No. 42/2008 Article 15, 17, 44	-	RR No. 3/2010 Article 17
	GR No. 20/2006	-	-
	GR (Ministry of Public Works) No. 18/2007 Article 4, 10, 35, 42	-	-
	GR (Ministry of Public Works) No. 18/2012	-	-
	GR No. 16/2005 Article 1, 38-41	-	-
	GR (Coordinating Minister for Economy No. 7/2011	-	-
Water conservation through water source protection, landscape, weather modification technology and rainwater harvesting particularly for water scarce areas	Law No. 7/2004 Article 26, 27, 34	RR East Java Prov. No. 5/2011 Article 29-36, 52	RR No. 3/2010 Article 28
	GR No. 42/2008 Article 49, 50, 53, 61	-	-
Water sources like groundwater rivers are used when surface rivers are not sufficient for agriculture and domestic water use is not more than 100 m <sup>3</sup> per month per household	Law No. 7/2004 Article 7, 28	RR East Java Prov. No. 5/2011 Article 56-57	RR No. 6/2011 Article 3
	RR No. 16/2005 Article 5	-	-
	RR No. 42/2008 Article 26, 63, 68	-	-
Water tariff where a progressive tariff is applied in order to improve water saving	GR No. 16/2005 Article 60	RR East Java Prov. No. 5/2011 Article 53	-

	GR (Ministry of Internal Affairs) No. 23/2006 Article 1, 3, 6	-	-
	GR No. 42/2008 Article 62	-	-
Water use for domestic, agriculture, industry and tourism and sanitation systems, particularly in the karst areas where the priority of water is for drinking and domestic use	Law No. 7/2004 Article 34, 40	RR No. 3/2010 Article 32, 38, 39, 40	-
	GR (Ministry of Public Works) No. 18/2007 Article 27, 38	RR No. 6/2011 Article 12	-
	GR No. 16/2005 Article 14	-	-
Water penalties where an incentive is given for water savers and <i>vice versa</i>	Law No. 7/2004 Article 94, 95	RR East Java Prov. No. 5/2011 Article 107	RR No. 6/2011 Article 23-27
Climate Change Adaptation Strategies			
Share of accountability between national and local government and the establishment of National Council of a Climate Change ( <i>Dewan Nasional Perubahan Iklim/DNPI</i> )	PD No. 46/2008	-	-
	GR (Ministry of Health) No. 1018/2011 Article 3, 6, 7, 8	-	-
National Action Plan for Climate Change Adaptation (RAN-API) particularly in the water sector	GR (Ministry of Public Works) No. 11/2011 Article 6	-	-

According to Table 14, the national and provincial policies formulate a general and broad description on a variety of issues regarding water management including the share of accountability for water management and water sources maintenance in national and local government where the local communities also need to be involved in terms of policy implementation. The establishment of the Water Resources Council is also described where it formulates policies in hydrology, hydrometeorology and the hydrogeology sector, regulates the management of water use, and monitors as well as evaluates the implementation of policies (PERATURAN MENTERI KOORDINATOR BIDANG PEREKONOMIAN 2011). Meanwhile the Regional Government of Pacitan (PERATURAN DAERAH PEMERINTAH PACITAN 2010) specifically regulates water management matters by region division of karst areas, where Punung becomes the center

of local activities with caves and coastal tourism sites or karst eco-tourism and the center of regional development of karst areas in Donorojo, Punung and Pringuku. Furthermore, the spatial planning in Pacitan is regulated based on its function, agriculture, forestry and the settlement sector where the settlement sector has the widest area within Pacitan and almost 12% covers urban and rural areas. In addition, the regional regulation of Pacitan (PERATURAN DAERAH PACITAN 1992) regulates human resources accountability in PDAM where PDAM is formed by the Regional Government of Pacitan to provide water needs for the population in Pacitan and regulates water management in the region.

In terms of decision makers for water management in Pacitan, there are several key players that regulate and organize water issues from water sources to end users in households. The key players are not merely from the government agencies, but also from the community-based water groups like HIPPAM. Although HIPPAM is having fewer customers due to the existence of PDAM, its role is still considered significant for those who are not yet connected with PDAM particularly during the dry season. Other water suppliers from non-governmental agencies to water users include private water groups which sell water tanks to households by using water tanker with 5000 liters capacity. The existence of private water tankers is also substantial for areas which do not have connections with PDAM and HIPPAM. Although the price is considerably more expensive, but when there is limited water available then it becomes one of the options for the communities to fulfill their water needs besides water support from the local government of Pacitan.



**Figure 58. Key players in water management in Pacitan (own figure compiled from different sources 2014)**

## 1.2. Challenges of Implementation

The enactment of government regulations in terms of water management in urban and rural areas has passed from the central government to regional government and local agencies since the 1980s particularly in the water supply infrastructure where the funds were required from international fund agencies through grants and loans. However, in the context of implementation of regulations, there are constraints at the national and local scale that the government encounters which include several aspects of water quality management, funding and political issues (PERATURAN MENTERI PEKERJAAN UMUM 2006; SETIONO, WOODCOCK, DJUMHANA, SUKARMA, PARTON 2012).

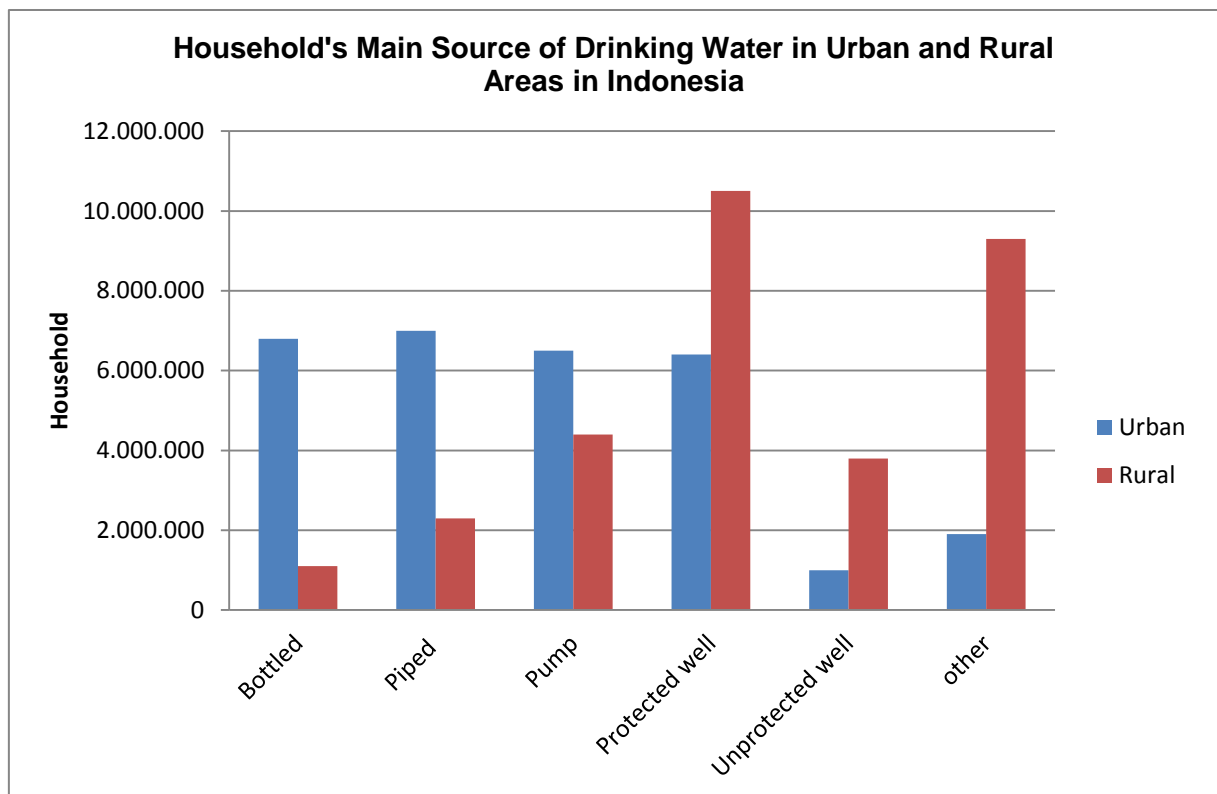
According to Government Regulation (2006), one of the aims of the Indonesian government for its water management strategy is to enhance integrated water management based on water catchment areas and not by administrative areas, so that the communities that live outside the water catchment areas can also fulfill their water needs and they are not constrained by their region; therefore the government is enacting regulation by sharing accountability and water services with local government. However, in the sense of ownership, there is a tendency by local government to rely on funding from central government for water supply projects based on the Law No. 7/2004 and Government Regulation No. 16/2005. There is an emphasis on role division and the responsibilities between the central and local government in water supply provision. Both sides own PDAM and the tariff regulator, thus the central government is providing technical assistance and access to capital for local government through fund lending and private sector agreement whereas the local government is constructing water supply infrastructure to provide water needs in the remote areas and other areas where water is scarce. Good coordination between central government agencies and local government can also establish a good water governance to improve water services which lead to more efficient use of resources and adequate maintenance of water infrastructure. A long-term and stable political condition is one of the challenges for good water governance where a five-year legislative and presidential election would affect the enactment of water policies.

One of the constraints encountered by the government is water coverage and service quality. As many Indonesians obtain drinking water from different sources and according to National Social Economy Survey or *Survey Sosial Ekonomi Nasional*/SUSENAS<sup>9</sup> (BADAN PUSAT STATISTIK 2012), wells and pumps are the main source of water, whereas other sources including rainwater, rivers, streams, lakes, piped water (PDAM), and bottled water from private groups are considered as water source

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<sup>9</sup> SUSENAS is a national survey that is conducted by the Indonesian Statistical Bureau or *Badan Pusat Statistik* (BPS) every year, taking the social economy and demography into consideration.

options. Although the price is considerably more expensive, the latter source is becoming popular as the main source of drinking water particularly in the urban areas where the service quality of PDAM pipes are considered low by having leaking pipes and high contamination of wells and groundwater. Meanwhile for domestic use, non-piping water options such as water pump or jet pump is also becoming popular due to the convenience of being able to get water easily without the need to install pipes to PDAM and the water quality of several PDAM has shown low quality due to lack of maintenance (POKJA AMPL DEPARTEMEN KESEHATAN 2005). Based on the interview results (2013), the communities who live in the areas surrounding water sources in Pringkuku prefer to have water pump or jet pump rather than to have pipe connection with PDAM Pacitan, because they do not need to pay for the pipe instalment as well as the monthly payment; therefore for them it is more convenient to have a water pump to fulfil their water needs.



**Figure 59. Household's main source of drinking water in urban and rural areas in Indonesia (drawn from SUSENAS in *Badan Pusat Statistik* 2010)**

Moreover, Badan Pusat Statistik (2010) in Figure 59 below also described that bottled water, piped water, pumps and wells are the main water sources for those who live in urban areas; meanwhile wells and other sources which utilize rainwater harvesting, rivers, stream and lakes are preferably sources for the communities in rural areas. The significant number of households using other sources in rural areas may be attributable to the community-based water groups or community and local government-driven water

programs. One of the heads of the village in *Kecamatan Pringkuku*<sup>10</sup> (2013) expressed that the village has their own community-based sanitation program by collecting IDR 1000 (7 cent) per month from every household to build a sanitation system for those who still do not have it and for other community-based water programs. The program is the result of the initiative of the communities and the local government of *Kecamatan Pringkuku* to establish a communal water sanitation program. The involvement of community does not occur in every region in Indonesia, particularly in the urban areas; thus it may become another challenge for the implementation of government regulation where the potentials in the community need to be developed in order to have an integrated water management at every level of decision maker.

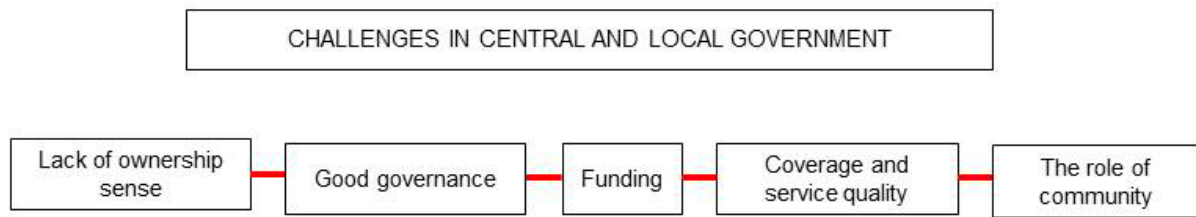
As depicted in Table 14 above, the climate change adaptation mainstream policies are not found in the Regional Regulation (*Peraturan Pemerintah*) of East Java Province and Pacitan. There is a bias of mitigation in mainstream policies related with greenhouse gas emission reduction strategy at the national level; whereas the climate change adaptation policies are still in the discourse at the regional level and not yet implemented into legal policies. However, the national government has established the National Council for Climate Change (*Dewan Perubahan Iklim/DNPI*) through Presidential Decree, and the mainstream discourses regarding climate change adaptation have sporadically appeared and been discussed within the communities and non-governmental agencies in several regions. The implementation of mechanisms from the central government to local government shows that there is a lack of coordination within governmental agencies in terms of climate change adaptation regulation. The Ministry of National Development Planning or BAPPENAS<sup>11</sup> has formed Pokja (*Kelompok Kerja*) or Working Groups based on different sectors and responsible for providing guidance to local government in the climate change affected sectors, such as agriculture, energy and forestry (MINISTRY OF NATIONAL DEVELOPING PLANNING 2014). Nevertheless, the implementation of such regulation does not reach every region within local government in Indonesia. The Provincial Government of East Java Province and Regional Government of Pacitan for instance, does not have specific Regional Regulation that involves the issue of climate change adaptation, but rather the issue of greenhouse gas emission reduction and climate change mitigation. Figure 60 below is the summary of challenges that are encountered by both the central and local government in the water management and climate change adaptation sector.

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<sup>10</sup> Interview was conducted in Desa Ngadirejan on 22 May 2013 with the head of the village.

<sup>11</sup> BAPPENAS is *Badan Perencana Pembangunan Nasional*, a ministry that is in charge of the Government of Indonesia in the national developing planning sector.





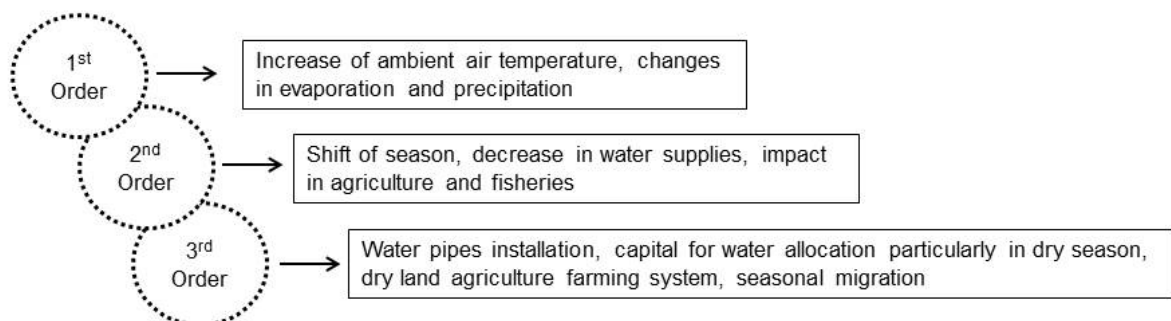
**Figure 60. Challenges that are encountered by both the central and local government to achieve Indonesian Government's water management strategy (compiled from different sources 2014)**

## 7. CONCLUSION

### 7.1. Research Findings

The karst areas of Pacitan that are included in Gunung Sewu Karst Region are located in the most western part of East Java Province and the most eastern part of the Gunung Sewu Karst Region. The three *Kecamatan* in Pacitan (*Kecamatan* Donorojo, *Kecamatan* Punung, and *Kecamatan* Pringkuku) are constrained by their physical condition in karst areas including limited water supplies during the dry season, no irrigation due to its karst geomorphology that percolates water directly into the ground, particular agricultural systems that depend on rain fed farming, and seasonal migration of communities particularly during the dry season.

The change in climate variability and extreme climate events accelerate the vulnerability of karst conditions where most of the rainwater pours downward into the caves and sinks, resulting in water scarcity in the form of limited water availability. The communities are depending on dry land farming, cassava, dry land paddy, maize, groundnut, soya bean and multiple cropping systems between these cultivars as secondary crops which are mainly rain fed farming systems. Thus increase the vulnerability whenever extreme climate events occur. Nevertheless, the government of Pacitan and the communities have developed adaptation strategies to cope with limited water supplies, traditionally and by regulation in two significant sectors, the water and agricultural sectors. Starting from the increase in temperature and the decrease in precipitation as the first order of the change in climate variability that affects the water resource sector, the next order of further impacts is caused by the first order, and finally results in the third order in the form of water pipe installation, capital investment for water allocation, particularly in the dry season and seasonal migration within the communities as described in Figure 61 below.



**Figure 61. Different orders in the change of climate variability in water resource sector in Pacitan (own figure 2013)**

The agriculture sector, besides having planting cultivars that are resistant to drought according to particular months, includes some communities that also apply the traditional Javanese agriculture calendar that is called *pranata mangsa* and was made as a result of observation and used as a practical guide for agricultural activities and integrated pest management. However, the application of *pranata mangsa* is still in dispute, as some communities believe that the calendar is no longer suitable with the current climate that keeps changing. Knowing the planting season is considered essential, in order to know which seeds to plant as the first crop of the year and substitute plants, either to be self-consumed or as cash crops, and to harvest the crops. Thus, when the first crop is planted late due to a delay in onset of the rainy season, then drought can affect the second crop that is commonly planted afterwards during extreme climate events. Generally, the first crop is planted in October-November for dry land paddy, continuing to harvest time in January-February. The second crop or *palawija* is planted in March-April to be harvested in May. While during the dry season in June-July-August-September, the communities are preparing the fields for the next plantation as well as harvesting cassava as the annual crop.

Furthermore, a long dry season caused by the extreme climate event, El Niño was experienced by the communities in Pacitan as the shift of seasons particularly in terms of the agricultural planting season and the time where water sources are severely depleted. The communities believe that the long dry season occurs every eight to ten years; thus they think that water sources need to be protected to preserve water during the rainy season when water is plentiful. Several occurrences of long dry seasons in Pacitan that were collected from interviews and FGDs were matched with the record of El Niño events from NOAA. *Telaga*, *belik*, and rainwater harvesting are considered as some of the adaptation strategies to cope with limited water, although the communities prefer not to use these when they have water connections from PDAM.

The existence of PDAM is essential for the communities in Donorojo, Punung, and Pringkuku, where these three *Kecamatan* have the highest number of customers in Kabupaten Pacitan among other *Kecamatan*. PDAM has built two IPAs in Donorojo and Pringkuku and covered almost 70% of water users in the three *Kecamatan* which use perennial springs as their water sources. *Kecamatan* Pringkuku has the highest number of water sources within the three *Kecamatan*, where most of those are perennial springs. Meanwhile other *Kecamatan* mostly have seasonal springs that are filled with water during the rainy season and depleted during the dry season. The price that PDAM charges to its customers is a progressive tariff which the customer pays according to their needs, 10 m<sup>3</sup> for Rp. 31.400 (€ 2) per month and Rp. 2640 (€ 2 cents) for every 1 m<sup>3</sup> of water that they use after that. Generally, the communities are willing to pay the water tariff despite of the

technical challenges that PDAM encounters in maintenance and water rotation that is done based on the time division. PDAM users in the northern part of IPA Pringkuku receive water for 14-15 hours a day and in the southern part for 17-18 hours per day; therefore water storage is essential for PDAM users to store water while water is running.

The communal inter-relation within the communities of karst areas of Pacitan is relatively solid which makes the social capital one of the essential factors in water resource management. The relation is shown by having communal water infrastructure, such as water sanitation systems for those who still do not have their own water infrastructure, which was initiated by the head of the village and the communities. Furthermore, water infrastructures are also built communally by the communities that are not yet connected by PDAM, by establishing long pipes to distribute water connections from water source to houses. This program was also initiated both from the communities and the head of the village. In the tourism sector, several sites are organized communally where the maintenance and operational costs are managed by the local community group and local government of Pacitan.

Water needs in Donorojo, Punung and Pringkuku are adjusted with the availability of water, where one household generally uses 10m<sup>3</sup> or 10,000 liters for four to five persons in one month. That means every person use roughly 80 liters per day for domestic use, including watering plants. The communities differentiate their water needs based on the water sources. Those with pipe connection to PDAM get most of their water to meet their needs from PDAM, whereas those who do not have PDAM use water from springs and dug/drilled wells for their daily domestic needs and PAH for washing clothes, as well as watering plants.

Despite the challenges of regulation being implemented, the institutional water governance in Pacitan is able to cope with the complexity of water management as well as the uncertainty of climate variability. Information regarding villages that have severe water issues is collected by the head of each village and given to the regional government at the end of the rainy season; thus when the dry season starts, water tankers from PDAM are ready to distribute water to the villages which severely need water free of charge. Although the water tankers are not necessarily sufficient to cover every village, the head of each village tries to find water sources to fulfil their water needs.

In addition, the essence of having records or archiving significant documents that are attributable to any sector, such as old maps, historical documents and photos, and time series climate data which can be support studies are not sufficiently done by the local government and authorities. As the decentralization program from central government takes place, the local agencies in the regional government are moving from

one place to another, resulting in the shifting of authorities and the archived documents are not well kept.

## 7.1. Hypotheses Review

After reviewing the research findings in the previous sub-chapter, the hypotheses of the research are briefly reviewed in this sub-chapter by looking back at every hypothesis depicted in chapter 1.

(H1): Water is an indispensable commodity for every individual, thus the access to water resource is also essential

As declared in the 1945 Indonesian Constitution (*Undang Undang Dasar 1945*) as the legal basis in law Section 33 Article 3 states, “The land and the water as well as the natural riches therein are to be controlled by the state to be exploited to the greatest benefit of the people”. This indicates that natural resources including water are essential good to be used for every person. Resource management ideally looks into every aspect and reference to be applied. The state or country has the right to fully manage water, including its infrastructure in the form of ownership to be used by every person. The state also has the right to give responsibility to the private sector in terms of water management without excluding the needs of people. Therefore, water access is essential for every person regardless of their geographical position and their physical environment. The central government has the responsibility to convey their task and responsibility to manage water into regional regulation. However, the Law No. 7/2004 on Water Resources Section 7, 8, and 9 implicitly gives this right to the private sector freely. This may interpreted as the private sector now has the full right to privatize the water sector and neglecting the needs of people.

(H2): There is correlation between climate variability, karst topography, water management, water scarcity and number of population in karst areas of Pacitan

The karst geomorphology of Pacitan does not enable the communities to have abundant surface water sources, particularly during the dry season where most of precipitation trickles down immediately down into an extensive system of sinkholes and caves. The change of climate variability, including the increase of temperature and less rainfall, as well as longer dry seasons and the shift of season, play an important role in water management in karst areas of Pacitan. Rain-fed agriculture is more vulnerable due to changes in climate variability where the karst structure does not enable irrigation for agricultural purposes. Water scarcity issues occur in almost every dry season with several villages severely affected by lack of water and where these communities need to walk up several kilometers to fetch water. However, the coverage of PDAM in most areas of

Pacitan enables those communities to get water easily from their houses. Although there are still some areas which are not yet covered by PDAM and still rely on other water sources like dug/drilled wells and PAH for their daily needs. Due to the physical environmental constraints, the communities, particularly the heads of households in *Kecamatan* Donorojo, Punung and Pringkuku, opt to do seasonal migration to other cities particularly during the dry season or when long dry seasons occur to get more income, while their families work in the agricultural field. Thus, generally the population from 2000 to 2012 has slightly decreased around 10% although the population in Pacitan has increased by roughly 13% between 1971 and 2010. Thus, the physical constraints in karst areas of Pacitan force the community to get better income from outside the city and return during the planting season.

*(H3): The local community acknowledges the existing adaptive capacity and the local wisdom that is attributable to water use in karst areas*

Agriculture and the water sector play an important role in terms of adaptive capacity in the community of Pacitan, particularly in the social economy. The making of terraces in sloping lands is considered the oldest and widest practice that has been implemented in the agricultural sector to retain moisture and sustain soil resilience. Planting dry land crops, such as dry land paddy, maize, groundnut, cassava and soya bean are also some of the existing adaptive capacities that are still being applied in recent times, resulting in *Kecamatan* Donorojo, Punung, and Pringkuku being the producers of those dry land crops for other areas in Pacitan. Planting the aforementioned crops is based on the seasonal calendar which generally starts in October when water is plentiful. Other adaptation strategies in agricultural practices include the traditional Javanese calendar, called *pranata mangsa*, which can be roughly converted into a Gregorian calendar that starts in July and runs until December for the onset of planting season, with January to June considered as the harvest season. However, the changes in climate variability have caused the validity of *pranata mangsa* to be disputed due to the science of its wisdom no longer reflecting reality. The younger generation are starting not to be as dependent on it as the senior generation are. From the water sector, the existence of PAH, *belik*, and *telaga* as water source options are also significant, particularly for the communities who are not yet connected by PDAM. Although nowadays the communities no longer use *telaga* as a water source except for fisheries purposes; however PAH and *belik* are still considered important, particularly in the northern part of Punung where PDAM has more constraint in terms of pipe installation.

## 8. RECOMMENDATIONS

In order to enhance water resource management particularly in the karst areas, where water is limited during the dry season, good governance in water resource management that depends on adaptive institutions as well as public participation are essential. Therefore, the involvement of stakeholders at every level to reduce vulnerability is recommended to cope with the complexity of water management and the uncertainty of climate variability. Water is as indispensable good that needs to be available for people, thus access to water needs to be provided by the central and regional government as the representative of the people. Certain elements such as adequate access to and distribution of information, as well as cooperation between governments and public participation needs to be focused on, in order to achieve institutional adaptation.

Due to decentralization by the Indonesian government where accountability is shared in terms of water and climate related regulation, the local government has more authority in governance management than it had before. Cross-administrative border issues often occur within institutional agencies in several regional governments due to the cross-border system that affects water resource management. Coordination between governmental agencies and regional governments needs to be more considered in order to manage water resources properly. Implementation of regulation from central government at regional government level also needs to be strengthened to get integrated coordination within these institutions. Working Groups (*Pokja*) as a top-down approach from central government needs to be more supported by relevant institutions from different sectors, as well as including public participation in a down-top approach.

Public-private partnership (PPP) may improve the development of water infrastructure and extend water supply through finance development, as long as water users are the beneficiaries of the water program. Although increasing public awareness and participation, transparency and accountability within PPP still has obstacles, incorporating institutions in terms of capacity building can improve public water service infrastructure by convening round-table discussions and facilitating negotiations between actors in the public and private sectors, as well as in the local communities.

Further research can be conducted in the future to measure water vulnerability of karst areas by taking water balance as a physical factor and the perception of communities regarding PDAM, as well as water demand as social factors into consideration. A vulnerability index can be measured by reviewing geographical conditions and analyzing which areas are more vulnerable to water access and to review the resilience level of the communities to cope with limited water, as well as by taking

longer periods of observation of climate variability to have a comprehensive measurement of climatic conditions in the respective areas.



## 9. SUMMARY

The Gunung Kidul karst areas, particularly around Pacitan, now face water challenges that need particular adaptation strategies. Seasonal changes in rainfall, as well as in temperature have changed the hydrological cycle, increased the intensity of drought and altered the cultivation seasons. Limited water availability is also affecting social structures. Furthermore, due to the geomorphological of the karst in Pacitan, where most of the precipitation immediately trickles down into an extensive system of sinkholes and caves, water scarcity has become the prominent issue, particularly in the Western areas of Pacitan that intersect with the Gunung Sewu karst areas, namely Kecamatan Donorojo, Kecamatan Punung and Kecamatan Pringkuku.

Surface rivers and point recharge water sources in the region are limited, where ponors drain water away from closed depressions during the rainy season. Therefore, rainfall and underground rivers are the main water sources in these regions. However, PDAM (*Perusahaan Daerah Air Minum*) or the Piped Water Supply that was developed in Pacitan in 1992, has been contributing water to these areas since 2004 and has expanded its coverage and service areas, particularly in the three *kecamatan* by building IPA (*Instalasi Pengolahan Air*). PDAM and The Ministry of Public Work are currently cooperating to cover the rest of the area by utilizing perennial water sources and by supporting the installation of water treatment infrastructure, especially in these three *kecamatan*.

The significant difference between the rainy and dry seasons enables the community to follow a particular agricultural system that plants cultivars that can hold water during the rainy season and resist low water conditions during the dry season. The three *Kecamatan* are also the main suppliers of dry land paddy in Pacitan, which for these communities is the main staple food. Multiple cropping systems enable the community to have several dry crops at the same time in their fields and then plant groundnut or maize as a second crop after the dry paddy is harvested. The communities also utilize other water sources, like *belik* or small springs found among small stalagmites that are formed by the percolation of water on cave floors, particularly during the dry season when water is limited. *Telaga*, or little lakes filled with rainfall, are no longer used for domestic purposes by the communities, except for fisheries and agricultural purposes during the rainy season due to its water quality. Rainwater harvesting or PAH (*Penampung Air Hujan*) is still used by some communities that are not yet connected to PDAM. Although the use of PAH is limited to washing clothes and is not used for drinking purposes, the existence of PAH is considered essential for these communities.

Another existing adaptation strategy that has developed in Pacitan is in the agriculture sector. Pacitan is in a monsoon area and is vulnerable to drought, normally during the second crop period whenever the rainy season ends earlier than usual or when rainfall in the dry season is below normal. Drought can also be encountered when the second crop is planted late due to a delay in the onset of rainy season. These conditions commonly occur during extreme climate events like *El Niño*. Therefore, it is important to plant the first crop at the beginning of rainy season in October/November, when water is available, so that the community knows when they will harvest the dry land paddy and plant the second round of dry land crops (*palawija*) afterwards.

During the dry season, between July and September, the community starts fallowing the fields to prepare for the next planting season, as well as harvesting cassava as one of the main dry land crops. Thus, if the onset of the rainy season shifts or if there is a prolonged dry season, rice cannot be planted, as rice needs plenty of water during the planting season. In this situation secondary crops play an important role as substitute plants, either for basic subsistence or as cash crops. During the dry season some communities even prefer to leave the area bare, since no water is available to do agricultural activities. Traditionally the community has also used the Javanese agricultural calendar called *pranata mangsa* for observing agricultural activities and integrated pest management based on climatological phenomenon. The practice which has been passed from generation to generation is disappearing among the younger generation due to the many anomalies in climate variability and shifting seasons which are making the *pranata mangsa* is being disputed.

The population in each of the three *Kecamatan* is around 50,000 inhabitants, averaging around 90 litres of water use per person per day. Meanwhile, based on the regulations, PDAM generates basic water requirements for domestic use of 10 m<sup>3</sup> per month or around 60 litres per capita per day, assuming there are five family members in a household. However, the amount of 10 m<sup>3</sup> per month is not always sufficient to fulfill water needs in one household, particularly for households which have other subsistence activities besides livestock and agriculture. Such households need to pay more for every additional one m<sup>3</sup> of water they use above the allocated 10 m<sup>3</sup> monthly amount. The communities are used to living with limited water availability and they treat water as a significant resource. Based on the conducted research, the communities that are connected with PDAM use most of their water for primary needs such as drinking, cooking and washing. Meanwhile, those that are not yet connected to PDAM use the water from PAH for washing and buy water from private groups for drinking and cooking purposes.

The existence of PDAM is significant for the communities in Pacitan, particularly in the karst areas. The communities rely greatly on PDAM, as well as on their dug/drilled wells that are built by themselves or communally. During the dry season when water is limited, the communities that are not yet connected with PDAM use water either from PAH, the nearest perennial springs that are still running or buy water from water tankers that are run by private companies and cost more than PDAM. Nevertheless, there are some areas of Donorojo, Punung and Pringkuku which have community-based water groups called HIPPAM (*Himpunan Penduduk Pengguna Air Minum*). These HIPPAM organize water delivery from natural water sources to the communities at less cost than PDAM. However, the existence of HIPPAM has decreased since PDAM was established, because the communities prefer to have connections with PDAM due to its convenience in terms of water taking.

Generally, Pacitan has succeeded in water governance. Pacitan is able to cope with the complexity of water management by having PDAM and the Ministry of Public Work. Since 2004, PDAM has been expanding its service and the local government in Pacitan has been collecting information from the heads of the villages in the three *Kecamatan* that suffer severe water issues, so that further actions can be taken to tackle water shortages in the respective areas. Although number of communities still suffers water scarcity every dry season, the local government of Pacitan is increasing their service to such communities, particularly in the provision of water needs. However, in terms of climate change adaptation, the implementation of top-down regulations is not well enforced. The regulations that are formed by the central government through DNPI (*Dewan Nasional Perubahan Iklim*) or the National Board on Climate Change regarding greenhouse gas emission reduction strategy and mainstream climate change adaptation policies are not well implemented. Local governments as well as the communities do not acknowledge the regulations. Therefore, public participation in down-top approaches will be essential to successfully enforce the existing regulation systems. Furthermore, Public-Private Partnerships (PPP) can also be used to help improve and finance the development of water infrastructure and extend the water supply, as long as water users are the beneficiaries of the water program.

## 10. BIBLIOGRAPHY

### 10.1. Monographs, Articles and Books

- ADGER, W. N. (1999a):** *Social Vulnerability to Climate Change and Extremes in Coastal Vietnam*. World Development 27(2). pp. 249-269.
- ADGER, W. N. (2000b):** *Social and Ecological Resilience: Are they related?* Progress in Human Geography 24 (3), pp. 347-364).
- ADJI, T. N. (2010):** *Spatial and Temporal Variation of Hydrochemistry and Karst Flow Properties to Characterize Karst Dynamic System in Bribin Underground River, Gunungkidul Regency, DIY Provice, Java, Indonesia*. Dissertation. Universitas Gadjah Mada. Yogyakarta.
- ANNANDALE, G. (2012):** *Quenching the Thirst – Sustainable Water Supply and Climate Change*. CreateSpace Independent Publishing Platform. North Charleston. USA.
- ARNELL, N. C., LIU, C., COMPAGNUCCI, R., DA CUNHA, L., HANAKI, L., HOWE, C., MAILU, G., and I. A. SHIKLOMANOV. (2001):** *Hydrology and Water Resources. In Climate Change 2001: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University. Cambridge.
- AXINN, W. G., and J.S. Barber. (2003):** *Linking People and Land Use. In People and The Environment: Approaches for Linking Household and Community Surveys to Remote Sensing and GIS*. Kluwer Academic Publishers. USA.
- BADAN NASIONAL PENANGGULANGAN BENCANA/BNPB. (2010):** *Peta Kejadian Bencana Kekeringan di Indonesia Tahun 1979-2009*. BNPB. Jakarta.
- BADAN PUSAT STATISTIK PACITAN [BPS PACITAN]. (2010a):** *Hasil Sensus Penduduk 2010 Kabupaten Pacitan*. Pacitan.
- BADAN PUSAT STATISTIK PACITAN [BPS PACITAN]. (2012b):** *Pacitan Dalam Angka*. Badan Pusat Statistik Kabupaten Pacitan. Pacitan.
- BADAN PUSAT STATISTIK. (2012):** *Perkembangan Beberapa Indikator Utama Sosial Ekonomi Indonesia*. Badan Pusat Statistik. Jakarta.
- BADAN PUSAT STATISTIK. (2010).** *Biro Pusat Statistik*. Jakarta.
- BAKALOWICZ, M. (2004):** *Karst Groundwater: A Challenge For New resources*. Hydrogeology Journal 13. pp. 148-160.
- BANDARAGODA, D. J. (2006):** *Institutional Adaptation for IWRM: An Effective Strategy for Managing Asian River Basins*. International Water Management Institute. Colombo.
- BALASZ, D. (1968):** *Karst Regions in Indonesia: Karszt-Es Barlangkutatas*, Vol. V. p.61. Budapest
- BARTSTRA, G.-J. (1976):** *Contribution to the Study of the Paleolithic Patjitan Culture, Java Indonesia Band 1*. Leiden: E.J. Brill.

- BAUER, S. (2006):** *Flächenverbrauch und Grundwasserschutz*. Beitrag zur Grundwasserposition BUND. Berlin.
- BERLAGE, H.P. (1966):** *The Southern Oscillation and World Weather*. K. Ned. Meteorol. Inst., Meded. Verh. 88, pp. 152.
- BERGER, R., REID, H., ALAM, M., CANNON, T., HUQ, S., and A. MILIGAN, A. (2009):** *Participatory Learning and Action*. The International Institute for Environmental and Development (IIED). Nottingham. UK.
- BOER, R. LAS, I., PURWANI, E. T., TAMKANI, K., M. A. RATAQ. (2008).** *Increasing Adaptive Capacity of Farmers to Extreme Climate Events and Climate Variability through Enhancement of Policy-Science-Community Networking*. Asia Pasific Network for Global Change Research.
- BOHLE, H.-G. (2001):** *Vulnerability and Critically. Perspectives from Social Geography*. IHDP Update 2/2001. Newsletter of the International Human Dimensions Programme on Global Environmental Change, pp. 1-7.
- BOUDAGHER-FADEL, M. L. and LOKIER, S. W. (2005):** *Significance Miocene Larger Foraminifera from South Central Java*. *Revue de Paléobiologie Genève* , pp. 291-309.
- BONELL, M., and M. BALEK (2006):** *Recent Scientific Developments and Research Needs in Hydrological Processes of the Humid Tropics*. Cambridge University Press. Cambridge.
- BROOKS, N., ADGER, W. N., KELLY, P. M. (2004):** *The Determinants of Vulnerability and Adaptive Capacity at the National Level and the Implications for Adaptation*. *Global Environmental Change* 15, pp. 151.163.
- BRONTOWIJONO, W. (2008):** *Sustainable Water Resources Management with Special Reference to Rainwater Harvesting; Case Study of KarManTul, Java, Indonesia*. Uni Karlsruhe: Karlsruhe.
- BROWN, A., and MATLOCK, M. D. (2011):** *A Review of Water Scarcity Indices and Methodologies*. The Sustainability Consortium. White Paper 106. University of Arkansas
- BURTON, I., and E. MAY. (2004):** *The Adaptation Deficit in Water Resource Management*. IDS Bulletin 35, pp. 31-37.
- CARTER, T.R., JONES, R.N., LU, X., BHADWAL, S., CONDE, C., MEARNES, L.O., O'NEILL, B.C., ROUNSWELL, M.D.A. and M.B., ZUREK. (2007):** *New Assessment Methods and the Characterization of Future Condition*. In: PARRY, M.L., CANZIANI, O.F., PALUTIKOF, J.P., VAN DER LINDEN, P.J. and C.E., HANSON (eds), *Climate Change 2007: Impacts Adaptation van Vulnerability*. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge. pp. 133-171
- CHAMBERS, R. (1994):** *The Origins and Practice of Participatory Rural Appraisal*. World Development. Vol. 22. No. 7. pp 953-969.

- DALDJOENI, N. (1984):** *Pranatamangsa, the Javanese Agriculture Calendar - Its Bioclimatological and Sociocultural Function in Developing Rural Life.* Environmentalist Vol. Issue 7, pp. 15-18.
- D'ARRIGO, R. W., WILSON, R., PALMER, J., KRUSIC, P., CURTIS, A., SAKULICH, J., BIJAKSANA, S., ZULAIKAH, S., L. O. NGKOIMANI (2006):** *Monsoon Drought Over Java, Indonesia, During the Past Two Centuries.* In: *Geophysical Research Letters*, Vol. 33, L04709.
- DIRECTORATE GENERAL OF WATER RESOURCES. (1979):** *East Java Groundwater Survey.* Vol.2. Ministry of Public Work. Government of Indonesia. Jakarta.
- DITTMANN, A., FACH, S., FUCHS, S., HOSSU, M., NESTMANN, F., and P. OBERLE. (2011):** *Aspekte des Wasserressourcen-Managements in Karstgebieten am Beispiel der Region Gunung Kidul auf Java, Indonesien.* In Bundesanstalt für Gewässerkunde für Fachverwaltungen des Bundes und der Länder: Hydrologie und Wasserbewirtschaftung 55, 2. Koblenz, pp. 57-67.
- EAKIN, H., and LUERS, A. L. (2006):** *Assessing the Vulnerability of Social-Ecological Systems.* Annual Review Environmental Resources (31). pp. 365-394.
- ENGLE, N. L. (2011a):** *Adaptive Capacity and Its Assessment.* Global Environ Change 1, pp. 647–656.
- ENGLE, N. L., JOHNS, O. R., LEMOS, M. C., and D. R. NELSON. (2011b):** *Integrated and Adaptive Management of Water Resources: Tensions, Legacies, and the Next Best Things.* Ecology and Society 16(1): 19.
- ERDÉLYI, M. and J. GÁLFI. (1988):** *Surface and Subsurface Mapping in Hydrogeology.* John Wiley & Sons. Budapest.
- FALKENMARK, M. (1989):** *The Massive Water Scarcity Threatening Africa-Why isn't it being addressed.* Ambio 18. No. 2, pp.112-118.
- FALKENMARK, M., and J. ROCKSTRÖM (2005):** *The New Blue and Green Water Paradigm: Breaking New Ground for Water Resources Planning and Management.* Editorial.
- FANKHAUSER, S. (1998):** *The Costs of Adapting to Climate Change.* GEF Working Paper 16, The Global Environmental Facility. Washington.
- FAO. (2007a):** *Coping with water scarcity; challenge of the twenty-first century.* UN Water.
- FAO. (2008b):** *Adaptation to Climate Change in Agriculture, Forestry and Fisheries: Perspective, Framework and Priorities.* Rome.
- FAO. (2008c):** *Coping with water scarcity; An action framework for agriculture and food security (FAO Water Reports).* Rome: FAO.
- FAO. (2010d):** *Aquastat Survey 2012.* FAO.
- FLATHE, H and PFEIFFER, D. (1965):** *Grundzüge der Morphologie, Geologie und Hydrogeologie im Karstgebiet Gunungsewu/Java (Indonesien).* Geol. Jb 83 , pp. 533-562.

- FREDERICK, K.D., and D. C. MAJOR. (1997):** *Climate Change and Water Resource - The Management of Water Resources*. Climatic Change 37, pp 7-37.
- FORD, D. W. (1989):** *Karst Geomorphology and Hydrology*. London: Unwin Hyman.
- FÜSSEL, H. M. (2007):** *Adaptation Planning for Climate Change: Concepts, Assessment Approaches and Key Lessons*. Sustain Science (2), pp. 265-275.
- GALLOPÍN, G. (2006):** *Linkages between Vulnerability, Resilience and Adaptive Capacity*. Global Environ Change 16(3), pp. 293–303.
- GARDNER-OUTLAW, T., and R. ENGELMAN (1997):** *Sustaining Water, Easing Scarcity: a second update. Population and Environmental Programme*. Population Action International. Washington D.C.
- GEO GLOBAL ENVIRONMENT OUTLOOK 3 (2002):** *State of the Environment and Policy Responses 1972-2032*. Chapter 2 Freshwater. Still Pictures. London.
- GIERTZ, S. B., DIEKKRÜGER, B., JAEGER, A., and M. SCHOPP. (2006):** *An Interdisciplinary Scenario Analysis to Assess the Water Availability and Water Consumption in the Upper Catchment in Benin*. Adv.Geoscience 9, pp. 3-13.
- GLANTZ, M.H. (1996):** *Currents of Change: El Niño's Impact on Climate and Society*. Cambridge University Press. USA.
- GLEESON, T., Y. WADA, M.F.P. BIERKENS, and L.P.H. VAN BEEK. (2012):** *Water Balance of Global Aquifers Revealed by Groundwater Footprint*. Nature 488. doi:10.1038/nature11295 , pp. 197-200.
- GLEICK, P. H. (1996a):** *Basic Water Requirements for Human Activities: Meeting Basic Needs*. Water International 21, pp. 83-92.
- GLEICK, P. H. (1998b):** *Water Planning and Management Under Climate Change: Global Change and Water Resource Management*. University of Council on Water Summer. Washington D.C.
- GRAY, W.M. (1993):** *Forecast of Atlantic Seasonal Hurricane Activity for 1993*. Fort Collins. C.O. Colorado State University.
- GROTHMANN, T., and A. PATT. (2005):** *Adaptive capacity and human cognition: The Process of individual adaptation to climate change*. Global Environmental Change vol.15 no.3. pp.199-213
- HANDOKO. (1995):** *Klimatologi Dasar. Landasan Pemahaman Fisika Atmosfer dan Unsur-Unsur Iklim*. Pustaka Jaya. Jakarta.
- HARGONO, B., SARTOHADI, J., HADI, P., SETIAWAN, B., and F. NESTMANN. (2012):** *Water Scarcity Assessment in the City of Yogyakarta*. Integrated Water Resources Management; Hartwig Steusloff (eds) (pp. 186-194). Karlsruhe: KIT.
- HARYONO, E., and M. DAY (2004a):** *Landform Differentiation Within the Gunung Kidul Kegelkarst, Java Indonesia*. Journal of Cave and Karst Studies v.66 no. 2 , pp. 62-69.
- HARYONO, E. (2008b).** *Gunungsewu Karst Ecosystem Java Indonesia; Unpublished PhD Paper*. Yogyakarta: Universitas Gadjah Mada.

- HENDON, H. (2002):** *Indonesian Rainfall Variability: Impacts of ENSO and Local-Air Sea Temperature*. In: American Meteorological Society Vol. 16 , pp. 1775-1790.
- HOLTHUIS, L.B. (1984):** *Freshwater Prawns (Crustacea Decapoda: Natantia) From Subterranean Waters of the Gunungsewu Area, Central Java, Indonesia*. Zoologische Mededelingen. Deel 58 No.9
- HUITEMA, D., E. MOSTERT, W. EGAS, S. MOELLENKAMP, C. PAHL-WOSTL, and R. YALCIN. (2009):** *Adaptive water governance: assessing the institutional prescriptions of adaptive (co-)management from a governance perspective and defining a research agenda*. Ecology and Society 14(1): 26
- INDONESIAN NATIONAL COMMITTEE FOR GEOPARKS (2013):** *Aspiring National Geopark of Gunung Sewu, Java*. Dossier Revision of Gunung Sewu Aspiring Geopark, Java, Indonesia.
- INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (2007):** *Climate Change 2007: Synthesis Report*. In PACHAURI, R. K and REISINGER, A.(eds). Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change .IPCC, Geneva, Switzerland.
- INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (2012):** *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*. A Special Report of Working Group I and II of the Intergovernmental Panel on Climate Change [Field, C.B., Barros, V., Stocker, T. F., Qin, D., Dokken, D. J., Ebi., K. L., Mastrandrea, M. D., Mach, K. J., Plattner, G.-K., Allen, S. K., Tignor, M, and P. M. Midgley (eds.)]. Cambridge University Press. Cambridge, UK, and New York. USA.
- JAEGER, W. K., PLANTINGA, A.J., CHANG, H, DELLO, K., GRANT, G., HULSE, D., McDONNELL, J. J., LANCASTER, S., MORADKHANI, H., MORZILLO, A, T., MOTE, P., NOLIN, A., SANTELLMANN. M., and J. WU. (2013):** *Toward a Formal Definition of Water Scarcity in Natural-Human Systems*. Water Resources Research Vol. 49. pp. 4506-4517.
- JASPERS, F. G. W. (2003):** *Institutional Arrangements for Integrated River Basin Management*. Water Policy 5 , pp. 77-90.
- JODHA, N. S. (1975):** *Famine and Famine Policies - Some Empirical Evidence*. Economic and Political Weekly 10(41), pp. 1609-1623.
- JONES, I.C., and J. L. BANNER. (2003):** *Hydrogeologic and Climatic Influences on Spatial and Interannual Variation of Recharge to a Tropical Karst Island Aquifer*. Water Resources Research. Vol. 39. No. 9. 1253.
- KRESIC, N. (2013):** *Water in Karst-Management, Vulnerability, and Restoration*. McGraw Hill. New York.
- KEATES, S. P. (2004):** *Quaternary Research in Indonesia*. London: Taylor & Francis.
- KUNDZEWICZ, Z. L., MATA, L.J., ARNELL, N. W., DÖLL, P., KABAT, B., JIMÉNEZ, B., MILLER, K., OKI, T., ŞEN, Z., and I. A. SHIKLOMANOV. (2007):** *Freshwater Resources and Their Management*. In PARRY, M.L., CANZIANI, O.F., PALUTIKOF, J.P., VAN DER LINDEN, P.J. and C.E., HANSON (eds). *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working*



*Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press. Cambridge, UK.

- LANGFORD, M. (2005):** *The United Nations Concept of Water as Human Right*. Water Resources Development Vol. 21. No.2 , pp. 273-282.
- LEHMANN, H. (1936):** *Morphologische Studien auf Java Geographische Abhandlungen* Series 3 No 9. Stuttgart.
- LENTON, R. (2004):** *Water and Climate Variability: Development, Impacts and Coping Strategies*. Water Science Technology 49 (7) , pp. 17-24.
- LINACRE, E. (1992):** *Climate and Data Resources*. Routledge. New York.
- LUKAS, M. and D. STEINHILPER. (2005):** *Living Condition in the Gunung Sewu Karst Region (Java Indonesia)*. Giessen: Institut für Geographie, Universität Justus-Liebig Giessen.
- MAKMUR, E. (2009):** *Drought Assessment Over Indonesia Related to El Nino and SSTA Indonesia*. Inter-Regional Workshop on Indices and Early Warning System for Drought, (p. 26). Nebraska.
- MARDIATNO, D. (2008):** *Tsunami Risk Assessment Using Scenario-Based Approach, Geomorphological and GIS. PhD Thesis*. University of Innsbruck. Innsbruck.
- MARWANTO H, SUBANDRIO A, RIYANTO ABN, and SUHARSONO. (1999):** *Study of the Trace of Ancient Solo River in the Southern Wonogiri, Central Java*, UPN Veteran Yogyakarta.
- MATANESIA MAGAZINE. (2011):** *Pacitan Menuju Geopark Dunia. Monthly; 4th Edition* , pp. 7-11. Surabaya, East Java.
- METZGER, N. J., LEEMANS, R., and D. SCHRÖTER. (2005):** *A Multidisciplinary Framework for Assessing Vulnerabilities to Global Change*. International Journal of Applied Earth Observations and Geoinformation Vol. 7. No. 4. pp. 253-267.
- MINISTRY OF SETTLEMENTS AND REGIONAL INFRASTRUCTURE. (2003):** *Water Resources Management Towards Enhancement of Effective Water Governance in Indonesia*. World Water Council. France.
- MINISTRY OF NATIONAL DEVELOPMENT PLANNING/BAPPENAS. (2012a):** *National Action Plan for Climate Change Adaptation (RAN-API)*. Jakarta.
- MINISTRY OF NATIONAL DEVELOPMENT PLANNING/BAPPENAS. (2014b):** *Rencana Aksi Nasional Adaptasi Perubahan Iklim (RAN-API)*. Jakarta.
- MOHIELDEEN, Y. (1999):** *Responses to Water Scarcity: Social Adaptive Capacity and the Role of Environmental Information. A Case Study from Ta'iz, Yemen*. Occasional Paper No.23 .
- MOLLE, L. (2008):** *Why Enough is Never Enough: The Societal Determinants Of River Basin Closure*. International Journal of Water Resource Development, 24(2), pp 247-256.
- MOSER, S. C., and J. A. EKSTROM. (2010):** *A Framework to Diagnose Barriers to Climate Change Adaptation*. doi/10.1073/pnas.1007887101.

- MUKHEIBIR, P. (2010):** *Water Access, Water Scarcity and Climate Change*. Environmental Management 45 , pp. 1027-1039.
- MUKTI, M. S. (2005):** *Carbonate Depositional Environment and Platform Morphology of the Wonosari Formation in the Area of East of Pacitan*. Riset- Geologi dan Pertambangan Jilid 16 No. 2 , pp. 29-38.
- NABHAN, G. P. (2013):** *Growing Food in a Hotter Drier Land. Lessons from Desert Farmers on Adapting to Climate Uncertainty*. Chelsea Green Publishing. USA.
- NELSON, D.R., ADGER, W.N., and K. BROWN. (2007):** *Adaptation to Environmental Change: Contributions of a Resilience Framework*. Annual Review of Environmental and Resources 32, pp. 395-419.
- NESTMANN, F., OBERLE, P., IKHWAN, M., LUX., T., SCHOLZ, S. (2009):** *Bewirtschaftung unterirdischer Fließgewässer in Karstgebieten - Pilotstudie auf Java, Indonesia*. WasserWirtschaft - Hydrologie, Wasserbau, Hydromechanik, Gewässer, Ökologie, Boden. Vol. 99. No. 7/8, pp 12-18.
- NIBBERING, J. (1991):** *Crisis and Resilience in Upland Land Use in Java*. In HARDJONO, J (eds): Indonesia:Resources, Ecology, and Environment , pp. 104-132.
- O'BRIEN, L. K., and R. M. LEICHENKO (2008):** *Climate Change, Globalization and Water Scarcity*. Expo Zaragoza. Spain.
- O'RIORDAN, T., COOPER, C. L., JORDAN, A., RAYNER, S., RICHARD, K. R., RUNC, K. R., and S. YOFFE. (1998):** *Institutional Frameworks for Political Action*. In RAYNER, S. and MALONE, E. (eds.). Human Choice and Climate Change. Volume 1. The Societal Framework. Washington D.C. Battelle Press, pp. 345-439.
- OHLSSON, L. (1999):** *Water Conflicts and Social Resource Scarcity*. Phys. Chem. Earth (B) Vol 25 No. 3 , pp. 213-220.
- OHLSSON, L. (1999):** *Environment Scarcity and Conflict. A Study of Malthusian Concern*. PhD Thesis. Department of Peace and Development Research. Göteborg University. Sweden.
- PAHAN, I. (2007):** *Panduan Lengkap Kelapa Sawit: Manajemen Agribisnis dari Hulu hingga Hilir*. Penebar Swadaya. Jakarta.
- PAHL-WOSTL, C. (2006):** *The Importance of Social Learning in Restoring the Multifunctionality of Rivers and Floodplains*. Ecology and Society 11(1), pp. 10.
- PANGAU-ADAM, M. (2009):** *Climate Change in Indonesia: Impacts and Mitigation Strategies*. Proceeding of the International German Alumni Summer School, Manado.
- PAWITAN, H. (2009):** *Water Management Issues and Technology Needs in Indonesia*. Master Class Seminar: Water Research and Management. University of Twente.
- PEREIRA, S. L., OWEIS, T., and A. ZAIRI (2002a):** *Irrigation Management under Water Scarcity*. In: Agricultural Water Management 57, p. 175-206.

- PEREIRA, S. L., CORDERY, I., and L. LACOVIDES (2009b):** *Coping With Water Scarcity*. Springer Publisher. New York USA.
- POKJA AMPL DEPARTEMEN KESEHATAN. (2005):** *Laporan Kegiatan Water Quality Assessment Pada PDAM di Indonesia No. 363*. Sub Direktorat Pengamanan Kualitas Air Direktorat Penyehatan Air dan Sanitasi. Departemen Kesehatan. Jakarta.
- POSTEL, S. (1992):** *Lost Oasis: Facing Water Scarcity*. USA: Worldwatch Institute.
- PIK POTSDAM (2012):** *Turn Down the 4 Degree Heat; Why a 4 Degree Celcius Warmer World Must be Avoided*. World Bank. Washington D.C
- PIELKE, R. A. J. (1998a):** *Rethinking the Role of Adaptation in Climate Policy*. Global Environment Change 8. pp. 159-170.
- PIELKE, R. A. J., PRINS, G., RAYNER, S., and D. SAREWITZ. (2007b):** *Lifting the Taboo on Adaptation*. Nature 445, pp. 597-598.
- PRINZ, D., and A. K. SINGH. (2000):** *Water Resources in Arid Regions and Their Sustainable Management*. University of Karlsruhe. Karlsruhe.
- PUSAT STUDI BENCANA (PSBA)-BAPPEDA PACITAN. (2007a).** *Pemetaan Zonasi Daerah Rawan Gempa Untuk Mitigasi Bencana Tsunami*. Pusat Studi Bencana (PSBA). Yogyakarta.
- PUSAT STUDI BENCANA (PSBA)-BAPPEDA PACITAN. (2007b).** *Laporan Pendahuluan Pemetaan Zonasi Daerah Rawan Gempa Untuk Mitigasi Bencana Tsunami di Kabupaten Pacitan*. Pusat Studi Bencana (PSBA). Yogyakarta.
- QUINN, W.H., ZOPF, D.O., SHORT, K.S., and R. T. W. KUO YANG. (1978):** *Historical Trends and Statistics of the Southern Oscillation, El Niño, and Indonesian Droughts*. Fishery Bulletin. Vol. 76. No. 3. pp. 633-678.
- RAJENTHRAN, A. (2002):** *Indonesia. An Overview of the Legal Framework for Foreign Direct Investment*. Economics and Finance No. 4. Institute of Southeast Asian Studies. Singapore.
- RAMU, K. (2007):** *Institutional Framework for Managing Water Resources in National River Basins in Indonesia*. Washington D.C.
- RASMUSSEN, E. M. (1987):** *Global Prospects for the Prediction of Drought: A Meteorological Perspective. Planning for Drought Toward a Reduction of Societal Vulnerability*. In WILHITE, D.A. EVASTEILING, W.E WOOD, D.A (eds). London: Westview Press.
- RIJSBERMAN, F. R. (2006):** *Water Scarcity: Fact or Fiction? Agricultural Water Management* pp. 5-22.
- ROSEGRANT, M. W., EWING, M., YOHE, G., BURTON, I., HUQ, and S., R. VALMONTE-SANTOS (2008):** *Climate Change and Agriculture Threats and Opportunities*. GTZ. Eschborn
- SAMEKTO, C., and E. S. WINATA. (2010):** *Potensi Sumber Daya Air di Indonesia. Seminar Nasional: Aplikasi Teknologi Penyediaan Air Bersih untuk Kabupaten/Kota di Indonesia, (p. 20)*. Jakarta.

- SAMODRA, H. (2005):** *Ekosistem Karst di Wilayah Pacitan. Minerals and Enegery*, Vol. 3. No. 2. Pusat Penelitian dan Pengembangan Geologi. Bandung.
- SARWANTO, BUDIHARTI, R., and D. FITRIANA. (2010):** *Identifikasi Sains Asli (Indigenous Science) Sistem Pranata Mangsa Melalui Kajian Etnosains*. Prosiding Seminar Nasional Pendidikan Biologi FKIP UNS. Solo.
- SAVENIJE, H. H. G. (2000):** *Water Scarcity Indicators; the Deception of Numbers*. Phys. Chem. Earth (B) Vol. 25. No. 3 , pp. 199-204.
- SCHAAKE, J.C. (1990):** *From Climate to Flow*. In Climate Change and U.S. Water Resources. P. E. WAGGONER (eds). pp.177-206. John Wiley, New York.
- SCUDDER, T. (1973):** *The Human Ecology of Big Projects-River Basin Development and Resettlement*. Annual Review of Anthropology. Palo Alto: Annual Review, Inc. pp. 45-55.
- SECKLER, D., AMARASINGHE, U., MOLDEN, D., DE SILVA, R., and R. BARKER (1998):** *World Water Demand and Supply, 1990 to 2025: Scenarios and Issues*. Srilanka: International Water Management Institute.
- SETIONO, I. M., WOODCOCK, J., DJUMHANA, B., SUKARMA, R., and B. PARTON. (2012):** *Indonesia Water Investment Roadmap 2011-2014*. The World Bank, Ministry of Public Works and Water Partnership Program. Jakarta.
- SHIKLOMANOV, I. A. (2000):** *Appraisal and Assessment of World Water Resources*. Water International 25 (1), pp. 11-32.
- SISWOYO, B. (2007):** *Hutan Rakyat dan Serbuan Pasar: Studi Refleksi Pengusahaan Hutan Rakyat Lestari secara Kolaboratif di Pacitan, Jawa Timur*. Jurnal Ilmu Sosial dan Politik, Vol 11. No. 2 , pp. 153-286.
- SJARIEF, R., and R. J. KODOATIE. (2007):** *Perspektif Pengelolaan Sumber Daya Air Terpadu di Indonesia*. In: Lokakarya Kaji Ulang Arah Kebijakan Nasional Pengelolaan Sumber Daya Air (National Policy for Water Resource Management Workshop. 4 April 2007. Jakarta.
- SMIT, B., BURTON I., KLEIN, R.J.T., and R. STREET. (1999a):** *The Science of Adaptation: A Framework for Assessment*. Mitigation and Adaptation Strategies for Global Change 4, pp. 199-213.
- SMIT, B., BURTON, I., KLEIN, R. J. T., and J. WANDEL. (2000b):** *An Anatomy of Adaptation to Climate Change and Variability*. Climatic Change 45, pp. 223-251.
- SMIT, B., and J. WANDEL (2006c):** *Adaptation, Adaptive Capacity and Vulnerability*. Global Environmental Change , pp. 282-292.
- SMIT, B., and O. PILIFOSOVA. (2001d):** *Adaptation to Climate Change in the Context of Sustainable Development and Equity*. In PATWARDHAN, A., and J-F. SOUSSANA (eds). Climate Change 2001: Impacts, Adaptation, and Vulnerability - Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press. Cambridge.

- SOENARTO, B. (2006):** *Pengelolaan Sumber Daya Air di Kawasan Karst*. In MARYANTO, I., NOERDJITO, M. and UBAIDILLAH, R (eds). *Manajemen Bioregional: Karst, Masalah dan Pemecahannya*, pp. 67-85. Puslit LIPI Biologi. Bogor. Indonesia.
- SONKA, S. (1987):** *Adaptation and Adjustments in Drought-Prone Areas: Research Direction*. In E. RASMUSSEN, *Global Prospects for the Prediction of Drought: A Meteorological Perspective; Planning for Drought Toward a Reduction of Societal Vulnerability*. EILHITE, D.A., EASTERLING, W.E., WOOD, D.A (eds) (Chapter 21). Westview Press. London.
- STAKHIV, E. and K. SCHILLING. (1997):** *What Can Water Managers Do About Global Warming?* The Management of Water Resources. Southern Illinois University Carbondale. USA.
- SULTHONI, A. (1985):** *Shooting Period of Sympodial Bamboo Species - an Important Indicator to Manage Culm Harvesting*. Proceedings of the Vth International Bamboo Workshop and the IVth Bamboo Congress. Ubud, Bali. Indonesia.
- SUNKAR, A. (2008):** *Sustainable in Karst Resources Management: The Case of Gunung Sewu in Jawa*. Dissertation. University of Auckland. Auckland.
- SURONO, T. B. (1992):** *Geology of the Surakarta-Giritontro Quadrangle, Jawa*. Jakarta: Geological Research and Development Center, Department of Mines and Energy, Directorate General of Geology and Mineral Resources, Republic of Indonesia.
- SYAUKAT, Y. (2011):** *Development of Piped Water Supply in Indonesia; Problems and Solutions*. Indonesia-Australia Business Conference and Regional Business Forum, (p. 36). Bali.
- TATE, E. L., and A. Gustard. (2000):** *Drought Definition: A Hydrological Perspective*. In: VOGT, J.J. and F. SOMMA (eds) *Drought and Drought Mitigation in Europe*. Kluwer, Dordrecht, pp.23-48.
- TEJALAKSANA, A. (2012):** *Water Management Pollution Policy in Indonesia*. The State Ministry of Environment. Jakarta.
- THE STATE MINISTRY OF NATIONAL DEVELOPMENT. (2011):** *The New Water Policy in Indonesia*. Jakarta.
- TORRY, W. I. (1979):** *Anthropological Studies in Hazardous Environments. Past Trends and New Horizons*. *Current Anthropology* 20(3), pp 517-540.
- TURTON, A. (1999):** *Water Scarcity and Social Adaptive Capacity: Towards an Understanding of the Social Dynamic of Water Demand Management in Developing Countries*. MEWREW Occasional Paper No. 9 Water Issues Study Group .
- UHLIG, H. (1980):** *Man and Tropical Karst in Southeast Asia*. *GeoJurnal* 4.1 , pp. 31-44.
- UN WATER. (2010):** *Climate Change Adaptation: The Pivotal Role of Water*. Policy Brief Publication. Switzerland.
- URUSHIBARA, Y. K and M. YOSHINO. (1997):** *Palaeoenvironmental change in Java Island and its surrounding areas*. *Journal of Quaternary Science*, 12(5), pp. 435–442.

- VAN BEMMELEN, R.W. (1970):** *The Geology of Indonesia*. General Geology Vol.1. Martinus Nijhoff. The Hague.
- VANCLAY, F., LEITH, P., and A. FLEMING. (2009):** *Understanding Farming Community Concerns About Adapting to Changed Climate*. In CZÚCZ, B., TORDA, G., MOLNAR, Z., HORVÁTH, F., BOTTA-DUKSSAT, Z., and KRÖEL-DULAY, G. A Spatial Explicit, Indicator-based Methodology for Quantifying the Vulnerability and Adaptability of Natural Ecosystem. Peter Lang International Verlag der Wissenschaften. Frankfurt.
- VERSTAPPEN, H.T. (1969):** *The State of Karst Research in Indonesia*. In STELCL, O. (eds). Problems of The Karst Research, Brno, Ceskoslovenska Akademie Ciencias. pp.139-148.
- VICKERS, A. (2010):** *Water Use and Conservation*. Waterplow Press. Massachusetts. USA.
- WALTHAM, A. S. (1985):** *Exploration of Caves for Rural Water Supplies in the Gunung Sewu Karst, Java*. Annales de la Société Géologique de Belgique T 108 , pp. 27-31.
- WATTS, M. J. (1980):** The Political Economy of Climatic Hazards-A Village Perspective on Drought and Peasant Economy in a Semi-Arid Region of West Africa. Paper presented to the Congress of the International Geographical Union, Tokyo, Japan. 3<sup>rd</sup> Sept.1980.
- WIGNYOSUKARTO, B.S. (2008).** *Hak Guna Air*. Universitas Gadjah Mada Yogyakarta, Yogyakarta.
- WHITE, C. (2012):** *Understanding Water Scarcity-Definitions and Measurements*. Global Water Forum Discussion Paper 1217. Australia
- WILHITE, D.A. and M. H. GLANTZ.(1987):** *Understanding the Drought Phenomenon: The Role of Definitions*. In: WILHITE D.A., ESTERLING, W. E., WOOD, D.A (eds) Planning for Drought. Vestview Press, Boulder, CO. pp. 11-27.
- WOOSTER, W.S. (1960):** *El Niño*. Calif. Coop. Oceanic Fish Invest. Rep. 7. pp. 43-45.
- WORLD BANK DEVELOPMENT REPORT. (2007):** *Making the Most of Scarcity: Accountability for Better Water Management in the Middle East and North Africa*. Water P-Notes Issue 40-48728. Washington.
- WORLD HEALTH ORGANIZATION. (2005):** *Minimum Water Quantity Needed for Domestic Uses*. WHO/SEARO Technical Notes for Emergencies. Technical Note No. 9. WHO Regional Office for Southeast Asia. India.
- YUWONO, J.S.E. (2009):** *Late Pleistocene to Mid-Holocene Coastal and Inland Interaction in the Gunung Sewu Karst Yogyakarta*. IPPA Bulletin 29. pp 33-44.

## **10.2. Government Regulations**

- PERATURAN DAERAH PEMERINTAH PACITAN. (1992):** *Peraturan Pembentukan Perusahaan Daerah Air Minum/PDAM Pacitan*. Pacitan.
- PERATURAN MENTERI DALAM NEGERI. (2006):** *Pedoman Teknis dan Tata Cara Pengaturan Tarif Air Minum Pada Perusahaan Daerah Air Minum*. No. 23/2006. Jakarta.

**PERATURAN MENTERI KOORDINATOR BIDANG PEREKONOMIAN. (2011):** *Rencana Kerja Dewan Sumber Daya Air Nasional No. 7/2011.* Jakarta.

**PERATURAN DAERAH PEMERINTAH PACITAN. (2010):** *Rencana Tata Ruang Wilayah Kabupaten Pacitan No. 3/2010.* Pacitan.

**PERUSAHAAN DAERAH AIR MINUM/PDAM. (2011):** *Surat Edaran Nomor: 690/231.A/408/2011.* PDAM Kabupaten Pacitan. Pacitan.

**UNDANG UNDANG REPUBLIK INDONESIA 7/2004. (2004):** *Undang Undang No. 7 Tentang Sumber Daya Air.* Jakarta.

### 10.3. Internet Sources

**ABRAMS, L. (2003):** *Water Scarcity.* [www.africanwater.org/drought\\_water\\_scarcity.htm](http://www.africanwater.org/drought_water_scarcity.htm). (31.03.2014).

**ANTARA NEWS. (2009):** *Ribuan Warga Pacitan Kesulitan Air Bersih.* <http://www.antarane.ws.com/berita/1257893338/ribuan-warga-pacitan-kesulitan-air-bersih>. (23.05.2012).

**GAPENSI. (2011):** *PU Tambah Kapasitas IPA Donorojo. Gabungan Pelaksana Konstruksi Nasional Indonesia.* <http://www.gapensijatim.org/index.php/baca/berita/02/11/2011/PU-Tambah-Kapasitas-IPA-Donorojo>. (16.06.2014).

**IRIANTO, G. (2005):** *Menyoal Hak Guna Pakai Air dan Dampaknya.* Kompas , 4 Juni 2005, Bogor. <http://www.litbang.deptan.go.id/artikel/one/274/pdf/Menyoal%20Hak%20Guna%20Pakai%20Air%20dan%20Dampaknya.pdf>. (20.04.2012).

**IQBAL. (2012):** *Kebutuhan Air Minum.* <http://personal.ftsl.itb.ac.id/iqbal/files/2012/09/kebutuhan-air-dan-proyeksi.pdf>. (25.07.2014).

**KEMENTRIAN PEKERJAAN UMUM. (2011):** *Atasi Kekeringan di Pacitan, PU Tambah Kapasitas IPA Donorojo.* <http://ciptakarya.pu.go.id/v2/?act=vin&nid=1001> (10.12.2012).

**KEMENTRIAN SEKRETARIAT NEGARA REPUBLIK INDONESIA. (2010):** *Produk Hukum Indonesia.* <http://indonesia.go.id/en/law-regulations>. (19.08.2014).

**NESTMANN, F. (2012):** *Nachhaltige Wasserwirtschaft in Südostasien-von den 1000 Hügeln zu den 9 Drachen.* Landesamt für Geologie, Rohstoffe und Bergbau (LGRB) im Regierungspräsidium Freiburg. <http://www.lgrb.uni-freiburg.de/lgrb/home/Wassergespraech/Nestmann>. (17.04.2014).

**NYIRISHEMA, R., and M. VERWEJI. (2013):** *Public-Private Partnership for Inclusive Rural Water Supply.* SNV Netherlands Development Organisation, Rwanda. <http://www.capacity.org/capacity/opencms/en/topics/gender-and-social-inclusion/public-private-partnerships-in-water-supply-rwanda.html>. (16.09.2014)

**NOAA-NATIONAL WEATHER SERVICE CLIMATE PREDICTION CENTRE. (2014).** *Cold and Warm Episodes by Season.*  
[http://www.cpc.ncep.noaa.gov/products/analysis\\_monitoring/ensostuff/ensoyears.shtml](http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml) (03.05.2014)

**PERPAMSI (PERSATUAN PERUSAHAAN AIR MINUM SELURUH INDONESIA). (2010).** *PDAM Kab. Pacitan.* <http://perpamsi.or.id/pdam-members/read/265/pdam-kabpacitan.html>. (24.05.2012).

**SIMONOVIC, S.P. (2009):** *Water Resources Management: A System View.*  
[http://www.siwi.org/documents/Resources/Water\\_Front\\_Articles/2009/WRMASystemsView.pdf](http://www.siwi.org/documents/Resources/Water_Front_Articles/2009/WRMASystemsView.pdf). (03.02.2014).

**WIRIADIWANGSA, D. (2005):** *Pranata Mangsa Masih Penting Untuk Pertanian.*  
<http://www.litbang.deptan.go.id/artikel.php/one/92/pdf/Pranata%20Mangsa,%20Masih%20Penting%20untuk%20Pertanian.pdf>. (11.06.2014).



## **ANNEXES**

### **1. Guided Question Lists for FGD and In-depth Interview**

- *Focused Group Discussion in 3 Sub-Districts (Kecamatan): Donorojo, Punung, Pringkuku*

#### **a. Household**

- Perception of the community for their environment
  1. Can you describe the border of your Village/Dusun?
  2. How would you describe water situation in your area?
  3. Which area that you think more vulnerable for water issues?
  4. Which area that you think safer/have more water supplies (wells, caves, springs, water tanks, rainwater harvesting, piped water/PDAM, etc)?
  5. Can you show on the map where the settlements, public facilities, agriculture fields, offices, etc. are located?

#### **b. Extreme climate events**

1. What is your perception of “normal” and “anomaly” year? Are you familiar with extreme climate event, e.g. ENSO?
2. To which extent is the extreme climate event known to the local population?
3. What is the perceived rainfall distribution during a “normal” year, and how does this relate to the availability of water in your area?
4. Have local residents perceived climate variations within the last two decades?
5. If climate variations were perceived, what are the major issues associated with climate variability? In which sectors are these issues related?
  - a. Agriculture
  - b. Social
  - c. Economic
  - d. Other sector
6. Are there any positive impacts associated with climate variability?
7. During extreme climate events, are the water supplies decreases significantly?
8. When does normally dry season occur? Can you draw the timeline for 15 months?

#### **c. Existing adaptive capacity**

1. Can you describe how many water you use in dry and rainy season? (liters per day per person)
2. Is there any water reduction during dry season?
3. Did you built your own water harvest tank?
4. If not, do you build with the community? How many people are sharing?
5. Is the water sufficient for your needs?

6. Do you buy more water during dry season?
7. What are your traditional strategies to deal with water use?
8. Does the (local) government provide water during dry season?
9. Are you familiar with policies regarding water supplies network program (e.g. rainwater harvesting/SPAH/SABSAH)? If yes, do you see any difference during dry season?
10. Are there any socialization programs in terms of water use/water network program (SPAH/SABSAH)? Have you involved in any of these programs?
11. What programs that has been done in order to anticipate water deficiency? Who has involved in these programs?
12. For those of you who are farmers, do you make any changes on your farming system? What kind of crops that you plant during dry season? Can you describe the timeline?

**d. The role of stakeholder**

1. What are the institutions that are involved in water management?
2. Which of these institutions play important roles in water management?
3. What kind of information/benefits do you get from these institutions?
4. Who controls the water supplies?
5. Are you familiar with IPA/water treatment plant that is currently planting by the Ministry of Public Work (PU)?

**e. Vulnerability**

1. In your experience, how far do you need to walk to get water supplies (wells, caves, springs, water tanks, rainwater harvesting, piped water/PDAM, etc) from where you live during dry season?
2. How many water you can get with the distances? (buckets, etc)
3. How far the distance to get water affects your subsistence?
4. Do you irrigate your field at all? If yes, how do you irrigate it?

• *In-depth Interview*

**a. Water supply**

1. How would you describe the water situation in your area?
  - Dry season
  - Rainy season
2. For how many months do you have sufficient water supply?
3. What kind of water sources do you usually have?

Telaga	Rainwater tank	PDAM
Water tanks	Springs	Wells
Rivers	Caves	Others

4. What kind of water sources do you use to drink?

Bottler water	Rainwater tank	PDAM
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Water tanks	Springs	Wells
Rivers	Caves	Telaga
Others		

5. How do you irrigate your fields?

- What source of water do you use?

Telaga	Rainwater tank	PDAM
Water tanks	Springs	Wells
Rivers	Caves	Others

- If you have to pay, how much? Rupiah per liters
- What kind of crops do they cultivate on your irrigated fields?

(Dry) Rice	Maize	Soybeans
Cassava	Peanuts	others

6. Would you use more water, if possible?

- If no, why?
- If yes, for what reason?

Irrigation	Daily needs	Home industry
House garden	Stock breeding	others

7. What kind of water supply would you use more?

Telaga	Rainwater tank	PDAM
Water tanks	Springs	Wells
Rivers	Caves	Others

8. What kind of water from which source do you use for which purpose?

Telaga	
Water tanks	
Rivers	
Rainwater tank	
Springs	
Caves	
PDAM	
Wells	
Others	

#### b. Microeconomics

1. What is your subsistence? Do you need much water for your subsistence?
2. Do you have second income? If yes, please explain why and when is the timeline between your first and second income.
3. Are there any small-scale industries in your area?
4. Are there any conflicts between small-scale industry and households? If yes, what kind of conflicts?

**c. Piped Water (PDAM)**

1. Is your village connected with PDAM?
2. What is your purpose of using the water from PDAM?
3. What do you think the quality of the water from PDAM?
4. How much do you pay for PDAM?
5. Are the pipes from PDAM functioning all the time? If no, what are the usual problems?

**d. Tanker Trucks**

1. How much water is being delivered? (liters per day per person)
2. What purpose do you do with water from tankers?
3. What do you think the quality?
4. Are the government/other institutions paying for the delivery?
5. How much do you pay for the water? Rupiah per liters

**e. Wells**

1. How much water is normally being used by one person/household?
  - Dry season
  - Rainy season
2. What is normally the purpose of using water from the well?
3. What is the average depth of the wells? (meters)
4. What method do you use to get water from wells?
5. What is the quality of the water?
6. How many households use the well?
7. How often do you go to the well?
8. Does the well provide you with water through the year?

**f. Sanitation, wastewater and solid waste management**

1. Do you have access to sanitation system?
2. What kind of toilet do you use?
3. Do you have your bathroom inside/outside?
4. Would you use human feces/urine as dung?
5. Do you build sanitary facilities together with the community?
6. Which sector (kitchen, toilet, taking a bath) of household contribute most of the production of water?
7. How did the sanitation system change in the last 20-30 years?

## **2. Panduan Pertanyaan FGD dan Wawancara**

- *Focused Group Discussion*

### **a. Rumah tangga dan ketersediaan air**

- Persepsi masyarakat terhadap lingkungan
  1. Gambarkan batas dusun anda pada peta yang telah disediakan.
  2. Bagaimana anda menggambarkan situasi air di wilayah/dusun anda?
  3. Wilayah mana yang menurut anda rawan terhadap ketidaktersediaan air?
  4. Wilayah mana yang menurut anda memiliki lebih banyak sumber air (sumur, goa, mata air, telaga, tanki air, PDAM, dll)?
  5. Tunjukkan pada peta yang sudah disediakan wilayah pemukiman, dan fasilitas umum yang ada di wilayah anda.

### **b. Kejadian iklim ekstrim**

1. Apakah persepsi anda mengenai tahun normal dan tahun anomaly? Apakah anda mengenali kejadian iklim ekstrim seperti ENSO?
2. Sampai mana anda mengenali kejadian iklim ekstrim di wilayah anda?
3. Berapa besar curah hujan yang umumnya diterima di tahun “normal” dan tahun “anomali”, dan bagaimana ini mempengaruhi ketersediaan air di wilayah anda?
4. Adakah perubahan yang mencolok terhadap cuaca pada 20 tahun terakhir?
5. Jika ya, isu apa yang terkait dengan perubahan cuaca tersebut? Sektor apa saja yang terkena dampaknya?
  - Pertanian
  - Sosial
  - Ekonomi
  - Sektor lain
6. Apakah ada dampak positif yang dirasakan dari perubahan iklim tersebut?
7. Selama kejadian iklim ekstrim, apakah ketersediaan air menurun drastis?
8. Kapan biasanya musim kemarau berlangsung? Gambarkan dalam waktu 15 bulan.

**c. Strategi adaptasi yang sudah ada**

1. Dapatkah anda gambarkan berapa banyak air yang digunakan disaat musim hujan dan musim kemarau? (liter per hari per orang)
2. Apakah ada pengurangan jumlah air yang digunakan disaat musim kemarau?
3. Apakah anda membangun tanki air sendiri?
4. Jika ya, apakah anda membangunnya bersama dengan penduduk sekitar, berapa orang yang menggunakan tangki air tersebut?
5. Apakah air yang tersedia sesuai dengan kebutuhan anda?
6. Apakah anda membeli jumlah air yang lebih di saat musim kemarau?
7. Apakah ada strategi tradisional dalam masyarakat setempat dalam hal penggunaan air?
8. Apakah pemerintah menyediakan air di saat musim kemarau?
9. Apakah anda mengetahui mengenai kebijakan mengenai Rencana Sistem Air Bersih dari pemerintah, Sistem Penampungan Air Hujan (SPA), dan Sistem Akuifer Buatan dan Simpanan Air Hujan (SPA)? Jika ya, apakah anda merasakan adanya perubahan setelahnya di musim kemarau?
10. Apakah ada program sosialisasi mengenai penggunaan air dari pemerintah atau mengenai Rencana Sistem Air Bersih? Apakah anda pernah terlibat dalam salah satu program ini?
11. Program apa saja yang telah dilakukan untuk mengantisipasi kekurangan air? Siapa saja yang terlibat dalam program ini?
12. Bagi anda yang bekerja sebagai petani, apakah anda memiliki system penanaman tertentu di saat musim kemarau? Jenis tanaman apa yang anda tanam di saat musim kemarau? Apakah anda dapat menggambarannya dalam waktu 15 bulan? (Kalender Tanam)

**d. Peran pengambil kebijakan**

1. Institusi apa saja yang terlibat dalam manajemen air di wilayah anda?
2. Institusi mana saja yang anda sebutkan diatas yang berperan penting dalam manajemen air?
3. Informasi/keuntungan apa saja yang anda dapatkan dari institusi di atas?
4. Siapa saja yang mengontrol sumber-sumber air di wilayah anda?

5. Apakah anda mengetahui mengenai program Instalasi Pengolahan Air yang sedang dibangun oleh Kementrian PU?

**e. Kerentanan**

1. Dari pengalaman anda, sejauh mana anda harus berjalan menuju sumber air di wilayah anda di saat musim kemarau (sumur, goa, mata air, tanki air, rainwater harvesting, PDAM, dll)?
2. Berapa banyak air yang di dapatkan dengan jarak tersebut? (ember, dll)?
3. Seberapa jauh jarak yang anda sebutkan di atas mempengaruhi pekerjaan anda?
4. Apakah anda mengairi (irigasi) lahan anda sendiri? Jika ya, bagaimana anda melakukannya?

• **Wawancara**

**a. Persediaan air**

1. Bagaimana anda menggambarkan kondisi sumber air di wilayah anda?
  - Musim kemarau
  - Musim hujan
2. Berapa lama dalam setahun anda mempunyai persediaan air yang cukup?
3. Sumber air apa saja yang anda gunakan untuk kebutuhan sehari-hari selain minum?

Telaga	Rainwater tank	PDAM
Tanki air	Mata air	Sumur
Sungai	Goa	Lainnya

4. Sumber air apa saja yang anda gunakan untuk air minum?

Air kemasan	Rainwater tank	PDAM
Tanki air	Mata air	Sumur
Sungai	Goa	Telaga
Lainnya		

5. Bagaimana anda mengairi (irigasi) lahan pertanian anda?

- Sumber air apa yang anda gunakan?

Telaga	Rainwater tank	PDAM
Tanki air	Mata air	Sumur
Sungai	Goa	Lainnya

- Jika anda harus membayar, berapa rupiah anda harus membayar per liter air?

- Tanaman apa saja yang anda tanam di lahan yang diirigasi?

Padiladang (gogo)	Jagung	Kedelai
Ubikayu	Kacangtanah	Lainnya

6. Jika memungkinkan, apakah anda akan menggunakan jumlah air yang lebih?

- Jika tidak, mengapa?
- Jika ya, untuk keperluan apa?

Irigasi	Kebutuhan sehari-hari	Industri rumahtangga
Mengairi kebun	Kebutuhan ternak	Lainnya

7. Sumber air mana yang anda sering gunakan?

Telaga	Rainwater tank	PDAM
Tanki air	Mata air	Sumur
Sungai	Goa	Lainnya

8. Sebutkan keperluan yang anda lakukan dari jenis sumber air dibawah ini

Telaga	
Tanki air	
Sungai	
Rainwater tank	
Mata air	
Goa	
PDAM	
Sumur	
Lainnya	



**b. Microeconomics**

5. Apa pekerjaan anda? Apakah anda membutuhkan banyak air untuk pekerjaan anda?
6. Apakah anda memiliki pekerjaan sampingan? Jika ya, jelaskan alasannya dan gambarkan timeline antara pekerjaan utama dan sampingan anda.
7. Apakah ada industry rumah tangga di wilayah anda?
8. Apakah ada konflik antara industri rumah tangga dan kebutuhan rumah tangga di wilayah anda? Jika ya, konflik apa?

**c. PDAM**

1. Apakah wilayah anda terhubung dengan PDAM?
2. Kebutuhan apa yang anda lakukan dengan PDAM?
3. Bagaimana kualitas air PDAM menurut anda?
4. Berapa Rupiah anda harus membayar PDAM per bulan?
5. Apakah pipa-pipa PDAM selalu berfungsi setiap saat? Jika tidak, apa yang biasanya menjadi masalah?

**d. Tanki air**

1. Berapa banyak air yang biasanya diantarkan? Berapa liter per hari per orang?
2. Untuk kebutuhan apa saja tanki air digunakan?
3. Bagaimana menurut anda kualitas air dari tanki air?
4. Apakah pemerintah setempat atau institusi lain membiayai tanki air yang anda gunakan?
5. Berapa Rupiah per liter yang anda bayarkan untuk air yang anda gunakan?

**e. Sumur**

1. Berapa jumlah air yang biasanya anda gunakan dari sumur per orang/rumah tangga?
  - Musim kemarau
  - Musim hujan

2. Kebutuhan apa saja yang anda lakukan dari air sumur?
3. Berapa rata-rata kedalaman sumur yang anda gunakan?
4. Metode apa yang anda lakukan untuk mengambil air dari sumur?
5. Bagaimana menurut anda kualitas air dari sumur tersebut?
6. Berapa jumlah orang/rumah tangga yang menggunakan sumur tersebut?
7. Seberapa sering anda pergi ke sumur untuk mengambil air?
8. Apakah sumur tersebut selalu berisi air sepanjang tahun?

**f. Sanitation, wastewater and solid waste management**

1. Apakah anda memiliki akses untuk system sanitasi?
2. Jenis toilet apa yang anda gunakan?
3. Apakah anda memiliki kamar mandi sendiri di dalam rumah/diluar rumah?
4. Apakah anda menggunakan feces sebagai pupuk?
5. Apakah anda membangun sarana sanitas bersama dengan masyarakat sekitar di wilayah anda?
6. Sektor apa saja yang berperan dalam penggunaan air (dapur, toilet, kamar mandi, dll)?
7. Bagaimana perubahan system sanitasi dalam 20-30 tahun terakhir?

## ERKLÄRUNG

Ich erkläre: Ich habe die vorgelegte Dissertation selbständig und ohne unerlaubte fremde Hilfe und nur mit den Hilfen angefertigt, die ich in der Dissertation angegeben habe. Alle Textstellen, die wörtlich oder sinngemäß aus veröffentlichten Schriften entnommen sind, und alle Angaben, die auf mündlichen Auskünften beruhen, sind als solche kenntlich gemacht. Bei den von mir durchgeführten und in der Dissertation erwähnten Untersuchungen habe ich die Grundsätze guter wissenschaftlicher Praxis, wie sie in der „Satzung der Justus-Liebig-Universität Gießen zur Sicherung guter wissenschaftlicher Praxis“ niedergelegt sind, eingehalten.

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Ort, Datum

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Unterschrift