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Culture and Risk Based Water and Land Management in Karst Areas: An Understanding of Local Knowledge in Gunungkidul, Java, Indonesia.

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Abstract

This study was conducted in Karst Gunungkidul Indonesia. Karst regions are characterized by the possibility of water scarcity during the dry season. This encourages local people to develop adaptation strategies to manage limited water and land resources. People have developed the skill to observe natural signs, from climatic features, plants and animal behavior, coupled with physical features identification, to guide them in how to manage annual season changes.

Keen observation of environmental changes, concerning climatic factors particularly, is known as *ilmu titen*. *Ilmu titen* has guided people to develop agricultural systems in adaptation to annual season changes. *Pranata Mangsa* is the most recognizable *ilmu titen* concerning climatic factor changes followed by plants and animal behavior changes, and is considered local knowledge. In implementation of *Pranata Mangsa* and physical features identification, people apply the *Tumpangsari* farming system which takes into consideration the timing of water and land consumption. The cycle of *Pranata Mangsa* consists of parable phrases to describe natural signs, thus it takes deep understanding and interpretation to derive natural hazards and risk from it. The challenges arise due to global climatic factors which affect the time frame of the *Pranata Mangsa* cycle.

The skill of *ilmu titen* on *Pranata Mangsa* needs to be re-invented to face global challenges within a local context. This study applies qualitative research in a participatory approach using Focused Group Discussion (FGD) and In-depth interview, supported by field observation and spatial analysis using information communication technologies (ICT). Local spatial knowledge that is embedded and embodied in Karst Gunungkidul people is transformed into a landscape model. The model aims to accommodate each time frame of *Pranata Mangsa* to help people identify, collect and analyze the changes or disturbances in their surrounding environment.

Local knowledge of Karst Gunungkidul needs to be re-invented in accordance with evolving environmental changes. *Pranata Mangsa* may be old fashioned and outdated, but the skill of gaining knowledge from nature and its relationship with the inhabitants: humans, plants and animals; determines how people manage water and land availability

on Karst environments to identify natural hazards and reduce the risk of annual water scarcity and the following effects.

Diese Studie wurde in der Karst-Region GunungKidul in Indonesien durchgeführt, welche weltweit bekannt ist für ihre konischen Hügel. Charakteristisch fürKarst-Regionen ist das Risiko von Wasserknappheit während der Trockenzeit. Diesesbringt die einheimische Bevölkerung dazu, Anpassungsstrategien zu entwickeln um mit den limitierten Wasser- und Landressourcen zu haushalten. So hat die Bevölkerung die Fähigkeit entwickelt Zeichen der Natur zu deuten, von klimatischen Bedingungen bis hin zum Verhalten von Pflanzen und Tieren, gekoppelt mit der Identifikation physikalischer Erscheinungen, um mit dem jährlichen Wandel der Jahreszeiten zurechtzukommen.

Intensive Beobachtungen, auch *ilmu titen* genannt, von Veränderungen der Umwelt, insbesondere klimatischer Faktoren, haben den Menschen geholfen ein landwirtschaftliches System zu entwickeln, welches sich dem jährlichen Wandel der Jahreszeiten anpasst. *Pranata Mangsa* ist die wichtigste *ilmu titen* und befasst sich mit der Veränderung klimatischer Faktoren und ihrer Auswirkungen auf das Verhalten von Pflanzen und Tieren und gehört zum lokalen Wissen. *Pranata Mangsa* und die Identifikation physikalischer Erscheinungen wird in der Tumpangsari Landwirtschaft angewandt, welche den Zeitpunkt des Verbrauchs von Wasser und Landressourcen beachtet. Der Zyklus von *PranataMangsa* besteht aus Parabeln die Zeichen der Natur beschreiben. Es braucht also tiefes Verständnis und Interpretations fähigkeit um daraus Naturrisiken abzuleiten. Diese Herausforderung nimmt auf Grund des weltweiten Wandels von Klimafaktoren, welche den zeitlichen Ablauf des *Pranata Mangsa* Zyklus beeinflussen, zu.

Die Fähigkeit von ilmutiten im *Pranata Mangsa* muss neuentwickelt werden um sich globalen Herausforderungen im lokalen Kontext stellen zu können. Die vorliegende Studie führt qualitative Untersuchungen in einem partizipatorischen Ansatz durch und nutzt Fokusgruppen-Diskussionen (FGD) sowie detaillierte Interviews. Dies wird unterstützt von Feldbeobachtungen und räumlicher Analyse, welche das *information* *communication technologies* (ICT) nutzt. Lokal-räumliches Wissen der Bewohner der Karst-Region Gunungkidul wird in ein Landschaftsmodell übertragen. Dieses Modell soll jeden Zeitrahmen von *Pranata Mangsa* abbilden, um den Leuten zu helfen die Änderungen oder Störungen ihrer Umwelt zu identifizieren, sammeln und analysieren.

Lokales Wissen der Karst-Region GunungKidul muss wieder hervorgeholt und passend zu den sich entwickelnden Umweltveränderungen neuerfunden werden. PranataMangsa mag altmodisch und überholt sein, doch die Fähigkeit Wissen aus der Natur und ihrer Interaktion mit Mensch, Pflanzen und Tieren zu ziehen, bestimmt den Umgang der Menschen mit Wasser und verfügbarem Land in einer Karstregion um Naturrisiken zu identifizieren und das Risiko der jährlichen Wasserknappheit und seiner Folgen zu reduzieren.

Abbreviation

BPS	Biro Pusat Statistik; Central Statictic Bureau
Bappeda	Badan Perencanan dan Pembangunan Daerah; Regional Board of Planning and Development
BMKG	Badan Meteorologi, Klimatologi, dan Geofisika; Meteorology,Climatology, and Geophysics Board
BP	Before present, a geological time period to define events occurrence in the past
Dasarian	Ten consecutive days within a month that is used to determine climatic factor changes
FGD	Focussed group discussion
HU	Hidran Umum; public hydrant
IWRM	Integrated Water Resources Management
PNPM	Program Nasional Pemberdayaan Masyarakat
PDAM	Perusahaan Daerah Air Minum; Regional Company of Tap Water, established under Regency (district) decree
RTRW	Rencana Tata Ruang Wilayah; Provincial or Regional Spatial Plan
SR	Sambungan Rumah; household connection of tap water fromPDAM piping network
PAH	Penampungan Air Hujan (Rain Water Tank)
UU	Undang-undang, National Government Act
PP	Peraturan Pemerintah, National Ordinance
Permen	Peraturan Menteri, Ministerial Ordinance
Kepmen	Keputusan Menteri, Ministerial Decree
Perbup	Peraturan Bupati, Head of Regency Decree
Perda	Peraturan Daerah, Decree issued by Governor or Head of Regency/District
Puskesmas	Pusat Kesehatan Masyarakat, Public health service at local level

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I. Introduction

1.1. Background

In recent years there has been growing attention on indigenous, local and traditional knowledge and the interface with science based knowledge in management schemes to meet changes in the environment (AGRAWAL, 1995). The world is certainly facing dynamic changes on water and on land due to climate change consequences as stated by the Intergovernmental Panel on Climate Change (IPCC, 2007). Like any part of the world facing changes, Southeast Asia faces ecological issues related to climate change and variability which threathens people's livelihood (HORNIDGE and ANTWEILER, 2012). Understanding and deploying local knowledge into development and environment conservation has been recognized as important and instrumental (SHEPERD, 2010:629). Land and water misutilization still remain on-going with all efforts undertaken by many actors and institutions to meet sustainable livelihoods failing to institute environmental ethics (LEOPOLD, 1949; SAUER, 1925).

Environment variability and changes have been endured by human beings throughout historical periods of human civilization. Prehistoric humans inhabited the earth and lived through periodics, abrupt and severe periods of environmental change due to climatic factors and their impacts (HEYD and BROOKS, 2009; SIMANJUNTAK, 2002). The phenomenon of natural hazards inevitably plays a role in a society's culture and development. Human beings and their assets have faced natural hazard threats, yet people have their own reasons to live in hazard prone areas and accept the potential risk. They still inhabit naturally hazardous areas (THOME, 2006) because some communities manage to develop certain strategies and coping mechanisms to their naturally hazardous environment which then become cultural adaptations (SUNKAR, 2008; SURYANTI, 2010).

Karst ecosystems were one of first human habitats where the caves provided steady dwellings near water and forest resources for their daily basic needs. Karst landscapes form in areas with carbonate bedrock which is subjected to slow dissolution processes as result of a combination of temperature, chemistry and soil acidity. Water is the main agent of landscape change in Karst terrains (WHITE, 1988; FORD and WILLIAMS, 2007; FLEURY, 2009), but human induced activities might worsen the process.

Karst aquifers in the world provide groundwater which is an important resource for water supply. An estimated 25% of the world's population lives in Karst areas and is dependent on the drinking water supply from the aquifers (FORD and WILLIAMS, 2007). Due to the high permeability of karst structure, the residents of these areas are often affected by some extreme water shortage. The hydrogeological conditions have an adverse effect on the entire water cycle.

Water and land are some of the vital sources determining human livelihood on earth. Water and soil are natural resources which can be affected by human activities, this include human induced activities on Karst area**.** Cross system interactions between Karst systems and human systems need to be understood to overcome the result of overlapping systems (FLEURY, 2009). Understanding the need to incorporate hazard mitigation into spatial planning has gained attention and been growing (THOME, 2006). Geomorphological, geological and hydrogeological analysis combined with comprehensive socio-cultural information permits more advantageous planning and management processes for governmental institutions.

Karst people have developed their own water and land management. There are hundreds of water and land management projects and spatial plan applications conducted in Gunung Sewu Karst area that unfortunately did not work as expected, did not accomplish targets and failed to achieve the goals for the people. Technological developments in water and land management and spatial planning which consider the local traditional knowledge of Karst communities needs to be explored. It is considered important to apply the local culture of water and land management which has been passed by from generation to generation in the Gunung Sewu in Gunungkidul Regency Karst community. Regulatory processes which reflect no deep knowledge and understanding of Karst system transform into a lack of political will to regulate development and land use (FLEURY, 2009). Full appreciation of economic, scientific and human values are needed for such planning and management to be effectively applied on Karst regions, within local culture and political context.

A previous study which conducted in Dadapayu village of Gunungkidul´s Karst area in 2003 showed that the inhabitants have adapted water consumption for domestic use and non-domestic use to the seasonal variations of water sources. Different mixes of water sources have been practiced in the annual daily activities to support their livelihood during dry and wet seasons, and take into account the availability, price and quality of the water (LUKAS and STEINHILPER, 2005). Although there was no 100% secure water source, the study showed that the inhabitants of Karst region have adapted and developed coping mechanisms due to their living environment, which became their cultural behavior (SUNKAR, 2008).

Projects have been conducted to tackle water shortage during the dry season in Gunung Kidul Regency, for example adding more rain water tanks, rehabilitation of ponds and the development of underground dams (NAYONO, LEHN, KOPFMÜLLER, and LONDONG, 2011). Water adaptation strategy in such unique environments like Karstic regions can be studied and analyzed to understand the landforms shape social, cultural, and political. Human activities on Karst environments will affect its systems and processes, particularly water and land related matters. The implementation of a spatial plan which accomodates human utilization of resources might have such impact, disturbance and risk. The ancient Karst Gunung Sewu community might have developed adjusted space occupation to cope with the severe condition of their environment due to water shortage during that era. The shaped landscape on Karst Gunung Sewu present ancient inter-correlation and behavioral adaptation between human and the environmental conditions (HARYONO, YUWONO, and FAIDA, 2008).

A joint Integrated Water Resource Management (IWRM) project between German and Indonesian Government conducted in Gunungkidul Regency said that population pressure and related escalating water consumption are the main reason for periodic water scarcity (HOSSU, 2009). Another study considered that improvement of water supply through improving local networks and rainwater capture would bring potential fresh water and promote sanitation, empower the population through education, economic conducive activities and enhance diverse job opportunities (WINTER, 2009). Research related to sustainability management of Karst Gunung Sewu by SUNKAR (2008) mentioned that further research is needed on the cultural dynamics of community.

Some changes in the water and land policies have shifted the cultural value as a result of modern development which neglected locality and create severe water shortages in some places in Karst Gunung Sewu. Culture has not been sufficient considered in formulating planning and management standards and regulations. Locality characteristics have not been sufficiently accomodated in government programs.

This research explores local knowledge called *Pranata Mangsa* with its phenology as part of their culture on water and land management which has been practiced for many years and reflects the community way of life. The cultural value of water in Karst Gunung Sewu needs to be included in water policy, planning and management. The cultural values of Karst Gunung Sewu reflected in its cultural landscape and way of life are considered important in water and land management, and spatial planning. Temporal data and information which may not be well recorded and documented needs to be collected from many sources and become a source for knowledge management based on local knowledge. It is considered important to re-immerse local knowledge of *Pranata Mangsa* and its phenology (bio-indicators) into water and land management and to develop knowledge management in the uncertainty of environmental changes due to the dynamic processes of climate. Recent landscape view on Karst Gunungkidul is a reflection and imprint of inherited and adaptation of people's knowledge. This study proposes to correlate landscape approach in application of local knowledge related to water and land management to mitigate the risk through a landscape model.

1.2. Research Problems

Human societies can hardly avoid having an impact on their occupied landscape. More over societies in fragile environments like Karst areas (FLEURY, 2009) use space or land for human needs that can trigger severe desertification in the fragile of Karst ecological systems. Karst systems can be disturbed by variety of physical, social and economic activities which are formulized and legalized in the planning and management regulations. Formal application of Karst ecosystem regulations in Indonesia still ends up in overlapping interests and results. Complexity arises as the communities and government continuously grow, ignoring hazards and vulnerability regarding the space or land available for human activities in such unique region like Karst.

Environmental ethics in decision making related to water and land management tends to be left behind when economics profit comes first. In cases like agribusiness expansion into certain areas which are sensitive and prone to chemical and mechanical treatment to meet a profit target. Ethics can also become a challenge in facing climate change (MÜLLER, 2008) related to cultural and social values in managing water and land. Climate change performs the weather less regular and reliable than ever and confuses people or communities who follow the traditional seasonal calendar as their guidance in agriculture particularly and no access to outside information.

Seasonal forecasting can greatly assist in managing climate risks in agriculture, particularly in risk prone rain fed environments by providing planners, managers and farmers with timely information, which allows them to decide upon and shift to the most suitable coping strategies over short time scales. However, the usefulness of seasonal climate forecasts depends on the capacity of farmers and extensionists to access and utilize climate information and react upon it in a timely manner.

The seasonal calendar called *Pranata Mangsa* came from a long time series of observations and experiences with different time frames of today's climate. However, the essence of climatic factors still relates to manage water and land issues, particularly ecological system and even disaster risk reduction management. The cycles in *Pranata Mangsa* are considered irrelevant today, but this still can be valuable as an early warning sign because water scarcity or drought occurs historically as an annual event.

Agriculture is designated the leading sector in economic growth for Gunungkidul regency as stated in the Strategic Plan and mapped in the Spatial Plan 2010-2030. Determining and zoning the location of certain land utilization require good knowledge and great understanding of Karst systems. Land and water utilization for human activities will result in some disturbances to the Karst and escalating risk to water scarcity or drought and desertification. Decision and policy makers need to understand the political ecology and environmental ethics in particular Kart areas in order to formulate ecological and environmental based planning and management.

Karst ecosystem exploitation seems to be escalating in coming years. There has been a gap between conservation or preservation regulation on Karst ecosystem and community livelihood. Karst communities have complex problems due to the lack of access to resources from their land, while social and economic conditions seem stagnant with no improvement from the government programs to community livelihood.

Clean water in Indonesia needs escalating attention and concrete actions in response to rapid population growth. Due to limited access to clean and safe water, large number of people in rural areas of Indonesia are still using available water resources for drinking water, bathing and washing. This phenomenon occurs in most Gunungkidul region, in particular where Karst Gunung Sewu lies on the southern part.

Water supply versus water demand, involve physical and socio-culture factors which are complicated. Not enough attention has been placed on local social and cultural configurations with regard to institutional processes of space or land regulation and water management that address risk reduction related to water scarcity or drought in Karst Gunungkidul. There is a need to consider and incorporate local knowledge into regional and local regulations to create space for different purposes while maintaining the natural Karst systems.

The local or traditional culture of water consumption and land use practices which have been known and applied in the rural Karst community since the early inhabitants might comprehend the consideration of the environment restraints. The traditional or cultural landscape which has shaped Karst Gunungkidul's picturesque view reflected the adaptation and, conquering behavior of the inhabitants to the environment. The risk of living in a severe environment and a challenging ecosystem have resulted in interaction between humans and the environment that has shaped their culture. The unique characteristic of Karst Gunungkidul need to be accepted and lived with. These include the hazards and the risk. But problems arose as the old or traditional landuse and water management vanished due to economical pressure and modern lifestyle effects and ambiguous development which neglected local values and norms. Rural communities are forced to expand the land use practices, exploit the land in an already harsh and severe environment.

There can be obstacles when policy makers, planners and the community have different perceptions and conflicts of interest regarding Karst environment utilization. The landuse practices in Karst Gunung Sewu show a spatially random pattern and are not related completely to water source location. Rural Karst Gunungkidul communities manage their water needs from nearby water sources like springs, ponds and water from rain harvesting. The way they manage the water and landuse practices considers the risk of water scarcity in dry season and this should be accommodated and translated into formal planning and management regulations in which policy makers and planners play a role.

In the spatial planning of Gunungkidul Regency 2010 – 2030, the Government stated that they plan to develop water resources infrastructure for rivers, springs, ponds, lakes, irrigation networks and drinking water networks. The level of awareness of Karst ecosystem between policy makers, planners and the community needs to be equal regarding developing water resources and supporting infrastructure to support the community livelihood and escalating economic value. Economic value is important but future livelihood which pays attention to local community is also important.

The strategic value of Karst ecosystems need to be wisely spread to all related stakeholders, which considers the relation between human and the environment.

World Water Forum in Den Haag (March, 2000) stated that Indonesia is one of countries that will suffer from a water crisis by 2025 due to lack of water management and inefficiency of water consumption. Lack of unique cultural resources may lead to the loss of human adaptive capacity as individuals, groups and societies, which actually own sufficient resources and adaptative coping mechanisms to environmental variability and changes, fail to apply local, traditional or indigenous knowledge. Mitigation measures to address environmental problems usually end up as an adjunct to existing plans which have not been developed with wider environmental considerations and context.

An Integrated Water Resources Management (IWRM) project has been introduced in Gunungkidul Regency since at least 2008, although initiated in 2003. The people are aware of the limitation of water resources and have been managed to optimize the use of water, but sanitation is another issue. The sanitation issues related to the people's knowledge of health. Local knowledge of health from *Pranata Mangsa* is not utilized among people in Karst Gunungkidul due to limited understanding related to health issue.

Any disturbance on Karst systems as a result of mistreated land, water and space could endanger the natural process and human livelihood. What do planners and professionals understand about the uniqueness of Karst systems? How deeply do they understand and involve related scientific experts in developing planning for unique Karst Gunung Sewu? Lack of fresh and safe water access in rural community is still the main problem in Indonesia, particularly in the rural Karst region. Local, traditional or indigenous knowledge based on water and land or space management and governmental policies implementation can both be adaptive or maladaptive to the environment. Addressing cultural based traditional or local knowledge namely *Pranata Mangsa* and its phenology in water and land management is complimentary to risk reduction and such tough problems and challenges.

Access to information as part of building knowledge societies is crucial in managing the specific landscape of Karst in the development agenda.

1.3. Research Questions

1) Has drought or water scarcity as natural hazards and its risk issues taken into account the water and land management based on local knowledge *Pranata Mangsa* as part of the cultural identity in the Karst rural community Gunungkidul Regency on Java island?
2) Has the seasonal calendar *Pranata Mangsa*'s local knowledge been understood and used to environmental ethics in daily activities of the communities in planning and managing available water and land?
3) How to synthesize and model rural Karst community's water and land management as part of disaster risk management based on the local knowledge which is imprinted on the cultural landscape?

1.4. Research Objectives

This research tries to mainstream cultural views on water and land management to reduce the risk of drought on Karst Gunungkidul.

(1) Analyze natural hazards and the risk, based on the cultural behaviour of an inherit seasonal calendar system *Pranata Mangsa* as local knowledge in Karst rural community Gunungkidul, Indonesia.

(2) Analyze the essence of seasonal calendar *Pranata Mangsa* for managing available water and land due to risk of water scarcity and promote it as embodied and embedded local knowledge management.

(3) Synthesizing local spatial knowledge and modeling Karst landscape for Karst Gunungkidul management based on local knowledge.

1.5. Hypotheses

To test the research questions, the following hypotheses were formulated as follows:

(1) The interaction between humans and the environment's natural hazards been taken into account in application of water and land management

in rural community Karst Gunungkidul based on local knowledge of *Pranata Mangsa*?

(2) The understanding local value on water and land management as embodied and embedded knowledge management, with the support from government in policy making and other actors in planning and management scheme, can address the uncertainty of environmental disturbance on water and land management and increasing people's capacity.

(3) Synthesizing local spatial knowledge of Karst Gunungkidul people can be developed into Karst landscape model based on local knowledge as bridging tool of future transforming and transferring spatial knowledge.

1.6. Expected Results

(1) An eco-adaptation culture which is reflected in water and land management practices to reduce the risk of water scarcity, addressing environmental ethics as well.

(2) A local seasonal calendar with comprehensive knowledge to manage water and land or space occupancy can play a significant role as part of risk reduction on water scarcity in Karst area in Gunungkidul.

(3) A model of water and land management in sociocultural aspect that contributes scientific basis for a better understanding of Karst Gunung Sewu in Gunungkidul regency, using local knowledge (culture) of water and land management to tackle the risk of water scarcity.

1.7. Thesis outline

Chapter 1 introduces the background of the study, the questions and challenges on application of local knowledge based management in Karst Gunungkidul, Indonesia. Chapter 2 will review the literature and previous studies that support this research to formulize conceptual framework. Chapter 3 will explain how the research is conducted, mostly using a qualitative approach combine with spatial analysis and environmental modeling. Chapter 4 describes the study area to get the picture of where the study area is, why the site selected, and what kind of potency the study area has. Chapter 5 describes water and land management practices in correlation directly or indirectly with seasonal based local knowledge in Gunungkidul Karst region. Chapter 6 aims to answer first and second objectives of this research, how local knowledge is applied within geographical, anthropological and philosophical approach by people or community understanding of the culture they develop, particularly in adaptation to their environment. Chapter 7 describes potencial disturbances on Karst landscape and answer how seasonal based local knowledge is transformed into simple landscape model in consideration of cultural landscape expressing human imprint on Karst landscape. Chapter 8 presents the review of the research hypotheses, the conclusion, and discussions lead to suggestions or recommendations.

1.8. Limitation of the Study

Gunung Sewu is administratively located between Gunungkidul Regency in Yogyakarta Special Province, Wonogiri in Central Java Province, and Pacitan in East Java Province in the South of Java Island Indonesia. This study focuses on and discusses Gunung Sewu which administratively belongs to Gunungkidul Regency. This region is a known Karst region which suffers from water scarcity or drought in the dry season. Not all sub-districts in Gunungkidul Regency classified into Karst Gunung Sewu, but the regional correlation is important to discuss here in term of local knowledge for regional planning and management.

This study articulates a cultural approach to managing water and land in the Karst area. The term culture refers to local knowledge of keen observation known as *ilmu titen*, related to physical features identification and seasonal based calendar called *Pranata Mangsa* and its phenology indicators which have contributed to water and land management since approximately the 17th century and been practicing particularly in agriculture, fishing and cosmology. The understanding of local knowledge from *Pranata Mangsa* addresses risk knowledge.

II. Literature Review and Previous Studies

2.1. Hermeneutics and Phenomenology

2.1.1. Hermeneutics

Hermeneutics is known generally as the art of interpretation, understanding, pre-hypothesis of meaning and philosophy. It developed from traditional through modern and contemporary hermeneutics. In sociology, hermeneutics means the interpretation and understanding of social events by analysing their meanings to the human participants and their culture. The central principle of hermeneutics is that it is only possible to grasp the meaning of an action or statement within the context of the discourse or world-view from which it originates. GADAMER's hermeneutics is recognized in sociology (1977). The hermeneutical dimension of critical theory includes in HABERMAS (1971) idea.

Complex thinking in contemporary hermeneutics can offer useful approaches to compare different forms of knowledge and rationality. It has provided new insights and has contributed to a renewed interpretation of the concept of nature. It is a new paradigm of science and epistemology. This approach has brought a greater awareness of the shortcomings of simple explanations in comprehending reality. It aims to overcome the limits of both reductionism and holism by integrating them into a wider perspective, which investigates the complex structure of interconnections and retroactive relationships in the real world (MAZZOCHI, 2006).

2.1.2. Phenomenology

Phenomenology, hermeneutics and the study of local knowledge systems are being applied in this study to interpret and understand the local seasonal calendar *Pranata Mangsa* and its phenology or bio-indicators which have become inherited cultural behavior, value and identity, as applied in daily life, based on ecosystem and ecological knowledge. Phenomenon captured in the seasonal calendar consist of geographical context explicitly or implicitly. The interpretation of phenomenon from seasonal changes is considered in line with hermeneutics phenomenology as stated by KAFLE (2011) and RICOEUR (1975).

2.2. Knowledge and Knowledge Management

The basis of all communication is knowledge, which enriches human lives in understanding themselves and the environment. The creation of knowledge is a process of qualitative refinement and quantitative accumulation in the classic epistemological approach. Its goal is to disclose the ultimate foundation—the 'meta' point of view from where we can see the ontological order and the objective truth—and to provide a neutral and universal language to explain natural phenomena (CERUTI, 1986; cited in MAZZOCHI, 2006). FEYERABEND (1987) pointed out, any form of knowledge makes sense only within its own cultural context, which means there is locality issue.

The United Nations Educational, Scientific and Cultural Organization (UNESCO) promoted knowledge societies with three strategic thrusts: (1) developing and promoting universal principles and norms based on shared values; (2) promoting pluralism through recognition and safeguarding of diversity, together with the observance of human rights, and (3) promoting empowerment and participation in the emerging knowledge society through equitable access, capacity building and knowledge sharing (HORNIDGE, 2012:30). The encounter between different cultures and knowledge systems are regarded as an encounter between a variety of traditions with embodied way of understanding phenomena and its particular 'logical thought' that put the observed phenomena to be placed within an whole out vision.

Knowledge is usually defined as either explicit or tacit knowledge (see Figure 2.1). What scientific research mostly deals with is the explicit knowledge, a codified knowledge. Tacit knowledge is non-codified and often personal or experience-based knowledge, which social science deals with. Geographical study is a mixture of tacit and explicit elements rather than being one or the other. In order to understand knowledge, it is important to define these theoretical opposites. Some researchers make a further distinction and talk of embedded knowledge. This way, one differentiates between knowledge embodied in people and that embedded in processes, organizational culture, routines. GAMBLE and BLACKWELL (2001) use a scale consisting of represented-embodied-embedded knowledge, where the first two closely match the explicit-tacit.

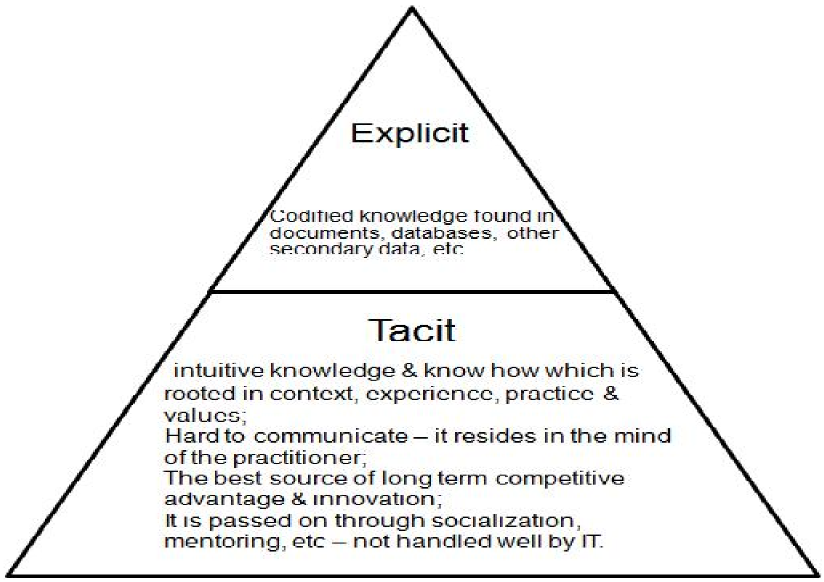


Figure 2.1. Knowledge Differentiation (GAMBLE and BLACKWELL, 2001)

"*Local knowledge refers to knowledge generated through observation and experience of the local environment by a specific group of people*." (BERKES, 1999). In this study, specific groups are represented by rural communities and individual residing in Karst Gunungkidul. These people inherited knowledge based on daily life experiences, embodied with physical features of the place where they live, work and behave in socialization.

Local knowledge is usually found scattered and dispersed, located at individual and household level as well as collectively through community stewards and other social actors (DEKENS, 2007a:24). Transmitted knowledge which is also multi generational does not meet with the same problems of legitimacy in the community as experiential knowledge because the former has been culturally internalised (personal communication between DEKENS with Dr. James Gardner, 2007a). This situation is pretty much no colloquial speech visualizing the seasonal calendar called *Pranata Mangsa* in Java which accommodates changing climate and environmental conditions. Table 2.1

describes the forms and levels of local knowledge, whilst in Table 2.2 we can find a general model of local knowledge.

Table 2.1. Forms and Levels of Local Knowledge

	Levels and forms of knowledge	**Examples**
I.	**Declarative Knowledge**	
1.1.	Recognition and naming knowledge	Attribution of entities to terms, discreet entities and diversity
1.2.	Factual knowledge	Traits of animal, plants, temperature, social status, process, salaries, administrative levels
1.3.	Categorical knowledge	Orderings of organisms, colors, kinship, development project types
II.	**Procedural Knowledge**	
2.1.	General processes, rules	Farming calendar, religious calendar, environmental crises, household cycle, development project cycle
2.2.	Specific processes (scripts, schemas, action plans)	Everyday routines, e.g. greetings and farewells, natural resource management, ritual sequences, project request schema, and non-routines
III.	**Complex Knowledge (concepts, belief systems)**	Cosmology, model of whole society, models of 'honor', of 'marriage', of 'justice', cropping systems, therapies, decision-making procedures.

Source: ANTWEILER (2012:59)

History and dynamic synchronicity is carried in local knowledge (HORNIDGE and ANTWEILER, 2012). Anteweiler argued that local knowledge be contrasted to what so called modern scientific knowledge, instead understanding both in understanding.

Table 2.2. General Model of Local knowledge: Ten interrelated qualities

No.	**Key characteristic**	**Aspects**
1.	Knowledge plus skill	Combination of specific factual knowledge and practice all action-oriented skills
2.	Adaptation to situational dynamics and variability	Keyed to common, but never precisely identical, features of particular place; thus adapted to ambiguous, mutable, stochastic and thus in-determinant issues
3.	Empirical local basis and experiential saturation	Based on local observation, low cost (minus risk trial and error and natural experiments, proven by coping over a prolonged period in the 'laboratory of life'

No.	Key characteristic	Aspects
4.	Redundancy and holism	Represented parallel in several cultural domains; embeddedness; holistic orientation through systematic relations with other aspects of culture
5.	Tacit nature of knowledge	Often implicit, uncodified, intuitive, corporeal embodied, less verbalized less susceptible to verbal or written communication, non-disciplinary
6.	Informal learning	Oral transmission, decentralized and piecemeal learning, learning by imitation, demonstration and apprenticeship more than by instruction
7.	Scientific character	Partially systematic, methodical, parsimonious, empirical hypothetical, comprehensive and generating causal theory
8.	Optimal ignorance	Information only as detailed and accurate as it needs to address the problem; no more no less
9.	Evaluation criterion, test basis	Practical efficacy as the yardstick vs. e.g. theoretical consistency, parsimony, elegance, etc. (but see 4)
10.	Resulting actions and problem solutions	Solutions familiar and thus broadly accepted by local peoples, oriented towards ‘’satisficing’’ and optimizing (vs. maximizing) and the use of local resources

Source: ANTWEILER (2012:64)

A number of studies have already been conducted in the whole Karst Gunung Sewu, particularly Karst region in Gunungkidul Regency. Table 2.3 describes some studies which related to local knowledge *Pranata Mangsa* for agriculture, either showing similar or quite different methods, and supporting the author's research. Table 2.4 shows some studies conducted on different subjects, point of views and dimensions. The previous studies enrich the discussion for further analysis and synthesis and support the conceptual framework used in this dissertation regarding knowledge management.

Table 2.3. Previous study related to seasonal calendar *Pranata Mangsa*

No.	Author (researchers)	Title (theme)	Method and result
1.	Winarto, Yunita T.; Kees Stigter; Hestu, Prahara; Anantasari, Esti; and Kritiyanto. 2011. Anthropological Forum,21:2, 175 – 197	Collaborating on Establishing an Agro-meteorological Learning Situation among Farmers in Java.	Anthropological and ethnographic study revealed that farmers learnt something quite new yet also similar with their inherited seasonal changes and physical features knowledge

No.	Author (researchers)	Title (theme)	Method and result
2.	Riza V Tjahjadi 1993.	The Javanese system of biodynamic farming : An excersize outside Java	Survey findings obtained from research conducted in a field station of Pesticide Action Network Indonesia, concerning the applicability if *Pranata Mangsa* for rice production using no chemical input fertilizer or pesticides. Main objectives was experimental application of traditional Javanesefarming system in modern times in varied location in order to develop a suitable model fro reducing pesticide application.
3.	L. Wiresapta Karyadi, Sadikin Amir, Sitti Hilyana. 2000	*Hubungan perilaku petani dengan aplikasi Pranata Mangsa* (indigenous knowledge system) *di desa tertinggal lombok selatan*. Research report. Agriculture faculty of University Mataram	Anthropology approach to analyze farmers behavior to the application of Pranata Mangsa in remote village South Lombok.
4.	Sukardi Wisnubroto. 1999.	*Pengenalan waktu traditional Pranata Mangsa dan Wariga menurut jabaran Meteorologi: Manfaat dalam pertanian dan sosial*	Agroclimatic analysis for agriculture with some adjustment to climatic factors
.	Daljoeni. 1984.Environmentalist Journal, vol. 4, Issue 7 Supplement, pp. 15 – 18.	*Pranata Mangsa*, the Javanese agricultural calendar—Its bioclimatological and sociocultural function in developing rural life	Agroclimate for agriculture with philosophical discussion

Table 2.4. Researcher or scholars' interest in different aspects or view on Karst Gunungkidul

No.	Author (researchers)	Title (theme)	Method and result
1	Haryono, E., and M. Day. Journal of Cave and Karst Studies vol 66, no. 2, 2004, pp. 62-69	Landform Differentiation within the Gunungkidul Kegelkarst, Java, Indonesia	Identified geologic variation and the correlation with landform diffrentiation in Karst Gunungsewu. Three major landform were identified
2.	Adji, T.N. Gunung Sewu Indonesian Cave and Karst Journal, vol. 1, March, 2004, pp. 1 – 18.	Karst groundwater aggresivity of Bribin underground river in Gunung Sewu	Describing degree of Bribin groundwater river aggresivity
3.	Rohmadi, C. Gunung Sewu Indonesian Cave and Karst Journal, vol. 1, 2004, pp. 19-30.	Karst Cave Arthopoda Gunung Sewu	Identified diversity of cave's Arthropoda in Gunung Sewu
4.	Yuwono, J.S.E. Gunung Sewu Indonesian Cave and Karst Journal, vol. 1, no. 1, 2005, pp. 40 – 51.	Ancient Mozaic of Gunung Sewu. Hypotheses result of archeological caves exploration in Tanjungsari sub-district Gunungkidul	Analyze the correlation geophysics and archeological factors which determine the spatial and temporal region transformation in Gunung Sewu
5.	Sunarto. Majalah Geografi Indonesia, year 9 – 10, no. 16 – 17, September 1995 – March 1996, pp. 15 – 27.	Geomorphological Analysis to Reconstruct Spatial Pattern in Karst Coast Krakal, Gunungkidul	Ancient spatial pattern reconstruction based on geomorphological analysis in Karst Coast Krakal Gunungkidul
6.	Faida, L.R.W. 2012. Dissertation, Postgraduate School University of Gadjah Mada, Yogyakarta.	Reconstruction of Karstic Forest in Karst Gunung Sewu, Daerah Istimewa Yogyakarta, Indonesia	Karstic forest reconstruction using Carbon dating in Karst Gunung Sewu, Daerah Istimewa Yogyakarta, Indonesia
7.	Sudiharjo, A.M. Dissertation in Agriculture Faculty University of Gadjah Mada Yogyakarta. 1998	Andolisasi Tanah di Kawasan Karst Gunung Kidul, in English: Soil Andolisation in Karst Gunung Kidul region	Tracing volcanic material in Karst region
8.	Sunkar, A. Dissertation in University of Auckland . 2008	Sustainability in Karst Resources Management: The Case of The Gunung Sewu in Java	Sustainability of Karst Resources Management was identified and analysed in Gunung Sewu

2.3. United Nations and Millenium Development Goals (MDGs) on water issues

Water is the essential lifeblood on Earth, with the power to generate, sustain, receive, and ultimately to unify life (United Nations Educational, Scientific and Cultural Organization (UNESCO) - International Hydrological Program (IHP), 2009[1]). Collaborative projects between individual nations and The United Nations have conducted monitoring of water and sanitation access. In 2012 World Health Organization (WHO), United Nations Children's Fund (UNICEF), the World Bank and donors announced new plans to greatly expand access to improved water and sanitation for millions of people over the next years. Each country is pledged to provide tens of millions of people with access to improved drinking water sources and improved sanitation to accelerate and reach the Millenium Development Goal (MDG) targets (UNICEF and WHO, 2012).

The United Nations Children's Fund (UNICEF) said that almost 3,000 children die from disease due to poor water and sanitation per day. More than three quarters of those who lack access to safe drinking water and basic sanitation live in rural areas, particularly due to economically issues. Millenium Development Goal target number 7.C states that by 2015 half proportion of the world population without sustainable access to safe drinking water and basic sanitation should decrease:

- The world is on track to meet the drinking water target, though much remains to be done in some regions;
- Accelerated and targeted efforts are needed to bring drinking water to all rural households;
- Safe water supply remains a challenge in many parts of the world;
- With half the population of developing regions without sanitation, the 2015 target appears to be out of reach;
- Disparities in urban and rural sanitation coverage remain daunting;
- Improvements in sanitation are by passing the poor.

[1] Water security issues, responses to local, regional, and global challenges

Sanitation and safe drinking water are essential for human life, dignity, and development. Progressing sanitation and drinking water must be enabled to support policies transform into applicable actions. Coherent and holistic approach within multi-stakeholders must be applied with defined leading sector or institution (GLOBAL ANALYSIS AND ASSESSMENT OF SANITATION and DRINKING-WATER (GLAAS), 2012). The Joint Monitoring Program (JMP) for water supply and sanitation progress report (UNICEF and WHO), 2012) estimates that 63% of world´s population has access to improved sanitation, and 89% of global population uses improved drinking-water resources (Figure 2.2). The GLAAS 2012 report said that 85% of identified countries show improvement in lead government agencies for sanitation by 2009. More than half of the responding countries in the world by 2011, includes Indonesia, reported that coordination mechanisms among drinking water institutions were defined and operational (Figure 2.3).

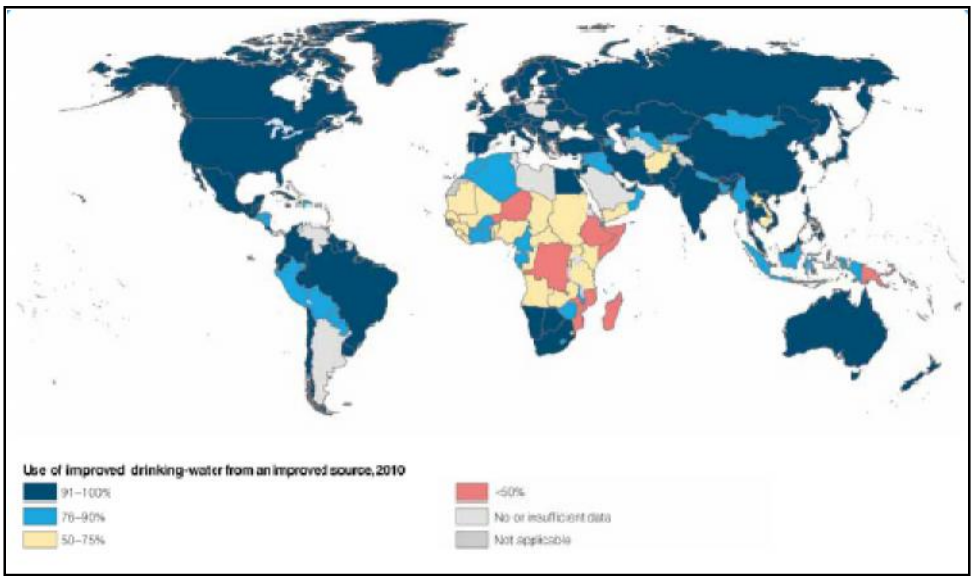


Figure 2.2. Percentage of population obtaining drinking water from improved source (source: UNICEF and WHO 2012)

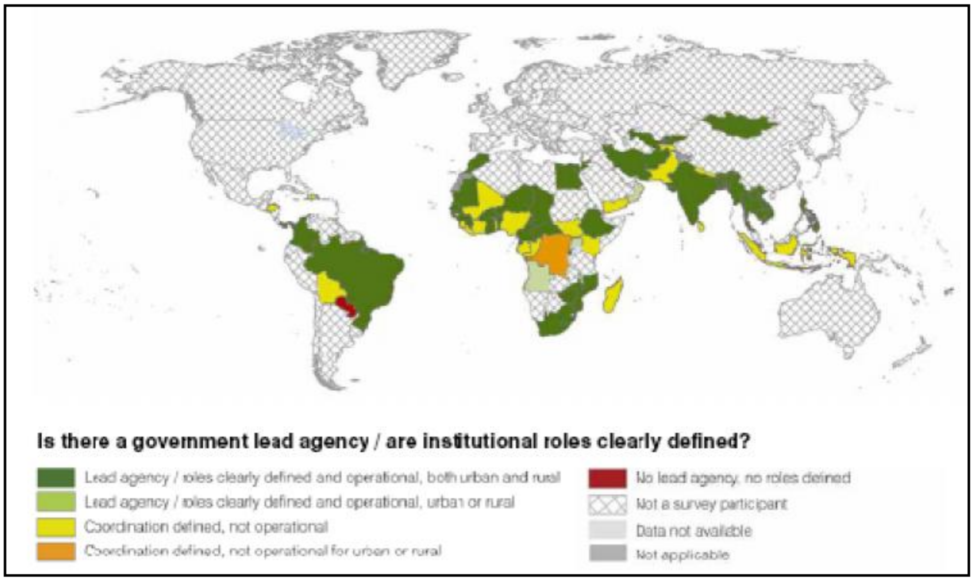


Figure 2.3. Drinking water, institutional roles clearly defined 2011

(source: GLASS, 2012:14)

In the GLAAS 2012 report, Indonesia is one of country who receives world aid for sanitation and drinking-water (see Table 2.5), compromise over US $ 1.5 billion annually (2008-2009 average). Indonesia is one of the countries that has high index of capacity of investment, and 50 % - 75% funds needed to meet MDGs target in urban drinking water.

Table 2.5. Countries that receives world aid for sanitation and drinking-water

Country	Average donor disbursement for sanitation and drinking-water, 2008 – 2009 (US $ million)	Donor financing for water, sanitation and hygiene (WASH) (as % GDP)
China	296	0.01
Viet Nam	274	0.29
India	252	0.02
Turkey	167	0.03
United Republic of Tanzania	161	0.77
Indonesia	**157**	**0.03**
Peru	139	0.11

Source: GLAAS, 2012

2.4. United Nations (UN) Water and Culture

UNESCO addresses indigenous water issues through separate programs. The Water and Cultural Diversity Database, which is part of the International Hydrological Program (IHP), and (2) the interdisciplinary program on Local and Indigenous Knowledge Systems (LINKS). UNESCO, in partnership with the Secretariat of the Convention on Biological Diversity (SCBD), the Secretariat of the UN Permanent Forum on Indigenous Issue (SPFII) and the Office of the High Commissioner on Human Rights (OHCHR), launched a grassroots climate change forum.

Through the Indigenous Peoples Kyoto Water Declaration, the indigenous participants of the 3rd World Water Forum committed themselves to forming a network on water issues that will strengthen the voice of indigenous people generally, and help empower local communities struggling to protect their water rights. Indigenous Peoples' Kyoto Water Declaration stated: the relationship to water; conditions of our waters; right to water and self determination; traditional knowledge; consultation; and plan of action.

Rural and local (indigenous) communities are finding themselves on the frontlines of climate change, suffering early impacts due to the particular vulnerability of their territories and their reliance upon resource-based livelihoods. Climate change poses a direct threat to the livelihoods of many indigenous groups due to their traditional and continuing reliance upon resources harvested from their immediate environment. Indigenous peoples therefore deserve specific attention when considering this global threat (NAKASHIMA, 2008).

2.5. Spatial Plan, Land Management, and Basic Management for Karst area in Indonesia and Gunungkidul Regency based on Constitutions (Regulations)

The process of allocation, forming, sizing and harmonizing space or land for multi-function uses are involved in spatial planning. Space can be defined as an area where human beings and their artefacts are threatened by spatial hazards. Spatial planning is a long-term decision for specific geographic need to consider all spatially relevant hazards and assess multiple hazards. Spatial planning is responsible for a particular spatial area, not only for a particular object (ARMONIA, 2007). Spatial planning includes the dynamic process of balancing spatial interests and conflicts (social, economic, legal, ecological, and disasters) and the application of all its related measures and tools. Effective planning for specific regions demands a full appreciation of all their economic, scientific and human values, within the local cultural and political context (WATSON, HAMILTON-SMITH, GILLIESON, and KIERNAN, 1997).

The distribution of population, the location of settlement areas, or technical infrastructure is basic information required for any kind of planning activity, particularly in spatial planning. Spatial planning has the potential ability to affect the vulnerability of a community related to spatially relevant hazards, since they own spatial dimensions (GREIVING, 2006). Spatial planning definitely requires a multi-risk approach due to the varied characteristics of hazards for different areas. Gunung Sewu Karst region annually suffers from a climatic water scarcity hazard. This information is related to vulnerability and risk factors. Risk perception in Indonesia is still related to local beliefs. Therefore, it is important to take into account local characteristics, particularly in Karst regions, in formulating spatial planning. Scale is important in spatial and landuse planning within ecological approach (BIRKS, BIRKS, KALAND, and MOE, 1988).

2.5.1. Spatial Planning

Spatial planning in Indonesia has hierarchy, from a national level to local level. Each level has some standard requirements to be fulfilled. Spatial planning mostly plays role as mitigation actions in disaster risk reduction efforts. The planning is related to other regulation or law, e.g. the Environment Act, river basin management law, and the Coastal and Small Island Act. Some of the formal regulations related to spatial plan from national level to local level in Karst Gunungkidul region are described as follows:

a) Governmental Enactment number 26 issued in 2007 regulates Spatial Planning *(Undang-undang* 26/2007);

b) Governmental regulation (*Peraturan Pemerintah*) number 26 issued in 2008 about the National Spatial Plan (*Rencana Tata Ruang Wilayah Negara*).

c) Provincial act number 2 issued in 2010 about Regional Spatial Plan of Yogyakarta Special Province (*Rencana Tata Ruang Wilayah Daerah Istimewa Yogyakarta*). Paragraph 101 mentions that eco-geotourism of Karst Gunungkidul is one of the Yogyakarta Special Province strategic region.

d) Regional Act number 6 issued 2011 about Regional Spatial Plan of Gunungkidul Regency (*Rencana Tata Ruang Wilayah Kabupaten Gunungkidul*, in detail as follows:

- Paragraph 11 article 2 (e) said about maintaining Karst ecosystem and preserving the unique of exsokarst and endokarst, balancing management of geological conservation region as knowledge and education center, and world heritage tourism. Paragraph 11 article 4, article 5 and article 6.
- Paragraph 14 article 4, article 5
- Paragraph 15 article 3
- Paragraph 17
- Paragraph 18 article 2 (c)
- Paragraph 23, article 6 (c)
- Paragraph 25 article 1, article 2, article 3, article 4, article 5 and article 8
- Paragraph 27 article 2
- Paragraph 29 article 29
- Paragraph 30, 31, 33

e) *Kepmen Kimpraswil* no. 534/KPTSM/2001 issued by Ministry of Regional Development and Public Works, guidance on minimum standard for settlement.

2.5.2. Basic Regulation Management of Karst Area

Karst landscape Indonesia stretches from the east to the west with different strategic functions, i.e. hydrologic function, and biodiversity keeper, and supporting livelihood. Thus, Government issued some regulations to preserve Karst region:

a) Ministry of Energy and Mineral Resources no. 17 issued in 2012 defines the Karst regioning.
b) Ministerial Decree of energy and mineral resources number 1456.K/20/MEM/2000 regulates Karst management.
c) Ministerial Decree of energy and mineral resources number 3045 issued in 2014 (*Keputusan Menteri* ESDM 3045 K/40/MEM/2014) regulates the determination of Karst Gunung Sewu landform.
d) Gunungkidul regional government issued policies due to mining prohibition on Karst hills (*Surat Edaran Bupati* number 540/0196) in 7th February 2011.

2.5.3. Basic Land Management

Basis agrarian law in Indonesia was established in 1960. The law was intended to end dualism between colonial land laws and traditional land laws. Land policy in Indonesia covers 30% of the total area where the rest is under forest tenure. This is due to sectoral segregation which somewhat demonstrate inconsistencies in the policies of Indonesian governance. Customary land interest known as *Adat* in Indonesia has just been recognized and given a space in one or two articles in National Law and other formal regulations in the last decade, yet challenges still emerge due to conflict of interests. Regulation on land management is sometimes overlapping and even cross-cutting with other laws pertaining to mining, forestry and fisheries.

The *Basic Agrarian Act* 1960 has no power over forest area in Indonesia due to the *Basic Forestry Act* 1967 which classified and stated that 70% area in Indonesia as state forest land not ruled by the Agrarian Law. Another issue is that the physical characteristics of land differ between locations and determine the development progress related to governmental policies as well.

Government Act number 16 issued in 2004 and number 11 issued in 2010 regulates the utilization of land, which collaborate with the *Spatial Plan Act*.

2.6. Water Management in Indonesia

An individual's and a nation's life depends on their water. Water is a vital resource that needs to be protected, conserved, and maintained to support humanity and all life on earth. Recently, water management problems increased due to climatic factors and complex anthropogenic factors. In Indonesia, as occurring troughout the world, there is too much water in the rainy season, and lack of water in the dry season. Natural cycles have been changing or showing different patterns.

In severe areas like the Karstic region, planning and designing water projects are frequently determined by financial resources rather than by considerations of optimal design. It also requires deep analysis of the socio-economic-cultural features of the area, because water demands are strongly related to population growth, public facilities and infrastructures, water consumptive activities such as industries and agricultural need (FALKENMARK and CHAPMAN, 1989:129). Thus, managing water needs to take into consideration local characteristics whilst engaging global issues. The Dublin Principles (GLOBAL WATER PARTNERSHIP (GWP), 2000) stated that:

1) fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment.
2) water development and management should be based on a participatory approach, involving users, planners and policy makers at all levels.
3) women play a central part in the provision, management and safe guarding of water.
4) water is a public good and has a social and economic value in all its competing uses.
5) integrated water resources management is based on the equitable and efficient management and sustainable use of water. Water is recognized as an integral part of the ecosystem, a natural resource and a social and economic good quantity and quality determine the nature of its utlisation.

The paradigm on water management has shifted from domination in the 19th century to sustainability one in the 1990's (GLEICK, 2000). Early integrative approaches which combined planning methodology with the hydrological approach were developed by VAN BUUREN in 1991 (BEVERINOTTI, PEREZ., BUHMAN, and PIETSCH 2010). The identification and understanding of problematic landuse and water flow was the main methodology. Landscape interactions reflected the contribution of water flows. VAN BUUREN (1991) said that allocation and relocation of landuse can be conducted by analyzing water related landscape structure, where catchment area as the main spatial and functional unit. Interaction of water flow in time and space could reveal patterns of landscape, particularly in such specific feature like Karst.

The GLAAS 2012 report said that almost 80% of respondent countries, including Indonesia, have indicated the right to water in policy or legislation. The translation of policies into concrete actions from national to local level still needs to be enhanced. Pro-poor economic policies and strategies for water and land management related issues in rural area should be clearly implemented. The European Water Framework Directive have promoted a river basin approach and referred to interrelations between water management and land use (WIERING, 2006).

Some of the formal water related regulation in Indonesia concerning water management for Gunungkidul Regency are described below:

a) State Government Act number 7 issued in 2004 concerns water resources. In paragraph 21 article 4, it is said that water resources preservation and conservation are conducted by technical and/or vegetative efforts using social, economic and cultural approaches. Paragraph 22 article 2 mentions water preservation during the rainy season so that it can be used. Paragraph 27 article 1 states about water resources zoning requires some space allocated for fishing, tourism, mining or conservation. Paragraph 61 article 1 requires that water resources inventories include the social economy and culture of community. Paragraph 65 article 2 said that water resources information consists of hydrology, hydrometeorology, hydrogeology, the policy of water resources, infrastructures, technologies and water resources environment and also the social economy and culture of a community related to that water resource.

b) Government regulation number 43 issued in 2008 concerns groudwater.

c) Government regulation number 38 issued in 2011 concerns rivers. It is said that each river is characterized by the geohydrobiology of the region and local social culture. Local social culture practices are related to behavior, daily customs, and norms of river utilization. River management success would likely depend on the participation of community or river inhabitants.

d) Provincial Act number 2 issued in 2010 concerns the Regional Spatial Plan of Yogyakarta Special Province

- Paragraph 29 (b) water resources infrastructure will be developed and located as ponds scattered in Gunungkidul regency. Ponds function as important water reservations to support community livelihood in Gunungkidul regency.
- Paragraph 29 (c) said that water resources infrastructure that will be developed along the underground rivers of Bribin, Seropan, Ngobaran, and Baron.

e) Interior Ministerial Resolution (Keputusan menteri dalam negri) number 50 issued in 2001 gives guidance that empowers farmers who benefit from water.

f) A Ministry of Regional Development Regulation has oversight of the establishment of National and or regional cooperation on water management.

g) A Ministry of Public Works Regulation has operational guidance of rivers and lakes management.

h) Ministry of Forestry Regulation number 52/KPTS/II issued in 2001 delivers river basin management guidance.

i) Ministerial Decree of Energy and Mineral Resources on Underground Water number 15/2012.

j) Gunungkidul Regency Regional Act number 2 issued in 2009 about regional cooperation of safe drinking water (*Perusahaan Daerah Air Minum* (PDAM)) in Gunungkidul Regency.

k) Gunungkidul Regency Regional Act number 17 issued in 2012 about permission on groundwater utilization and exertion.

From Government Acts and the following laws which are mentioned above, it is clear that culture should be considered in water resources management. The community´s culture is visualizing the interaction between human and the environment.

2.7. Cultural and Philosophical Approach (Geographic, Behavior, Ecosystem and Landscape)

Local, indigenous, and traditional knowledge has developed a concept of the environment that emphasizes the symbiotic character of humans and nature. Inherited environmental knowledge with particular specialization is an important part of human kind's cultural heritage as the result of countless civilizations and traditions that have emerged over human history time. Cultural diversity is as important as biodiversity for our future. It is a potential source of creativity and enrichment embodied in several social and cultural identities, each of which expresses its uniqueness or characters (UNESCO, 2002).

2.7.1. Culture

Definitions and concepts of culture have been identified and mostly related to anthropology. Meanwhile, geographers study the spatial expression of culture which reflects relationships between human society and both the natural, and social environment (DE BLIJ, 1996:217). Cultural geography deals with cultural landscape, hearths, diffusion, ecology, perception and ethnicity and regions (DE BLIJ, 1996:220-221). Culture is expressed in attributes, such as dress styles or modes, building styles, farms and fields and other embodiments considered as peculiarity. Serious conflicts that occur and emerge in some region in the world express the issues of human territoriality and proxies of resources with spatial context.

Particular cultural patterns might play important and crucial roles in coping with environmental variability and changes (HEYD and BROOKS, 2009). Natural factors have and been shaped cultural behavior of Karst Gunungkidul as part of Gunung Sewu community and reflect on the cultural landscape, the imprint of land on the culture. Interaction between the community and the environment has become the basis of their life. Soil and water management based on the character of Karst Gunung Sewu have shaped unique cultural landscapes in the region. It reflects human adaptation to the unique of Karst Gunung Sewu in terms of space utilization on soil, water and other natural resources.

The expression of relationships between human society and natural environment imprint on the land distinct characteristics of cultural landscape and ecology. However, a map cannot visualize the whole cultural landscape because culture involves visual appearance, life pace and other non-spatial organization (DE BLIJ, 1996:222). WINARTO, STIGTER, HESTU, ANANTASARI, and KRISTIYANTO (2011) conducted research on dialectical knowledge to cope with water scarcity or drought besed on the local knowledge context and lessons learnt from Climate School Field (Sekolah Lapang Iklim (SLI)) in Wareng village, sub-district Wonosari, Gunungkidul, Indonesia. The alumnus of the Climate School Field admitted that *Pranata Mangsa* as their inherited seasonal calendar knowledge has shifted due to climate variability in the last decades.

Adaptation in ecological term is defined as a strategy to tackle and to cope with environmental change even in the worst one, such as Karst region during prolonged dry season. Eco-adaptation culture has been developed, since ancient cave inhabitant, historic time, and been evolved in modern society of Karst Gunungkidul. Geomorphologic and climatic factors characterize human adaptation, and in turn, human activities induced natural process as well. SUNKAR (2008) revealed that human use of landscape changes in Gunung Sewu met the classification of BIRKS et. al (1988), i.e. hunter-gatherer economy, slash-and-burn agriculture and pastoralism, permanent manured field utilization, more efficient use of permanent manured fields, and dependence on artificial fertilizers. Gunungsewu landscape follow seasonal changes, it is open during dry season and green during rainy season (SIMANJUNTAK, 2002:31). Inhabitant of Karst Gunungkidul have developed evolving adaptation culture responding to the environment process.

2.7.2. Cultural Landscape

All landscape in the world exists somewhere in particular, thus cultural landscape are local. This study tries to understand Karst characteristics in a cultural landscape through the application of local knowledge which reflects interaction between human and their Karst environment. The works of LEOPOLD (1949), SAUER (1925), and HUMBOLDT (1814) inspire this cultural landscape approach coupling with other scholars thoughts.

Figure 2.4. Picturesque of Conical Hills Gunung Sewu in wet (left) and in dry season (right) (Source: LUKAS and STEINHILPER, 2005)

Landscape reflects the physical, biological and cultural character of human everyday lives in evolution. Conical hills Karst Gunungkidul landscape change seasonally, depicting the inhabitants behavior (see Figure 2.4). A rural historic landscape is defined as a geographical area that historically has been used by human activity, occupancy or intervention and that possesses a significant concentration, linkage or continuity of areas of land use, vegetation, buildings and structures, roads and waterways and natural features. A cultural landscape is defined as a geographic area, including both culturally shaped by human and natural resources and the wildlife or domesticated animals, associated with inherited events, activities, or person or exhibiting other cultural or aesthetic and ethic values (SAUER, 1925 adapted). Cultural landscapes can range in scale from thousands of acres of rural tracts of land to a small homestead with a front yard of less than one acre. Cultural landscape concepts can be used to manage natural resources (see Figure 2.5)

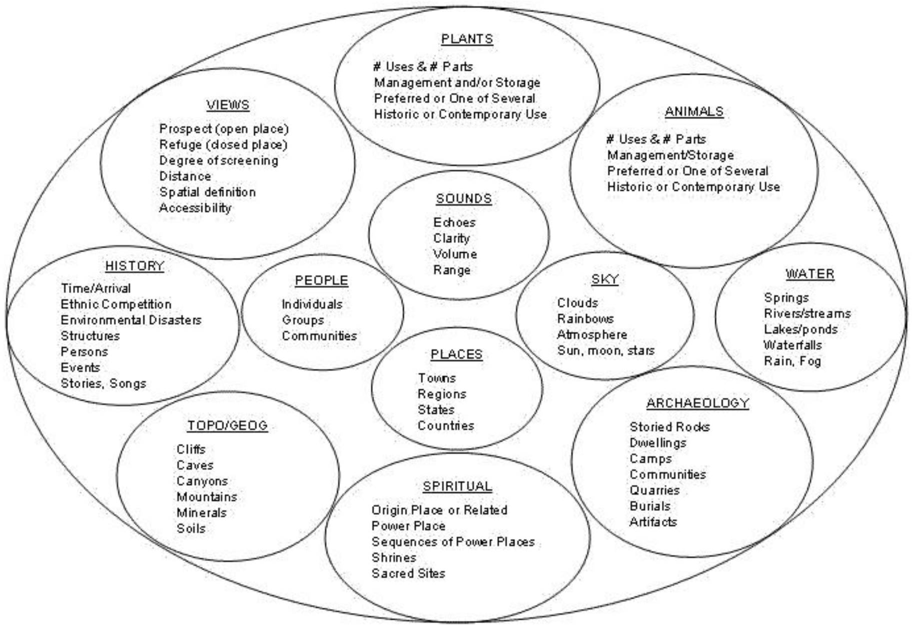


Figure 2.5. Cultural Landscape Paradigm to manage natural resources (TOUPAL, 2003:8)

Dynamic environment processes are natural, yet also induced by anthropogenic factors. Development in the name of modernization continuously affects the cultural landscape of Karst Gunungkidul practices and change the way of people interact with the environment. Reconstructing water management from local knowledge of rural Karst Gunungkidul community into so-called high and modern technology water management should be considered important, while also encouraging the community to enhance their strategy in managing climate related variability.

Introducing environmentally-friendly livelihood activities, as well technology, needs to be proven by giving real benefit to be accepted and implemented (SUNKAR, 2008). The failure of water projects in the rural Karst Gunungkidul areas could be attributed to differences in water culture. Projects need to adopt a cross-cultural and interdisciplinary approach. Scientist´s knowledge, in particular of water and space issues, needs to be broader to encompass a variety of relevant disciplines such as history, sociology and anthropology. The views of indigenous and rural people must be balanced with the methodologies based on modern development techniques. Water is life itself and a human right. It is critical to understand what and how people view water in different ways (AKIWUNI, 2010).

Traditional cultural landscape on Karst Gunung Sewu seems to decrease as intensive modern agriculture and silvi-culture programs neglect the unique Karst systems. In some part of Karst Gunung Sewu, some traditional or local culture related to water management is still preserved and passed by generations (SULASTRIYONO, 2005). One xample of local culture related to the value of water is the *Jonge* ponds cleaning ceremony (*upacara bersih telaga*) in sub-district Karangmojo, one of sub-districts in Gunungkidul Regency. Another cultural practice of local wisdom or cultural knowledge that considers the preservation of the environment is *´´Cing-cing goling´´*. These two examples represent traditional ceremony in respecting the environment and are inherited from Majapahit Kingdom era. The traditional cultures were brought by soldiers and royal family when they escaped from Majapahit Kingdom and eastablished early societies and communities.

The importance of preserving local community culture *´´masyarakat adat´´* capable of conserving and protecting their environment needs to be considered in managing water and space utilization by law or government policies. Local community ´´m*asyarakat adat´´* Hutan Wonosadi in Duren Hamlet, Beji Village, sub-district Ngawen has managed to protect and preserve their nearby forest which support livelihood.

Space utilization for community livelihood must consider ecological impact, in particular water resource use in unique Karst ecosystems. Water efficiency and rain water harvesting have already been known and practiced in Gunung Sewu area. The community knows how to use water wisely and efficiently, since their livelihoods are at stake and they have developed water management as norms and values. The words reduce and reuse have actually been practiced in some locations as their way of life in water management (SURYANTI, 2010), and they manage to use varied water resources to anticipate the lack of resources in the dry season (LUKAS and STEINHILPER, 2005).

Karst Gunung Sewu has been proposed as World Heritage by International Speleogist in 1993. Therefore, the cultural aspects related to maintaining the Karst system should be accommodated. Historical events resulting in the establishment of permanent settlement and people movement in Gunung Sewu was summarized and reviewed in SUNKAR's research (2008). The philosophy of local culture water management need to be supported by local government policy and planning. Different perceptions and manifestations of cultural water management reflect on the landscape due to land use practices, better knowledge and understanding between scientific, society and the government. For example the management application of cultural landscape in New Zealand can be seen in Figure 2.6.

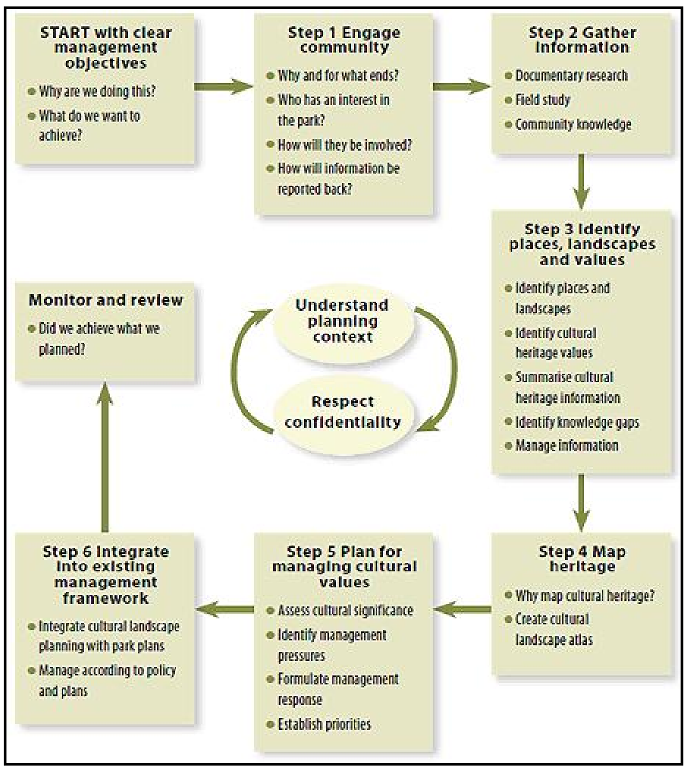


Figure 2.6. Management application of cultural landscape in New Zealand (Source: BYRNE and NUGENT, 2004)

A region or an area is characterized by culture. Living space can be transformed into occupancy type, such as constructed buildings, channeling water or tilling land. Cultural landscapes in Gunung Sewu related to human adaptation to the unique system of Karst can be seen in many locations, but may be varied. Terraces, mixed crops and big trees are indicators for cultural ecology, expressing the relationship between the natural environment and human inhabitants. People in Karst Gunung Sewu have transformed their living space by structuring rain-fed terraces, collecting water in ponds and harvesting rainwater. This alters their environment with a lasting cultural imprint (DE BLIJ, 1996:221).

Determining the ways in which human values and practices correlating humanity and natural environment and the adaptive or maladaptive cultural pattern, are important complementary and supporting steps for developing technology, engineering and managerial coping and adaptation strategies in the world of intensifying environmental risks (HEYD and BROOKS, 2009). In the context of environment interaction, culture can be determined as an adaptive system which expresses human adaptation to the environmental variability. MILLER and WEITZ (1979) said that there four reasons for how culture developed and why changes, namely:

1) Culture is a system that corrrelatez community to their environmental setting;
2) Culture changes are adaptation strategies, reflecting individual reactions that to respond the environmental changing processes;
3) Cultural adaptations are technology, subsistent activities, and methods to organize the community for production activities;
4) Ideas or concepts which drive cultural behavior, like beliefs related to ritual religion or faith, might be useful for adaptive actions.

2.7.3. Seasonal based Calendar and Its Cultivation System (*Pranata Mangsa* in Javanese Calendar)

Javanese people have inherited seasonal based knowledge for agriculture for centuries, particcularly during the Mataram Kingdom era in central Java, when *Pranata Mangsa* was formulated by Pakoeboewono VII. It designated the summer solstice in the peak rotation on 22 June 1855, and was applicable appropriately in central Java, geographically located within the Merapi volcanic ranges. The establishment of *Pranata Mangsa* was documented in the Kings historical stories and kept in *Radya-Pustaka* museum in Solo, Central Java.

Seasonal based local knowledge known as *Pranata Mangsa* is applied in the study site within some adjustments to the environment. Correlation between water availability, consumption and its management reflects on how the community utilizes the resources and the supporting conditions in the rural Karst Gunungkidul. Farmers conduct a seasonal cropping system based on water availability due to seasonal changes (Figure 2.7). The community has adjusted to the climate and hydrological systems. Their main food or staple food have also been adapted to the climatic factors, for example during rainy season rice is cultivated, and cassava is cultivated during dry season.

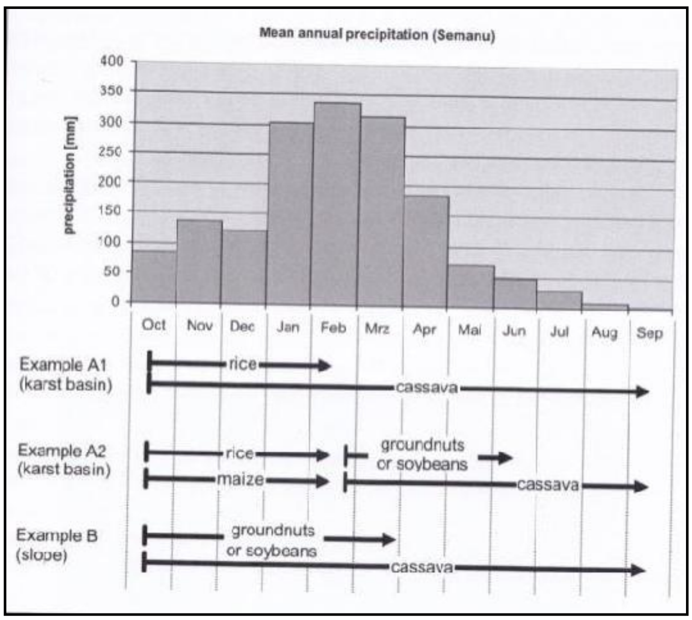


Figure 2.7. Seasonal crop (cultivation) calendar of Dadapayu community in Gunung Sewu (source: LUKAS and STEINHILPER, 2005)

The seasonal cultivation calendar reflects the water footprint in the area. The water footprint is an indicator of freshwater use that looks not only at direct water use of a consumer or producer, but also at indirect water use. The water foot print can be regarded as a comprehensive indicator of freshwater resources appropriation, next to the traditional and restricted measure of water withdrawal (HOEKSTRA, CHAPAGAIN, ALDAYA, and MEKONNEN, 2009). The individual, community and business water footprint can be defined as the total volume of fresh water that is used to produce goods and services consumed by each of them.

The rural community in Karst Gunung Sewu might have no scientific background in cultivating certain crops and has only inherited the transferred knowledge of cultivating from their elder generations. Seasonal based knowledge *Pranata Mangsa* has taken into account the climatic factors and changes of climate or season by noting particular changes from the vegetation, animals, winds, temperature and other climate related parameters.

The traditional cultivation system plays important role in alleviating the threat of food insecurity during the dry season. Intensive modern cultivation systems which are not adapting to climatic factor changes might increase the environmental risk related to drought and raise food insecurity during the dry season in Karst Gunung Sewu, the probability and exposure of drought risk will likely to increase.

Vegetation is a goood indicator of changes in climate systems. In agriculture, farmers are usually aware of the cycles by adapting seasonal cultivation or crops. By doing so, they also consider the consumption of water and the available space to grow the plants. Rural farmers who still practise traditional farming systems must understand the microclimate of their ecosystem.

Phenological knowledge is embodied and embedded in the traditional cultivation system. Phenology is the study of annually recurring events in plants and animals such as leaf unfolding, flowering, fruit ripening or the arrival of migrating birds which introduced during 19th century. This study utilizes the fourth assessment report of the IPCC said that the results of phenological research play a major role in assessing the observed changes in natural and managed systems. Phenology has gained prominence since modern recognition of climate change and variability.

Rural communities in Karst Gunungkidul have practised a phenological approach for agriculture practices and water management. *Tumpangsari* cultivation systems that passed from generation to generation in land-use practice have considered phenological aspects related to climatic factors that restrain productivity (Figure 2.8). The *Tumpangsari* system has also taken into account the landform or geomorphological condition of Karst Gunung Sewu.

Figure 2.8. *Tumpang sari* cultivation system in Gunung Sewu (corn, gogo/rain-fed paddy, banana, and cassava)

2.7.4. Culture and Political (institutional) View on Environment

Ecology began as a form of geography to some extent in general and naive discussions about the role of climate, temperature or altitude on biological systems. Ecological ideas have long had major influences in the fields of health, environmental history, cultural ecology, cybernetic analysis of social and economic systems, human geography and development theory (GREENBERG and PARK, 1994). Comprehending the nature of culture leads to better understanding of the relationships between natural environments and human society or inhabitants of certain environment, such as Karst areas. Some policy perspectives need to accomodate climatic variability and environmental changes which allow natural systems space and time to settle or become understood.

Marginalization of nature in modernized societies by macro-scale policies and limited action policies expand the exposure and vulnerability to natural hazards. Policy makers and plan makers need to consider local and cultural water and land management practices in planning systems. Socio economic expectations due to the standard of government development programmes have lead to environmental pressure on the Karst system.

Human and Karst interaction issues are arguable in land use and spatial plan regulation. Policy and plan makers must undertstand the basic and most common Karst landforms: what, where and why they form where they do and then how to get the natural processes into the planning agendas. Controlling the land use and space regulation require better understanding as a critical part of formulating and developing sensible and appropriate enactments for unique landforms like Karst Gunung Sewu in Java (FLEURY, 2009).

Mal-adaptation of government policies which failed to cope the environment variability, as in the case of West part of Sahel, where the development policy failed to meet the mitigation and adaptation requires due to the unique characteristics of the environment and behavioral changes. Adaptation strategies from cultural behavior to cope with water shortage as a result of the complex correlation between climate, geomorphology, geology, hydrology and anthropogenic factors, needs appropriate management from the government and multi-scale institutions.

Land and water are active counterparts to human beings. State governments and local governments or communities need to work on a response plan and on a preparedness and strategic mitigation plan to meet the annual water shortage when the dry season comes. More emphasize on risk management rather than emergency response or crisis management in term of good political will and policy making.

2.8. Water on Karst Ecosystem

Water flow and location of its sources shape human behavior. The important role of Karst water utilization have been known since early human habitation. Karst spring water was utilized for millennia, since irrigation in Shanxi

Province, China in 453 BC and by the Mayan people of Yucatan (classical period AD 317-889) who centered their civilization around cenotes penetrating karst aquifer (FORD and WILLIAM, 2007). Cities and rural populations around the world some rely on Karst water supplies. The distribution of Karst regions in the world can be seen in Figure 2.9.

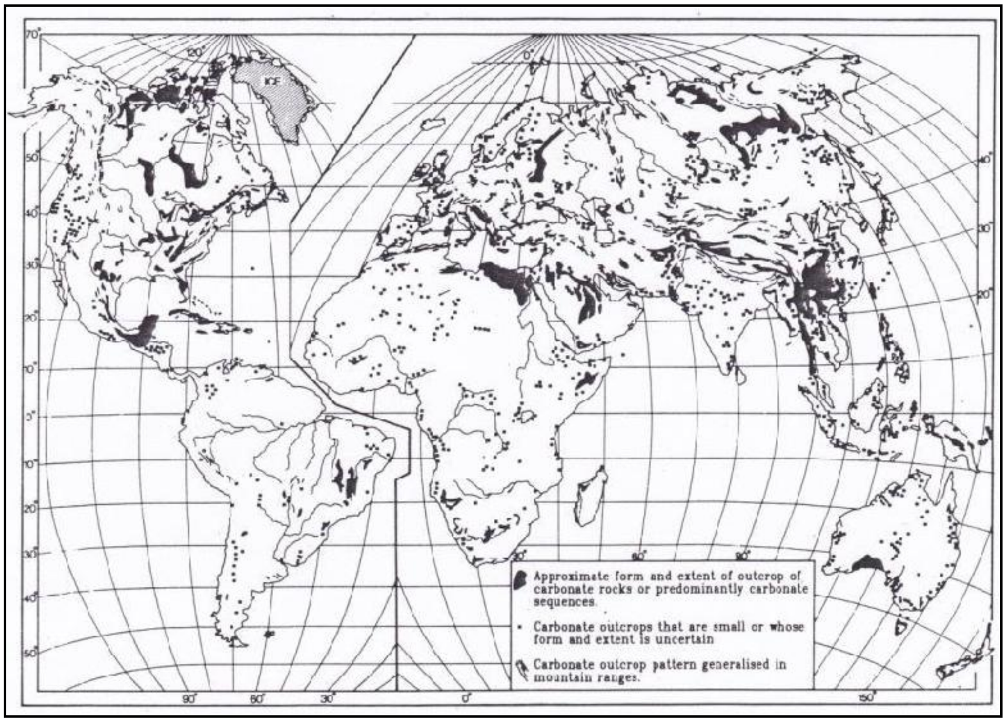


Figure 2.9. Karst Distribution in the World
(source: FORD and WILLIAM, 2007)

Human activities above and below ground tend to escalate the disturbance on fragile Karst systems which are non-renewable resources. Anthropogenic factors will accelerate natural processes in the Karst region. Many human actions which consume space cause Karst regions degradation, although Karst carrying capacity is not large. Physiographic and hydrologic features typical of a well-developed Karst Terrain as seen in Figure 2.10 need to be better understood to assist better development planning.

Community based water management in the application of spatial planning, from participation to dialogue, debate and negotiation have happened around the world as well as in Indonesia. Even though Indonesian water resources account for almost six percent of the world water resources or about 21% of total water resources in the Asia Pacific region, clean water is becoming a serious problem in Indonesia. The availability of clean water in term of quantity tends to decrease due to environmental degradation and pollution. The rate of water resources degradation accounted for 15-35 % per capita annually.

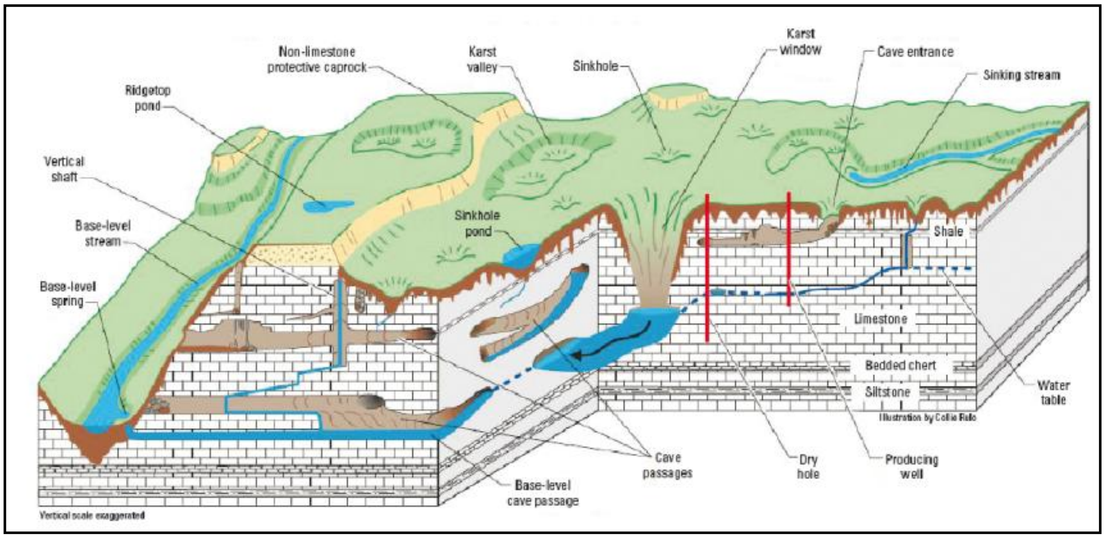


Figure 2.10. Physiographic and hydrologic features typical of a well-developed Karst Terrain (modified from CURRENS, 2002, cited on TAYLOR and GREEN)

There is several factors causing degradation of water resources quality in Indonesia, such as domestic waste. The data show that of 51,372,661 houses in Indonesia, there is only 42.8% has domestic waste treatment. About 56.15% of household disposes their domestic waste directly into river bodies[2].

Karst Gunung Sewu in South Java Indonesia has been known in the world of science for the unique conical or kegel karst which are likely to suffer water shortages due to its characteristics. Figure 2.11 shows the distribution of Karst regions in Java. Water shortages in the dry season have been accepted as part of living in Karst region. Methods of water management based on local knowledge among villages in Karst Gunungkidul show slight differences between. Traditional landuse practices, buildings, walls and other component of the landscape mosaic. The traditional ways of life can be used to better

[2]State of water environment, and water related issues and policies analysis by Water Environment Partnership in Asia initiated by Ministry of the Environment Japan

understand the natural resources management, particularly local specific water management in Karst Gunungkidul, to enhance evolving changes.

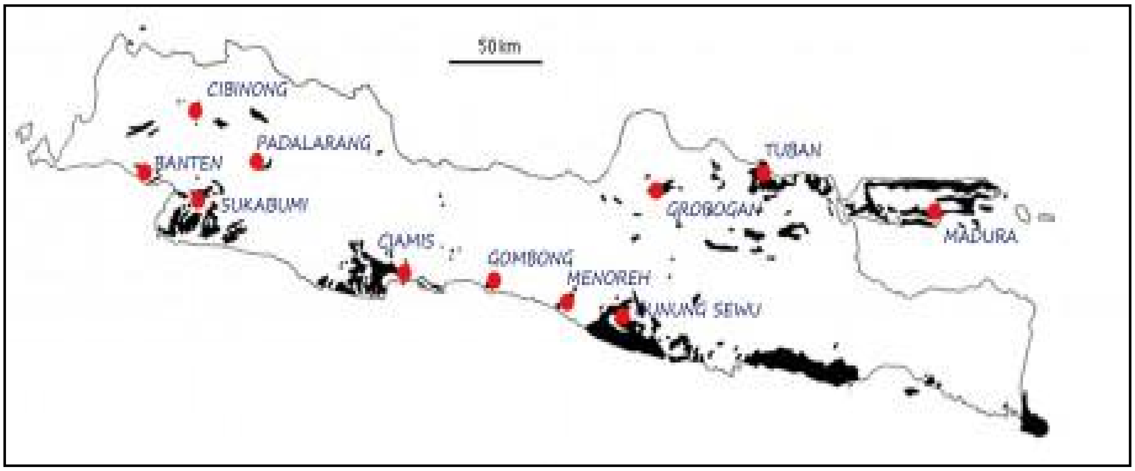


Figure 2.11. Distribution of Karst Region in Java (RAHMADI, 2008:6)

2.9. The Risk on Karst Ecosystem

Kegel karst or cone karst relief in Gunung Sewu was found to be related to humid tropics (FORD and WILLIAMS, 2007). Karst classification mapping is needed to define the disturbance of human induced activities on the Karst ecosystem. Based on governmental spatial plans, groundwater management and environment law, Karst classification mapping can be used as a baseline to evaluate disturbance on this ecosystem.

Karst processes have potential hazards. Human activities troughout the world, connect and interact with the natural environment, explore the resources, create the hazardous processes. Escalating human occupation upon Karst terrain and hazard exposure will result in ceaseless impacts and risk. Geomorphic features and processes were an essential part of social survival when humans first begin adapting, learning and communicating finding about the environment. Human impact on Karst environment in the prehistoric time was very limited with a low probability of damage to properties and people (DE WAELE, GUTIERREZ, PARISE, and PLAN, 2011).

Integrating disaster risk reduction strategies into spatial planning means there is a necessity to simulate the future impacts of disaster, including climate variability effects. Spatial plans must be evaluated against integrated risk maps in order to have an understanding of the possible consequences of disasters upon space allocation. Designated space occupation should withstand the risks, otherwise another option should be sought. Local governments in Indonesia still need to enhance incorporation of Disaster Risk Reduction strategies into their spatial planning (SUTANTA, RAJABIFARD, and BISHOP, 2009).

Figure 2.12. Sinkholes in dry-fed cassava field Karst Gunung Sewu
(Source: YUWONO[3])

The significant hazard in Karst Gunung Sewu is water shortages or drought in dry seasons and the potential physical appearance of sinkholes which threaten man made artifacts on the surface of the earth (Figure 2.12). Risk management in this context poses challenges to integrating the best available science with sensitive social and political processes that seek responsiveness to public concerns, legitimacy with respect to potentially affected stakeholders and practicality in terms of producing implementable outcomes (FORESTER, and THECKETHIL, 2009).

2.9.1. Hazards

Hazards due to Karst processes need to be investigated with specific techniques or methods. Anthropogenic factors might worsen hazards on Karst

[3]Introduction to Karstic Archaeology article in Yuwono's website for educational purpose

areas. Escalating human occupation of Karst areas continuously raised impacts and risk (PARISE and PASCALI 2003 cited in DE WALE, GUTIERREZ, PARISE, and PLAN, 2011). Cost effective risk reduction might be feasible in some Karst areas, but proper investigation, and administrative decisions are most likely needed, the latter frequently requiring unpopular preventive planning strategies (DE WALE, et. al., 2011).

Sinkholes are the most common hazard studied (FORD and WILLIAMS, 2007; BECK and SAYED, 1991; GUTIERREZ, COOPER, and JOHNSON, 2008). Application of new methods to investigate sinkholes are increasing in order to mitigate the risk of the occurrences. Underestimated hazards in Karst region include flooding after intense heavy rains and rapid changing of flow rates of Karst springs (DE WALE, 2008). Studies of flood occurrence possibility in Karst Gunung Sewu have only been conducted in limited numbers. However, the flow rate variability of underground rivers in Gunung Sewu have been researched by some hydrogeologists, ADJI, and SUDARMADJI (2008); and NESTMANN, OBERLE, IKHWAN, and KLINGEL (2010).

2.9.2. Susceptibility and Vulnerability on Karst System

Karst area is fragile and thus needs some protection for multiple uses and stakeholders. State Government in Indonesia has issued guidance and regulations about Karst Region management from the Ministry of Energy and Mineral Resources. Regulation enforcements help to maintain the Karst system when appropriately applied. Humans and the environment are inseparable in this system. There is inter-correlation and interaction between human activities and societies in the Karst area. Human activities occupy spaces which affect and disturb the Karst ecosystem.

Vulnerability in Gunung Sewu relates to trends, pressures and seasons which affect a Karst community’s livelihood and capacity to determine how they adjust the seasonal variability and changes. SUNKAR (2008) mentioned that the key factors behind the choice of land-use practices in Gunung Sewu, show that environmental degradation is often triggered by external social factors such as population growth, politics and economic problems, more than by the limitations imposed by biophysical factors. However, in communities where nature is the source of the essentials for survival, communities develop strategies or adaptations to resource scarcities, which reduced the rate of the exhaustion of the resources, by giving more returns or benefits to the environment.

2.10. Incorporating Local Knowledge of the Seasonal Calendar and Risk into Water and Land Management and Spatial Planning

Water shortage and drought are part of climate variability. Water management is a critical issue in unique Karst environments due to climatic cycles. The combination of extended dry period probability and the consequences for people, communities and the environment lead to drought risk term. Drought risk management tries to reduce the impact of the occurrence as both probability (mitigation) or the consequences (adaptation). The diverse effects of droughts can be assessed on an ecosystem framework (MORRIS, GRAVES, DACCACHE, HESS, and KNOXX, 2010).

The impacts of drought hazards span from economic, environmental and social sectors, which can be reduced through preparedness and mitigation (DONALD, MICHAEL, CODY, and KELLY, 2000). It is important to formulate plans to deal with annual water shortages in the whole Karst Gunung Sewu and take into account the changes of climate and the environment from natural or human induced processes. The planning process should involve various levels of government and integrated level of cooperation across institutions boundaries.

Risk related activities mostly take place at regional and local level. Thus spatial planning and land management need to be incorporated at various levels and be clarified between other formal planning systems consisting of sets of plans and programmes (GREIVING, 2006). Hazard-related information has to be provided by multi sector planning. Vulnerability-related information is in most cases, known in spatial planning because facts like the distribution of the population, the location of settlement areas, or technical infrastructure is basic information required for any kind of planning activity. Vulnerability related information in spatial planning is only relevant for risk management whereas no risk assessment is needed. This is seen particularly in the results of the analyzed planning practice (GREIVING, FLEISCHHAUER, and WANCZURA, 2005).

Spatial planning can be understood only as one important supporting actor for risk management measures. Understanding and incorporating spatial planning and risk management can be seen in Figure 2.13. Spatial planning issues in Indonesia are related to:

1) Spatial planning: "dynamic process of balancing spatial interests and conflicts (social, economic, legal, ecological and disasters) and the application of all its related measures and tools – challenging tasks due to many interests and stakeholders."
2) European influence on Indonesia,
3) 20 year plan-period, 5 years revision – is it an appropriate time frame?
4) Problems with spatial planning to be sorted out first, related to basic mapping:
    i. Valid data and scale are essential.
    ii. Spatial information updating of system is necessary because of rapid development.
    iii. Clear responsibilities for Disaster Risk Reduction measures: National Board of Disaster Management or Regional Board of Disaster Management.
    iv. Risk perception between individual and institutional.
5) Problems with enforcement – how to improve people´s awareness and participation.

Natural disasters are periodic and usually leave signatures on the landscape. Landform analysis is conducted to help map hazard zones and support spatial planning, land and water management (SARTOHADI, 2007). Spatial analysis is the center of how GIS are used in transforming and manipulating geographic data. We can better understand the nature of hazards and their impacts by using spatial analysis. It should be a consideration to incorporate risk management and spatial planning for disaster prone areas within locality specification. Local knowledge of environmental issues is an input to support spatial planning, land and water management.

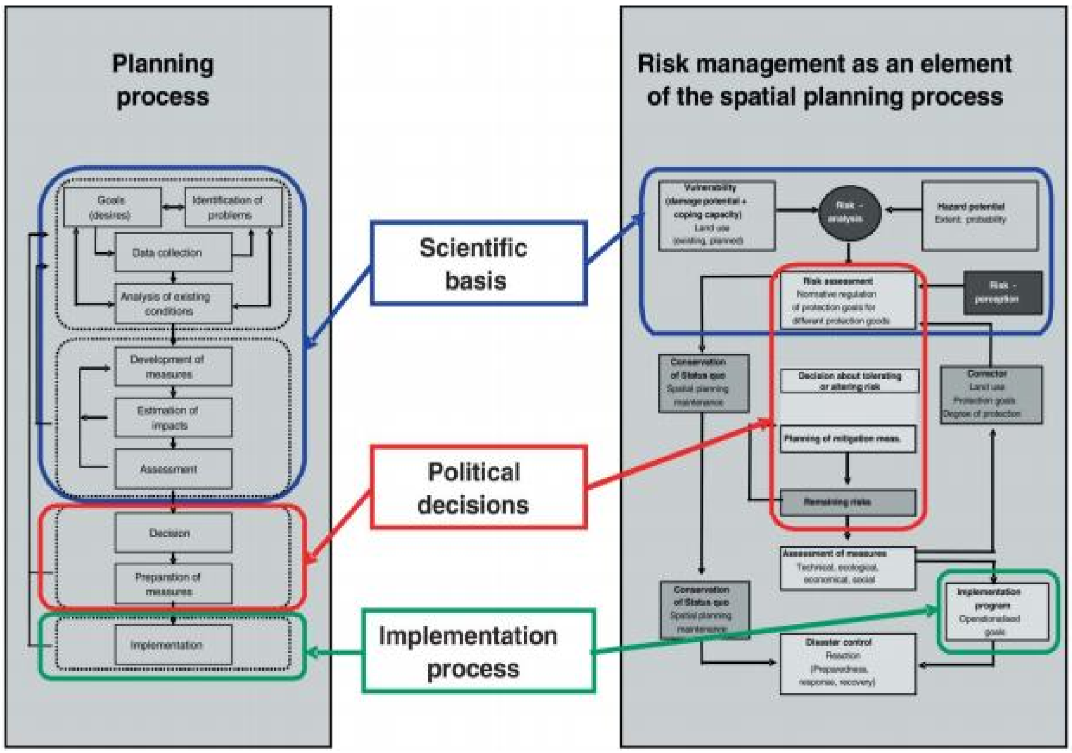


Figure 2.13. Planning Process and Risk Management
(Source : GREIVING, 2006)

III. Research Methods

This study tries to adress global issues of water and land management based on local knowledge, optimizing and exploring an understanding of local knowledge from the seasonal calendar based knowledge *Pranata Mangsa* with its phenology (bio-indicators) and its related application. A geographical approach is applied on water and land management, by building a landscape model of the Karst environment, coupling with a philosophical approach. Collecting and analyzing the cultural value of water and land which has been inherited as a culture, the contribution of environmental adaptation with values and beliefs practiced in a community, thus encourage the study of spatially cultural behavior.

The landscape approach from local knowledge and understanding aims to explore the past which could answer the future possibilities as described by geography scholars such as HUMBOLDT (1845), RITTER (1968), HAGGET (1983), WAUGH (2009) and GOMEZ and JONES (2010). Analysis of concept or theory based on phenomenology approach is applied in this study by using seasonal calendar cycles experienced and interpreted by Karst Gunungkidul communities. The conclusion in this study is not an absolute statement, rather it is controlled by empirical discovery which lead to open discussion.

3.1. Selection of The Study Area

Karst regions exist all over the world. The parental rock is carbonate which covers 13% of the land surface. Karst is susceptible to erosion which leads to denudation or outcrops by flowing water. Some Karst area in the world have suffered from destruction and are listed as endangered ecosystem (KARST WATERS INSTITUTE / KWI). The latest top ten endangered Karst included Kalimantan Karst, in Indonesia. The top ten endangered Karst in the world can be seen in Figure 3.1. Nominations of endangered Karst communities were described by the KWI (TRONVIG and BELSON) and a committee evaluated them based on the following criteria:

1) Significance of the species and communities in the threatened area.
2) Significance of the threat.

3) A clear benefit from publicity of the problem.

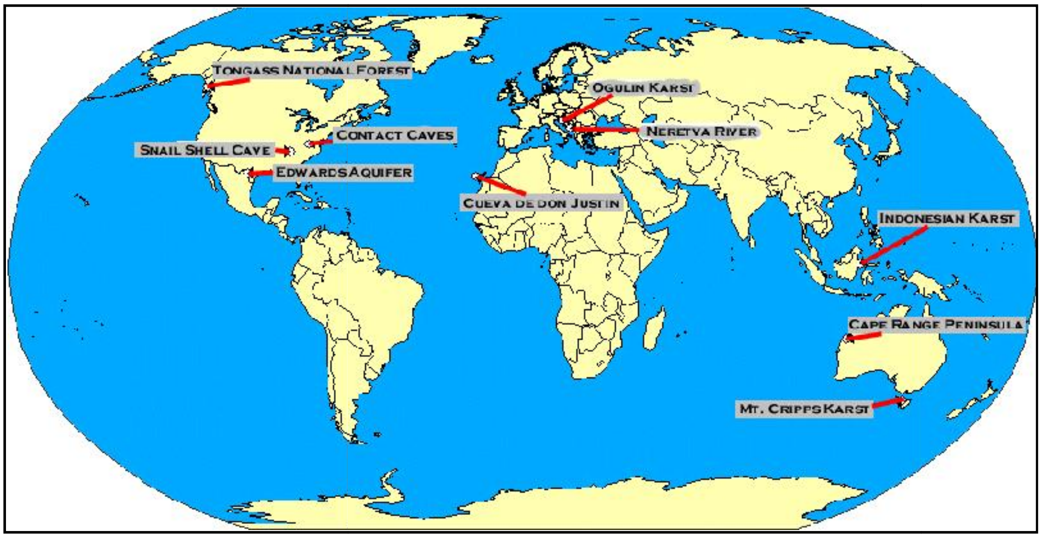
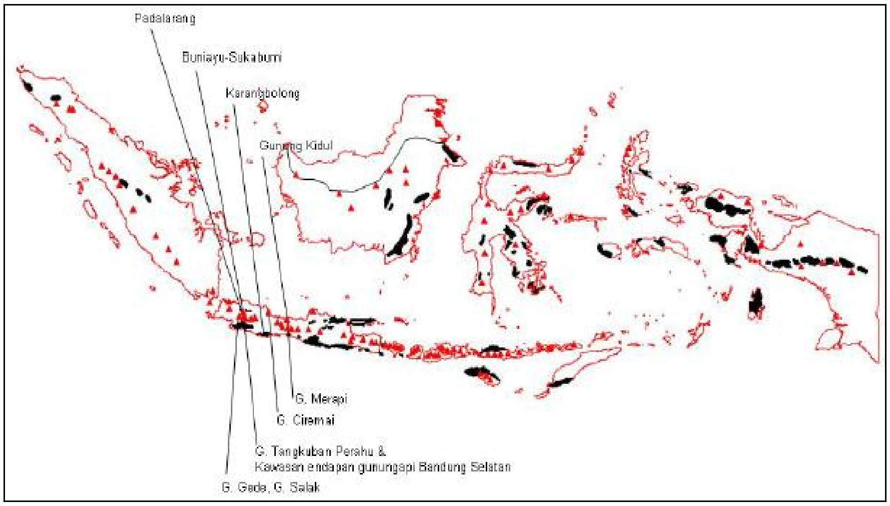


Figure 3.1.Top ten endangered Karst in The World
(KARST WATER INSTITUTE (KWI), TRONVIG and BELSON)

Karst areas in Indonesia are distributed in South Java, Madura, Bali, Maros in South Sulawesi, part of Papua Island and some small islands in the Eastern part of Indonesia (Map 3.1). Gunung Sewu Karst region which lies in South Java, Indonesia has been studied many times and in 1999 was proposed as a World Heritage site by the International Union of Speleology in the category of Geobiodiversity on tower karst, cone Karst or similar (HAMILTON and SMITH, 2006). On 6th December 2004, the President of Indonesia declared that Karst Gunung Sewu was to become an Eco-Karst region, thus three regional governments proposed a geopark for their regions, namely Gunungkidul, Wonogiri, and Pacitan.

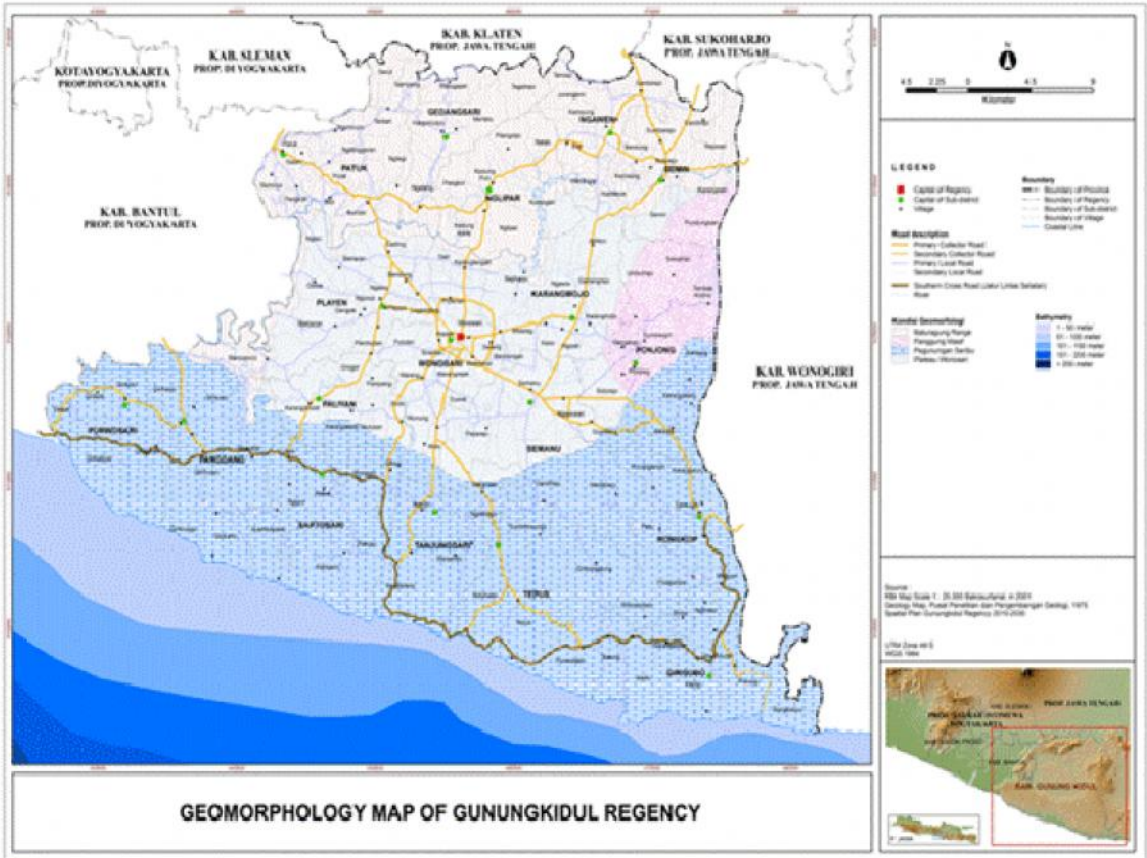
Gunungkidul Regency, where one part of Karst Gunung Sewu area is located, has been known internationally in the world of science for its traces of prehistoric man and also for its gorgeous chain of cone-shaped or conical hills Karst. Scientists have said that Karst Gunung Sewu in Gunungkidul Regency, South Java is found nowhere else on the planet (LEHMANN, 1936; PANNEKOEK, 1948; UHLIG, 1980; FORD and WILLIAMS, 2007). Gorgeous caves, along with its underground rivers and the great varieties of exokarst (surface karst) and endokarst (underground karst) won Gunung Sewu the status of a World Natural Heritage Site in 1994 from the International Union of Speleology.



Map 3.1.Distribution of Hydrogeological Karst sediment in Indonesia (black spot) by PURADIMAJA (2006:6)

The study location is identified for being arid and barren but could probably have been a capital city with a dense settlement area in the pre-historic age (YUWONO, 2000; SIMANJUNTAK, 2002). It means that a relationship between human and the environment have been existed since the first human on earth. Prehistoric inhabitants lived near water sources, such as caves and developed ancient Karst community.

Map 3.2 shows the geomorphology of Gunungkidul Regency where the southern part is Karst area and part of the Karst Gunung Sewu system. Gunung Sewu Karst is situated in the faulted block of Southern Java Zone, which extends some 85 km east-west and slopes gently, at approximately a 2% gradient, southward, being marked by a high (25–100 m) cliff along the south coast (PANNEKOEK, 1949; VAN BEMMELEN, 1970). The Gunung Sewu area is adjacent to the Indian Ocean on the south central coast of Java (HARYONO, 2008). The elevation range is between zero and 400 meter above mean sea level, in which its highest portions are centrally located about 25 kilometer from the coastline.



Map 3.2. Geomorphology Map of Gunungkidul Regency (source: Gunungkidul Regency Spatial Plan 2010 - 2030)

Due to its geomorphological setting and hydrogeological characteristics, Karst Gunungkidul suffers from annual water scarcity during the dry season. In 2008, water scarcity occurred in the area covering 11 sub-districts, 58 villages, 364 hamlets, with 29,019 households, and 106,573 people. This study will be conducted at these ten sub-districts located on Karst systems. According to Gunungkidul Regency Spatial Planning 2010-2030, sub-districts that are geomorphologically classified as Karst area in Gunungkidul Regency are Ponjong (6 villages), Semanu (3 villages), Girisubo (8 villages), Rongkop (8 villages), Tepus (5 villages), Tanjungsari (5 villages), Saptosari (7 villages), Paliyan (3 villages), Panggang (6 villages) and Purwosari (5 villages). These villages are listed in Table 3.1.

Table 3.1 List of Sub-districts and villages in Karst area Gunungkidul

Ponjong sub-district 1. Gombang 2. Sidorejo 3. Bedoyo 4. Karangasem 5. Sumbergiri 6. Kenteng	Semanu 1. Candirejo 2. Dadapayu 3. Semugih	Girisubo 1. Balong 2. Jepitu 3. Karangawen 4. Tileng 5. Nglindur 6. Jerukwudel 7. Pucung 8. Songbanyu	Rongkop 1. Melikan 2. Bohol 3. Pringombo 4. Botodayakan 5. Petir 6. Semugih 7. Karangwuni 8. Pucanganom	Purwosari 1. Girijati 2. Giriasih 3. Giricahyo 4. Giripurwo 5. Giritirto
Tepus 1. Sidoharjo 2. Tepus 3. Purwodadi 4. Giripanggang 5. Sumberwungu	Tanjungsari 1. Kemadang 2. Kemiri 3. Banjarejo 4. Ngestirejo 5. Hargosari	Saptosari 1. Krambil Sawit 2. Kanigoro 3. Planjan 4. Monggol 5. Kepek 6. Ngloro 7. Jetis	Paliyan 1. Karangduwet 2. Karangasem 3. Giring	Panggang 1. Giriharjo 2. Giriwungu 3. Girimulyo 4. Girikarto 5. Girisekar 6. Girisuko

Source: Spatial Plan Gunungkidul Regency 2010-2030

Sub-districts are formally stated as hydrology and ecology protection areas covering approximately 80,704 acres. Despite of similarity in managing water resources and space occupation, this study tries to draw any differences in practices. Sub-districts which have established business centres or support centre regions might have discrepancy in managing local natural resources and cultural behavior. Norms and values of water management practices in relation to the natural environment could differ from one sub-district to another. Variation of community adaptation to the environment setting, referred to as cultural behavior, will be used as input to synthesized and model culture based water management as mitigation of risk. This study aims to promote Karst Gunungkidul as a potential world class cultural heritage site and should be appropriately managed in terms of human and environment interaction imprint on cultural landscape.

3.2. Addressing Karst Gunungkidul Issues and challenges based on Cultural (Behavioral) Local Knowledge derived from and based on Seasonal Calendar

This study applied qualitative methods, analyzing and synthesizing local knowledge derived from seasonal calendar, correlating weather and climate knowledge with land and water management at household and community level. Qualitative researchers aim to gather an in-depth understanding of human behavior and the reasons that govern such behavior. The qualitative method investigates the why and how of decision making, not just what, where and when people develop such adaptation, mitigation strategies and coping mechanisms towards uncertainty of changes related to climate for their land and water management on Karst region.

This study utilized particularly participant observation, Focus Group Discussion (FGD) and indepth interview with key persons (informants) or selected sample of different communities. Open ended interview was used to get perspective or perception of spatial behavior based on local seasonal knowledge. Th scientific method follows an inductive to deductive process from the old and new problem; formation of tentative theories; attempts at elimination through critical discussion, including experimental testing; and the new problem that arise from the critical discussion of theories.

3.2.1. Data Collection and Analysis

This study proceeded by executing a qualitative approach, supported by quantitative data. Quantitative data is collected from secondary data, including remotely sensed data from satellite images and aerial photos. Qualitative data was collected in the by field observation, through focused group discussion and in-depth interview with key persons to attain research objectives. Key persons and FGD involve respondents who are considered as understanding the situation and characteristics of their origin. The author was helped by the head of sub-districts and the head of villages to invite representatives of:

1) Farmers, i.e. household farmers, head of farmers organization.

2) Local government representatives who manage water and land (space) related subject and issues in sub-district and village.
3) Community stakeholders: local housewives group (*Pembinaan Kesejahteraan Keluarga*/PKK), local community leader, youth community.
4) Water tank private company (if such existed in the village or sub-district)
5) Local institutions managing water and land, community based water management, i.e. Tirta Kencana, SPAMDes, etc. (if such existed in the villages or sub-district).

Steps that are conducted in this study:

1) Literature review.
2) Data Collection:
   a) Secondary: Institutional data, paper, articles to support qualitative data and information.
   b) Primary : FGD, In-depth and key person interview to collect qualitative data and information. Purposive sampling is applied here.

Research of this study involved field trips, semi-structured and unstructured interviews in which participants used their observational powers and shared experiences to construct narratives, creating a picture of the Karst's past and its current changes over recent time. Having grown up in a Karst area the key persons have spatio temporal experiences and a series of reflections to draw from.

Phenomenological research has overlaps with other essentially qualitative approaches including ethnography, hermeneutics and symbolic interactionism. Phenomenological and associated approaches can be applied to single cases or to serendipitous or deliberately selected samples.

The parameters used in the questionnaires were:

A. Water themes and related issues:

(1) Knowledge of hazard and perception of water scarcity (drought) as a risk in their village.

(2) Practice of traditional beliefs (related to water management) on sacred locations for nature (water) preservation or conservation.

(3) Significant changes on water availability during 5-10 years or more.

(4) The sustainability possibility of governmental water management projects, such as Bribin, Seropan and Baron, and to fit in with local (household and communal) water management.

(5) The length of people use rain water tanks (PAH) in the village

(6) The Reason of rain water tank (PAH) location.

(7) The length of surrounding *Telaga* (doline pond) can keep the rain water.

(8) The access to the *Telaga* or other water sources and the transportation types.

(9) Traditional conservation or rehabilitation for Telaga conducted by individual or community, and the rehabilitation condition.

(10) Significant change in the need of the Tankers during 5 – 10 years, and the water sources of the Tankers come from.

(11) The practice of reduce, reuse, recycle or recharge from the (household) wastewater (e.g. water from rice cleansing, washing water, etc.)

B. Land management (themes) and related issues:

(1) The practices of local (traditional) land cultivation, particularly *Pranata Mangsa* and its phenology indicators

(2) Reason to choose or cultivate certain crops, related to water availability

(3) Mal-adaptation or false start cultivation (salah mongso, shifting cultivation onset) experiences.

(4) Knowledge of particular trees/plants indicating the start of the dry or rainy season

(5) Knowledge of environmental changes due to the loss of particular trees as indicators.

(6) Knowledge and practice of (traditional) food security, e. g. saving corn, cassava, paddy grain (*gabah*) in certain location or into a jar.

C. Parameter of Culture and Risk

Focused group discussion (FGD), in-depth interview with key persons and participants observation are conducted to collect data and information related to local (traditional) knowledge for water and land management. Cognitive mapping is applied to get space perception from the community including location to nearest water source, rain harvesting tank, sanitation, waste disposal, farm field, cattle stock, their settlement, and other space utilization surrounding them. Socio-economic conditions also contribute to the cultural dimension of Karst Gunungkidul. For example, expenditure for water consumption has been required regularly when the dry season occurs.

The causes and consequences of human behavior, i.e. norms and values will be better understood by getting accurate descriptions of rural community customs, habits, practices, way of life and activities. Participant observation, a person-centered interview, together with a good quality data record can be used as a means to collect data as well as analytical tool on human behavior (DEWALT, DEWALT, and WAYLAND 1999 cited in SUNKAR, 2008). This study tries to identify and analyze the application of local (traditional) knowledge on water and land management in different administration (sub-district and villages), namely:

(1) the principal of reduce, reuse, and recycle, and local norms and the value of water for different purposes;

(2) the differences or variation in water and land management between areas where local norms and values (cultures) are still being practiced and the ones do not practice or apply these; are there any efforts from the local community to reduce their Karst environment disturbances regarding the uniqueness of Karst Gunungkidul?;

(3) The correlation of Karst disturbance in the area with local culture, shape the livelihood and landscape;

(4) The correlation or no-correlation between local knowledge with water and land management.

3) Data Analysis

(1) Qualitative : using hermeneutics phenomenology approach for philosophical view and human geography for cultural behavior.

The semiotics approach of hermeneutics phenomenology is applied as science of signification, theory of the production and interpretation of meaning. The meaning is made by the deployment of acts an objects which function as "signs" in relation to other signs. Systems of signs are constituted by the complex meaning-relations that can exist between one sign and another, primarily relations of contrasts and superordination/subordination, e.g. class/member, whole/part. Signs are deployed in space and time to produce "texts" whose meanings are construed by the mutually contextualizing relations among their signs. This study tries to reveal the meaning of signs or symbols from the cycle of seasonal based local knowledge *Pranata Mangsa* from the perspective of the individual and community for daily basic activities correlate with water and land management.

(2) Spatial analysis: landscape modeling using ArcGIS (ArcScene) and environmental model

The values of Karst people in Gunungkidul are embedded in their cultural behavior, which affect their landscape shape. Thus, reading landscape from a model requires interpretation of culture. Each person experiences spatial dimensions within life span which correlate with the location and resources. People in Gunungkidul Regency within three different geomorphologic characteristics understand that their adaptation to the surrounding environment and ecosystem determine their livelihood. The southern part inhabitants, as with other parts inhabitants, have a different cognitive spatial knowledge dimension which determine their response to changes reflecting their relation to the place in which they live.

The spatial dimension of hazard and risk on Karst landscape Gunungkidul in response to seasonal based local knowledge *Pranata Mangsa* is assessed and modeled using spatial tool, i.e. ArcGIS/ArcScene, and environmental model. The software is used to support knowledge bridging of cognitive spatial local knowledge. Bridging the meaning of Karst landscape which accomodates people's activities and socialisation of knowledge. Landscape models are used as visualisations both to assess and analyse spatial dimension perception and behavior and also to prompt participatory management.

3.2.2. Assessing Natural Hazards and the Risk of Karst Environment based on Local Knowledge on Seasonal Calendar

Disturbances of natural systems are inevitable. The result represents the capacity and resiliency to cope with changes. People develop resiliency through ecological knowledge in response to surrounding environmental changes which becomes as local knowledge. This study investigates "people's science" on natural hazard and risk, based on people's daily experiences throughout time of Gunungkidul Regency geomorphologically, hydrogeologicaly, and several hazards.

By understanding of constitutes ‘Outstanding Universal Value’ in a managing environment context based on local knowledge, this study seeks to assess the hazard message culturally and the potential hazard and risk within seasonal calendar cycle *Pranata Mangsa* using phenomenological hermeneutics from a philosophical approach that couples to cultural geography. This will help understand how people can interpret or paraphrase their knowledge on seasonal based knowledge for their activities. Using the time frame of the seasonal *Pranata Mangsa* calendar (Figure 3.2), hazard and risk shall be interpreted and translated from Karst Gunungkidul people's views, values, beliefs and norms as reflected on the relationship with their environment. A desk study or literature review for critical and conceptual thinking has been conducted and anthropological tools are employed in the research including participants observation, FGD and in-depth interview.

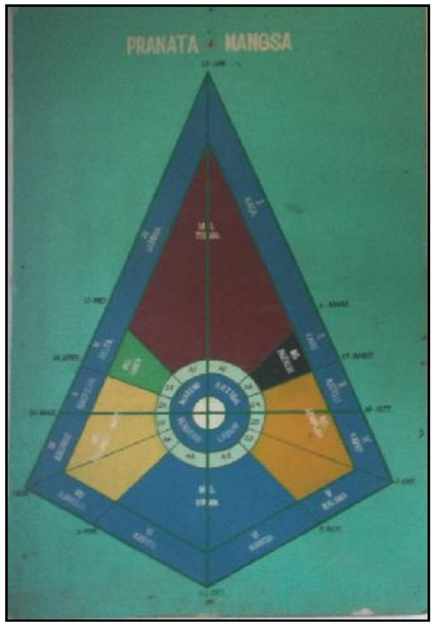


Figure 3.2. *Pranata Mangsa* Timeframe (cycle combine with Gregorian calendar)
(Author field survey in Kenteng village, 2013)

The cycle of *Pranata Mangsa* frames indicators from animal behavior, plants growth stage, and atmospheric signs. There are 12 different time frame on the seasonal calendar (see Figure 3.2). The calendar uses symbolic signs or indicators to be interpreted and applied, considering individual and community perception. Each indicator represents linked ecosystems on the cyclic pattern. This study tries to explore and analyze how people relate to different distinct indicators of hazard and how this generates risk awareness understanding.

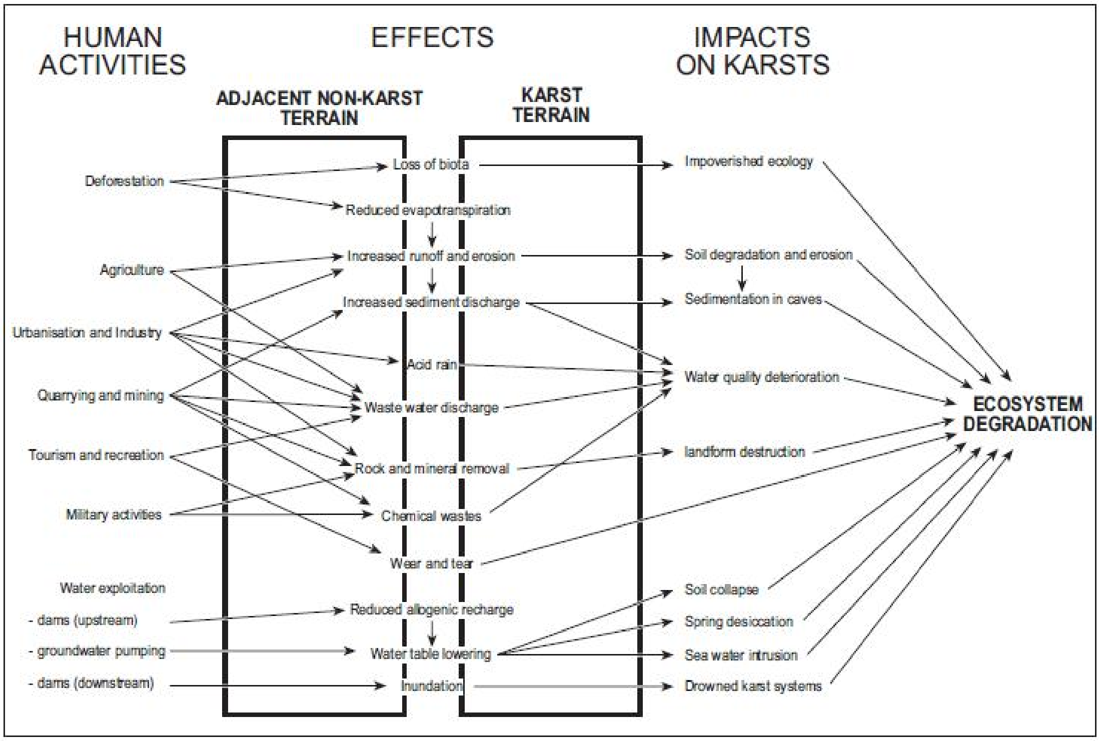


Figure 3.3. Matrix of Anthropogenic activities effects and impacts on karst terrain (source: WILLIAMS 1993 on URICH, 2002:7)

Following the time frame of *Pranata Mangsa*, human induced activities in specific region such as Karst, lead to the possibility of disturbances (see Figure 3.3). The disturbances of anthropogenic activities, which consume resources in Karst Gunungkidul, reflect people's behavior towards their environment through time and might escalate the exposure of such risk. Individual and community understanding towards environmental warning or signs is assessed in this study, whether or not people acknowledged early warning from environmental clues on the cycle of the seasonal calendar *Pranata Mangsa*. To see if people can distinguish the indicators and seek answer to uncertainty or climate variability in the application of their knowledge. Understanding hazard and risk in Karst regions through seasonal based local knowledge is aim to further investigate the relationship between human and the environment, which latter analyze and integrate in the next sub-chapter.

3.2.3. Assessing and Analyzing the Essence of the Seasonal Calendar *Pranata Mangsa* for Managing Available Water and Land due to Risk of Water Scarcity and Promote it as Embodied and Embedded Local Knowledge Management

Local knowledge *Pranata Mangsa* with its phenology (bio-indicators) has taken into account the cycle of seasons with associated risks that might occur, such as floods, drought or water scarcity and diseases. Identification of potential hazard and risk have been initiated in the previous sub-chapter. In correlation with that, this discussion of methodology tries to assess and analyze the essence of the seasonal calendar in application as local knowledge in Karst region Gunungkidul. Capturing and construing seasonal changes to become embedded knowledge in managing resources, particularly limited ones, requires knowledge of seasonal adaptation, mitigation strategies and coping mechanisms as cultural behavior.

People develop certain behavior due to their environment's characteristics. Karst Gunungkidul annually suffers from water shortage or scarcity. This phenomenon has been well known in rural Karstic regions like Gunung Sewu. Application of the seasonal calendar *Pranata Mangsa* as embedded local knowledge is hoped to re-establish keen observation between people and the environment on Karst Gunungkidul to face climate and environment changes. Cultural behaviors which have been developed and inherited from seasonal based local knowledge need to be correlated in the way people manage land and water as limited availability resources.

The understanding of local knowledge *Pranata Mangsa* from representatives of people in rural communities in Karst Gunungkidul will be investigated to generate safer communities with low or acceptable risks. Using FGD's and indepth interview, data and information related to acceptable risk due to seasonal changes and how people perceive the possibility of risk will be collected. Risk here adapted from the concept of World of Risk (BECK, 2006), which means the anticipation of catastrophe and presupposes human decisions. This study tries to seek seasonal based local knowledge for risk reduction with adjustment of locality and the purpose of the study. Furthermore, by analyzing the essence of seasonal based local knowledge through people's understanding, perception and behavior culturally, the study aim to explore ecosystem service and ecological balance within that knowledge.

Ecosystems are interacting, dynamic, complex functional units with plant, animal and micro-organism communities, where human roles are integral. People obtain benefits from ecosystems and take provision from it for food and water, regulating cultural services and benefits and supporting service to maintain life on Earth. Thus, ecosystem service is a desired service that humans to take advantages from ecosystems with ethical considerations. The ability of ecosystems to deliver services can be assessed by a variety of qualitative and quantitative methods. This study applies a qualitative approach to see people's understanding on the ecosystem services and ecological balance that they can learn from the cycle of seasonal calendar in Karst Gunungkidul community.

Semi-structured and unstructured questionnaires are used to collect related information from respondents representing the villages which geomorphologically classified as Karst region in Gunungkidul regency. First step to collect data was doing FGD. The second step was indepth interview with selected key persons or informants. People's understanding of the correlation between the loss of certain bio-indicators from *Pranata Mangsa* to environmental changes is explored through discussion of open ended questionnaires. That included whether the loss of certain biodiversity can be replaced by other types in the Karst region.

Knowledge that scattered from different people's understanding is collected to be organized as knowledge management of Karst Gunungkidul. Seasonal based knowledge also has social meaning related to hazard identification and potential risk, thus it needs to be explored to gain the embedded knowledge management. However, this study is considered only a start in organizing and developing embedded knowledge management of Karst Landscape. As CHECKLAND (1985) stated

> *Any discipline which is concerned with rational intervention in human affairs...must both establish theory and engage in practice. Theory and practice will exhibit a groundless relationship, each generating the other, with neither being prime. The mutual development of theory and practice calls for action research in real situations, research in which the researcher has to allow the situation to take him/her where it will, research whose focus is the change process itself rather than some hypothesis under test.*

3.2.4. Synthesizing Local Spatial Knowledge and Modeling Karst Landscape for Karst Management based on Local Knowledge in Gunungkidul Regency

The third objective of this study is to derive a Karst landscape model from local knowledge by means of GIS to bridge the cognitive spatial local knowledge obtained from people's perception, understanding and behavior. Landscape parameters are namely relief, soil, water, climate and biota (flora and fauna). Micro-climate characteristic have been described using symbols and indicators from biota behaviors in *Pranata Mangsa*, therefore this study tries to transform that knowledge into three dimensional spatial visualization. The 3D model aims to be platform to build seasonal based local knowledge management in managing water and land on the Karst Gunungkidul landscape. The landscape model takes into consideration water and land related parameters, and thus can also be used to identify and analyze the efficiency of water use and disturbances.

The model is used to help identify area of understanding, identify sensitive parameters, organize ideas and explore hypothetical scenarios that compares different conditions. Karst landform is a three dimensional shape of landscape modelled by using satellite images, aerial photos, and supported by field observations. To this the author add embedded local knowledge, then synthesize and model water and land management on Karst region as a tool to share knowledge related to early warning, preparedness, and mitigation. Local spatial knowledge from people is assessed during discussion regarding their surrounding environment.

Landscape has to simultaneously fulfill several functions: production, regulation, capability and an information function (KINDLER and BANZHAF, 2001: 51). Participants from FGDs and in-depth interviews are questioned about their cognitive spatial knowledge and how they read their Karst landscape upon which their livelihood depends. Landscape character and values can represent local knowledge of Karst's community in Gunungkidul in correlation with their understanding of seasonal changes.

Institutional landscape reading is also conducted by exploring Gunungkidul Regency spatial plan (2010-2030), but in consideration of different scale and time frames to seek the geographical dimensions. Investigating landscape sensitivity is important to derive strategies for future Karst Guungkidul landscape development and management. Karst Gunungkidul is differentiated into three different type of geomorphology, namely hydrological sub-system (*Sub-Sistem Hidrologi* / SSH) Panggang, Baron-Wonosari and Sadeng. Therefore, it is important to explore community knowledge of landscape by considering the morphology coupled with other physical factors, such as soil, climate (mainly rainfall and temperature), hydrology and geology.

Spatial analysis will be used in this research to examine the relationships between social, cultural, economic, ecological, and landscape phenomenon. In order to examine climatic related hazards and their correlation, spatial analysis provides a means of understanding the nature of hazards and their social, economics, and ecological impacts. Spatial analysis is the center of how GIS are used in transforming and manipulating geographic data (PINE, 2009). GIS is applied in this study with regard to spatial data management, analysis, visualization and modeling. Maps from spatial planning, landuse planning, water related maps, and satellite images will be used to conduct spatial analysis. The use of temporal data give global descriptions of disturbances on cultural landscape characteristics of Karst Gunungkidul. Secondary data, such as photos from previous research, news, and other reliable sources which support validation of spatial analysis will be gathered as well.

The eagle and the frog approaches are utilized. Spatial approach is applied to map and analyze spatial variation of water culture practices and the relation between environmental disturbance with changes of cultural landscape. Karst landscape within Gunungkidul Regency administrative boundaries will be used as units analysis. Map and image interpretation and analysis will be conducted to support identification of human activities on Karst landscape, namely the spatial dimensions of water and land use management in regions both with and without cultural behavior of water management and landuse practices that are at risk of water scarcity.

Karst environment disturbance dues to human induced activities may show different spatial distribution. Considering scale is important in water and land management based on and derived from landscape analysis, where administrative boundaries play a significant role in policy cooperation. This study is expected to provide baseline information of local knowledge management using landscape models of water and land management in application of seasonal based knowledge, particularly *Pranata Mangsa*, and propose cultural and participatory landscape management of Karst Gunungkidul.

3.3. Theoretical Framework

Human adaptation and capability to cope with the natural hazards of extreme environmental conditions should be followed by considering the disturbance that is effecting the natural system. The term eco-sustainability has been used increasingly in official and technical documents stating the environment can be valuable resource to be utilized wisely and safely. Previous research by SUNKAR (2008) conducted in Karst Gunungkidul showed and confirmed that the communities have adapted "Living with Karst" as opposed to "Living on or in Karst". I argue that living in harmony with Karst has been the inherited philosophical wisdom and values for generations since early human settlement time in Karst Gunungkidul region. Rural Karst Gunungkidul people have knowledge to think geographically through their inherited knowledge based on seasonal calendar with its Phenology (bio-indicators).

Geomorphology, geology, hydrogeology and climate related conditions have shaped the whole Karst Gunungkidul in geologic time and can be seen in the present days. Early inhabitants of this area have lived in suitable places, namely cave and low land areas that provide resources for their life support system. In the prehistoric time, Karst Gunungkidul inhabitants developed adaptation strategy or coping mechanism to live with natural cycle processes.

To reduce the adverse impact of human induced activities, Karst systems need to be properly managed and risks mitigated. Potential and challenging efforts and research of Karst Gunungkidul in environmental assessment, human disturbances, public awareness and institutional planning will enrich knowledge and understanding of the unique Karst system. Land and water are key natural resources that determine Karst Gunungkidul inhabitants livelihood. This study promotes the cultural landscape of Karst Gunungkidul as result of "living with Karst" environment. It is a symbiosis of techniques of space and water with traditions and is full of values harmonizing with the environment. Innovative solutions might be derived from traditionaly inherited knowledge of water harvesting, management of space, natural resources protection, rural architecture and organizing urban center as promoted by UNESCO's programme. Combining fact based and value based knowledge is ultimately the aim of the study which is to foster learning system (see Figure 3.4) from local knowledge of rural Karst Gunungkidul people.

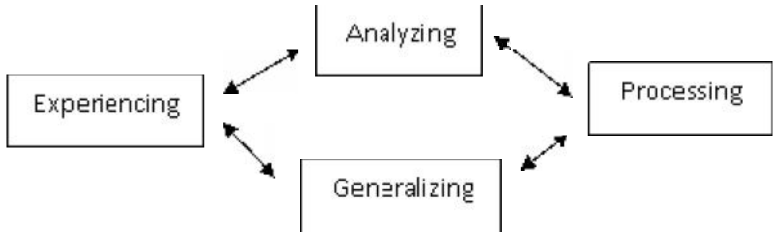


Figure 3.4. The Learning Cycle

Water is a critical issue in Karstic areas. Water problems cannot be unraveled by instant technological solutions. They require consideration of cultural, educational, awareness, communication and scientific matters. Optimizing space and water availability have shaped the community of Karst Gunungkidul's life system. Culture based water management and spatial planning is the way to live with Karst. Norms and beliefs which have been practiced have shaped their identity. The inert and living infrastructures that form rural landscapes and the collected knowledge of resources use are included in landscape cultural values. The shifted paradigm of culture in some rural Karst Gunungkidul have been caused by many parameters, including economic pressure and what so called "modernized thought" that translated into inappropriate actions in the environment and ecosystem.

Environmental ethics exist in local knowledge *Pranata Mangsa* as ecological values and the spirit of knowledge showing the appreciation of the Earth. The essence of local knowledge *Pranata Mangsa* consist of various knowledge when interpreted thoroughly (see Figure 3.5) Rural communities in Gunungkidul has learnt to accept the risk of living in such unique characteristics of Karst Gunung Sewu environment and this transforms the way they value and manage available water and land resources. Hence, this research borrows a philosophical approach that uses phenomenology hermeneutics, due to values and beliefs inherited as local knowledge of seasonal calendar. This study is using the term phenomenology hermeneutics to describe and interpret the meaning of seasonal changes experienced by individuals and communities, and how people imprint their inherited and experienced geographical knowledge on Karst Gunungkidul landscape.

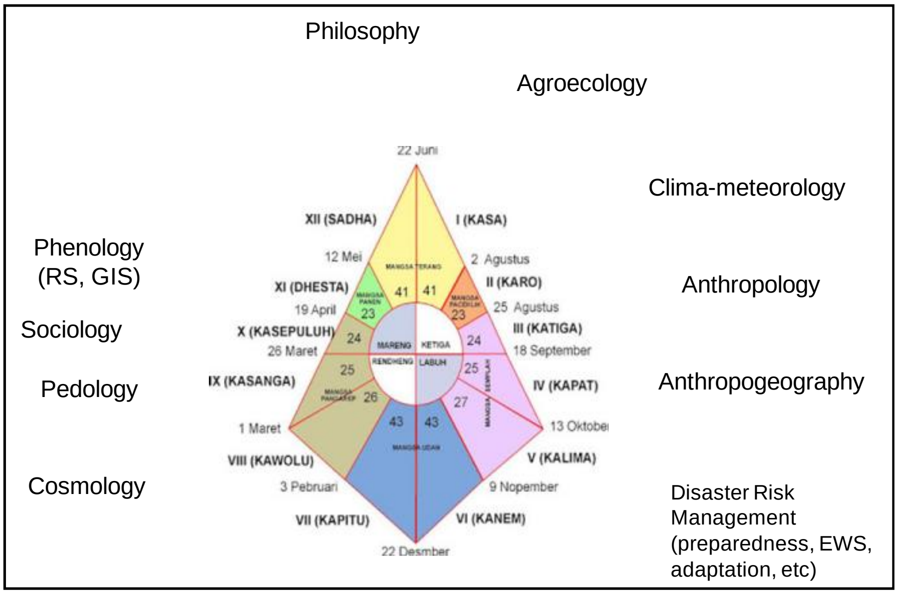


Figure 3.5 *Pranata Mangsa* teaches and correlates with varied knowledge

Exploring and analyzing individual and communal experiences of uncertainty due to climate factors, is an interpretive study of human experiences on Karst landscape with distinct differences between wet and dry season availability of resources. Making and marking identity through landscape management for water and land issues derived from local knowledge is considered important to manage Karst resources in relation to cultural behavior which imprint on the landscape describing water and land planning and management practices (see Figure 3.6). Cultural identity explores issues of symbolism, meaning, and human functions on the ecosystem and ecology system. Local knowledge *Pranata Mangsa* is a cultural identity for those who still or do not apply the 'traditonal" seasonal calendar. The knowledge play the role for households and communities which affect development from local to regional. The cultural development transform to cultural landscape. Thus, it requires to formulate management and planning from cultural knowledge. The phenomenology landscape is correlated here with the work of geographers, and other interests, such as archaeology, anthropology and philosophy works.

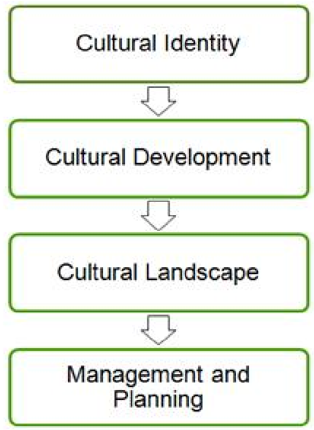


Figure 3.6. Cultural Identity to Management and Planning

Settlement, public infrastructure and other supporting utilities in Gunungkidul Regency from the first established government up to recent governments show different implementations and varied spatial patterns due to water and other resources. Accommodating and incorporating culture community into the policy domain will escalate community capacity. Eco-adaptation of water culture on Karst Gunung Sewu needs to be enhanced in terms of inhabitant's life security. Cultural water management and land use practices need to be re-enhanced and re-modelled to meet recent conditions found in this study, to reduce risks of water scarcity.

Hazard and risk-scape concepts apply in risk management as a strategy for water and land management, deriving and interpreting an understanding of the seasonal calendar to adapt, cope with and mitigate uncertainty change. Building resilient Karst Guungkidul landscapes derived from an understanding of seasonal based local knowledge; a landscape management approach that integrates water and land management that includes food security and risk issues.

Bridging knowledge for rural Karst Gunungkidul in ecosystem services is the desired service for human needs, coupled with the consideration of water and land ethics. Karst ecosystem services can be analyzed from the provisioning, supporting, regulating and cultural perspective. Hence, this study tries to derive the ecosystem service and ecological balance understanding from the local seasonal calendar *Pranata Mangsa*, including early warning of the risk in water scarcity which lead to food insecurity and decreasing livelihood. The past and present status of seasonal based local knowledge is definitely affected by uncertainties regarding environmental changes. The knowledge has evolved through decades of changes but the essence of the environment and ecological management must evolve too. Modernization of water management and built-up area in rural Karst Gunungkidul may lead to severe drought when dry season come, when traditional mechanisms for coping with drought is undermined in the name of modernization.

Geographers describe culture as pattern of learned human behavior that forms a durable template by which ideas and images can be transferred from one generation to another, or from one group to another (HAGGET 1983:269), and different experiences determine the process. Using phenology hermeneutics to explain, explore, and describe the essence of *Pranata Mangsa* application and understanding from the people and the "text". The basic framework of thought can be seen in Figure 3.7. The conceptual thinking framework is to reach embedded intelligence and smart Karst community learning, behavioral adaptation and experiences from seasonal based knowledge of changes. Develop a model to bridge cognitive spatial local knowledge from local people towards broader understanding and interpretation of *Pranata Mangsa* in evolving climatic factors and environmental changes.

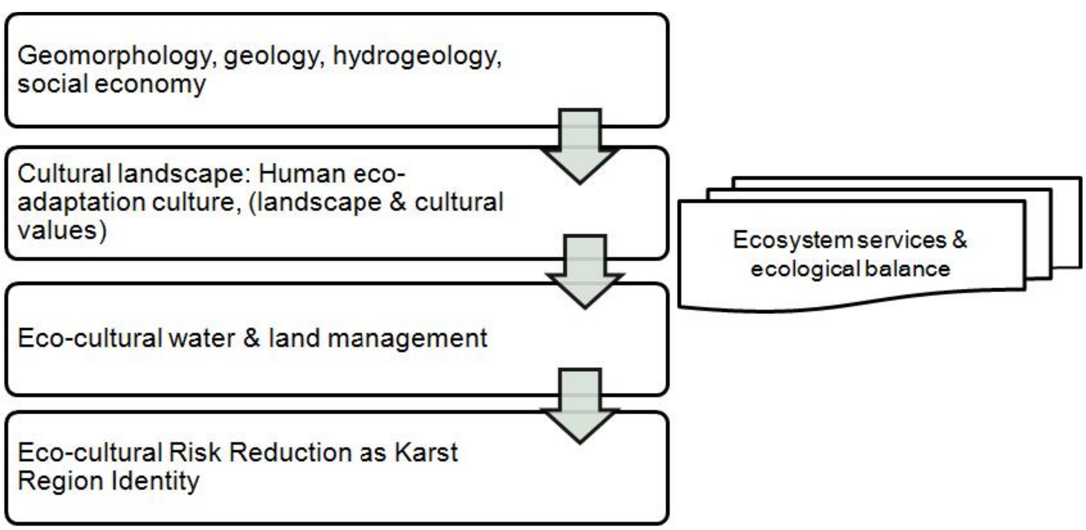


Figure 3.7. Theoretical Framework

IV. Description of Study Area

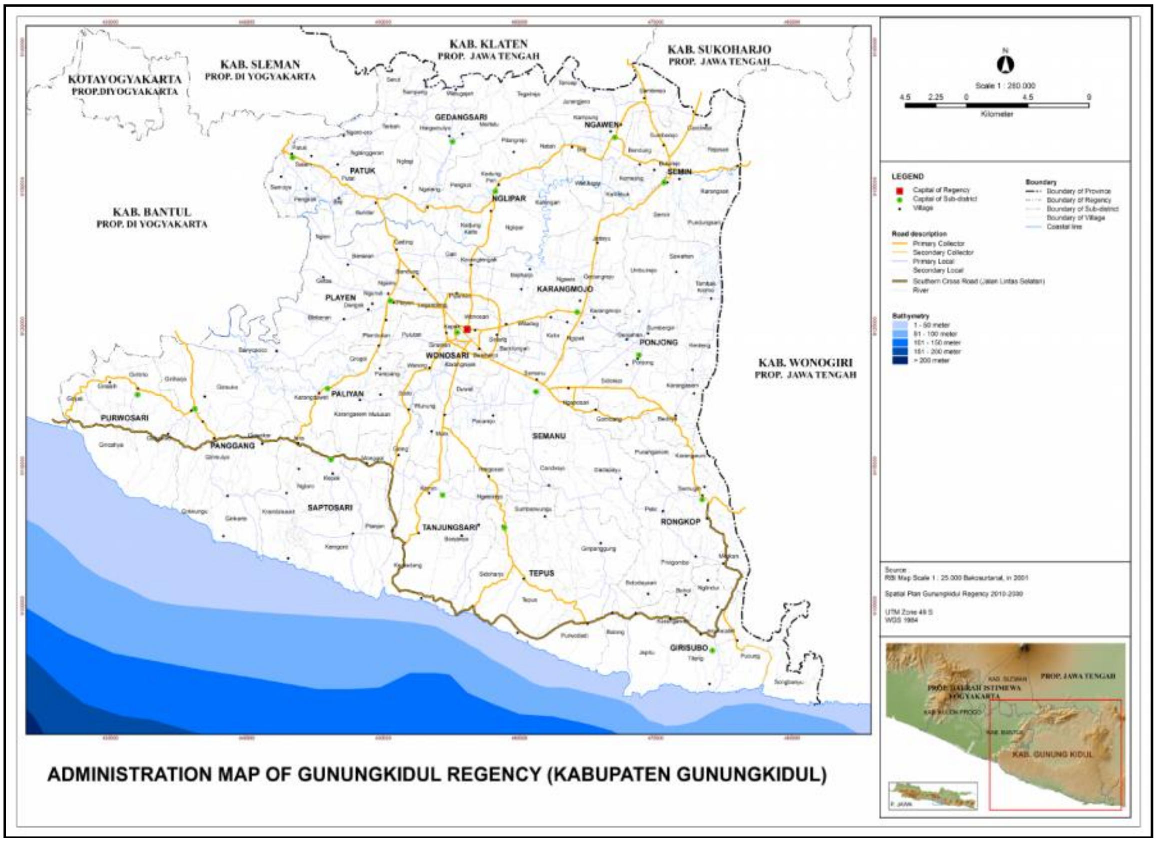
4.1. Administrative Setting

This study took place in Gunungkidul Regency, located in the Southern part of Java island, Indonesia (see Map 4.1). The site study is known as one of the marginalized regions due to its Karst characteristics. Karst Gunungkidul is part of Karst Gunung Sewu which is mentioned often in literature issued during Dutch colonialism, the Kingdom Era and in recent publications across a wide range subjects particularly those analyzing human environment relations.

The whole Karst Gunung Sewu is located in the Southern part of Java between three provincial administratives, namely Yogyakarta Special Province, Central Java Province and East Java Province. This study covers Gunung Sewu region which is administratively located in Gunungkidul Regency, Yogyakarta Special Province. The boundary of Gunungkidul Regency is listed as follows:

1) Northward: Playen sub-district, Paliyan sub-district, Semanu sub-district Basin Wonosari, Semin sub-district Baturagung range, Rongkop sub-district, Semanu sub-district, Ponjong sub-district, and Paliyan sub-district.
2) Eastward: Wonogiri Regency of Central Java Province.
3) Southward: Hindia ocean.
4) Westward: Bantul Regency of Yogyakarta Special Province.

The total coverage area of Gunungkidul Regency is 1,485.36 acres (see Table 4.1) covering 18 sub-districts, 144 villages, and 1,441 hamlets (Table 4.2). There are ten sub-districts located on Karst morphology according to the Gunungkidul Spatial plan (2010-2030), namely Panggang, Purwosari, Saptosari, Tepus, Tanjungsari, Rongkop, Girisubo and the Southern part of Paliyan, Semanu and Ponjong sub-district.



Map 4.1. Administration Map of Gunungkidul Regency (Spatial Plan 2010 - 2030)

Table 4.1. Coverage area of Gunungkidul Regency per sub-district in 2009

No.	Sub-district	Area (km^2)	Percentage to Gunungkidul Area
1.	Panggang	99,80	6.72
2.	Purwosari	71,76	4.83
3.	Paliyan	58,07	3.91
4.	Saptosari	87,83	5.91
5.	Tepus	104,91	7.06
6.	Tanjungsari	71,63	4.82
7.	Rongkop	83,46	5.62
8.	Girisubo	94,57	6.37
9.	Semanu	108,39	7.30
10.	Ponjong	104,49	7.03
11.	Karangmojo	80,12	5.39
12.	Wonosari	75,51	5.08
13.	Playen	105,26	7.09
14.	Patuk	72,04	4.85
15.	Gedangsari	68,14	4.59
16.	Nglipar	73,87	4.97
17.	Ngawen	46,59	3.14
18.	Semin	78,92	5.31
	Total area	1,485.36	100

Source: Gunungkidul Regency in Figures 2009

Table 4.2. Number of Villages and Hamlets (sub-villages)
in Gunungkidul Regency 2009

No.	District	Villages	Hamlets (sub-villages)
1.	Panggang	6	44
2.	Purwosari	5	32
3.	Paliyan	7	50
4.	Saptosari	7	60
5.	Tepus	5	84
6.	Tanjungsari	5	71
7.	Rongkop	8	101
8.	Girisubo	8	82
9.	Semanu	5	111
10.	Ponjong	11	119
11.	Karangmojo	9	104
12.	Wonosari	14	103
13.	Playen	13	101
14.	Patuk	11	72
15.	Gedangsari	7	67
16.	Nglipar	7	53
17.	Ngawen	6	67
18.	Semin	10	120
	Total number	144	1441

Source: Gunungkidul Regency in Figures 2009

4.2. Physical Setting of Karst Gunungkidul

Physical features in this sub-chapter are parameters to identify hazard on Karst area Gunungkidul Regency. Such physical features characterize a specific region with a probability of disturbances due to human activities. They are also part of a landscape setting with visual and spatial order and arrangement, imprinting human activities on Earth over time.

4.2.1. Geomorphology

Gunungkidul Regency is well known as Gunung Sewu region in a geomorphologic sense. Gunung Sewu region stretches along the South coast of Java from the river mouth *Kali Opak* in Yogyakarta Special Province to Pacitan Bay in West Java Province. This study focuses on 65% of Karst Gunung Sewu which is administratively located in Gunungkidul Regency, the western part of larger Gunung Sewu (HARYONO and DAY, 2004). The geomorphological setting of Gunungkidul Regency is described in Table 4.3.

Table 4.3. The Geomorphological Setting of Gunungkidul

Karst geomorphology	Location	Limestone composition	Topography	Elevation (ma.s.l)
Valleys	Wonosari Plateau	Napal globigerina, wackstone, sands	Flat	120 – 140
Hills	Gunung Sewu	Boundstone, packstone	Hilly	75 – 400
Coasts	Southern coast	Packstones	Flat to Hilly	1 – 25

Source : KUSUMAYUDHA, 2000

The geomorphological setting is important as a consideration in development planning. Understanding geomorphological process in Karst regions helps better understanding of land capability and land suitability which leads to space allocation for precise utilization that minimizes capacity pressure. Geomorphological characteristics of Karst Gunung Sewu have been visualized on map by the Regional and Development Planning Board of Gunungkidul Regency in their spatial planning for 2010 – 2030. Figure 4.1 presents the Gunung Sewu Karst underground cross section.

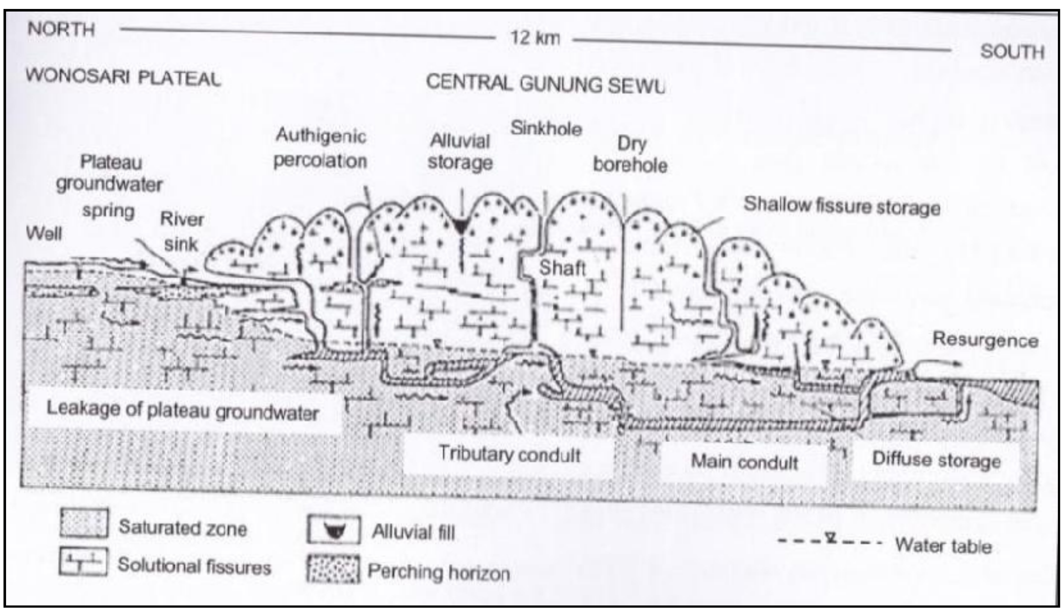


Figure 4.1. Cross-section of the Gunung Sewu Karst Underground
(source: LUKAS, and STEINHILPER, 2005)

The morphology differentiation of Karst Gunungkidul is divided into three main types (see Figure 4.2). The labyrinth-cone karst is most pronounced in the southern portion of the Gunungkidul, where the carbonates are most intensively jointed and faulted. This area was subject to the maximum displacement as a result of the compressional stresses associated with the subduction zone of the Australian Plate (TJIA, 1966; DWIYANA, 1989). Residual cone karst has developed primarily in the northeast of the study area and locally near the south coast where corrosion plains are close to sea level. The most characteristic polygonal karst in Gunung Kidul occurs in the western part of the area. Polygonal karst is particularly well developed in the western part Karst Gunungkidul, namely Panggang and Purwosari sub-districts. Gunungkidul Karst in some localities enclosed depressions resembling the cockpits of Jamaica and Papua New Guinea (WILLIAMS, 1971). In the Eastern part of Karst Gunungkidul, Sadeng dry valley is estimated to be the pre-historic site of human inhabitantion in Gunungkidul due to its preferencial conditions for ancient civilization (see Figure 4.3).

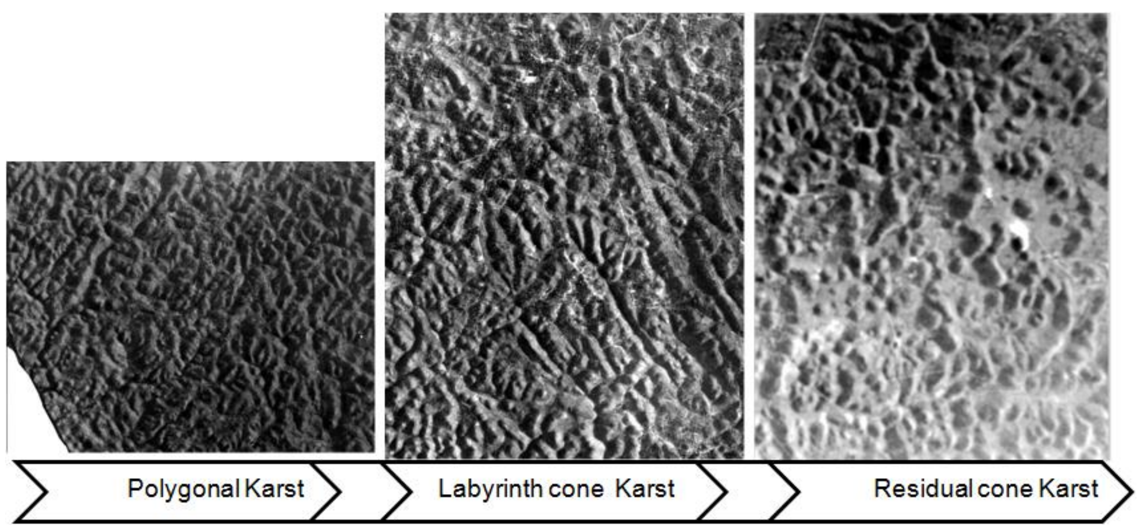


Figure 4.2. Morphological of Karst in Gunungkidul from West to East (source: HARYONO and DAY, 2004)

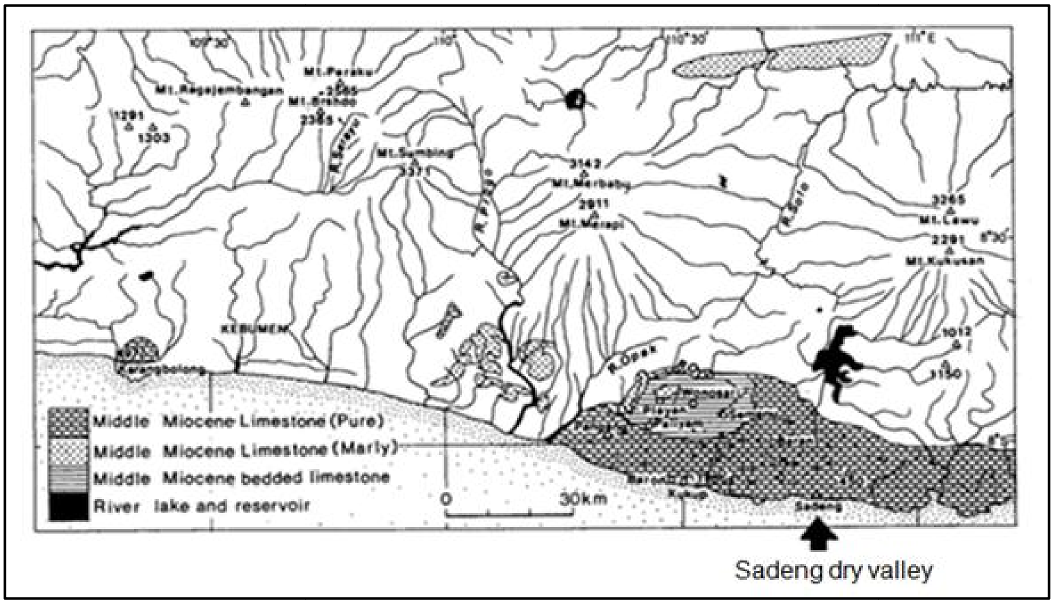


Figure 4.3. Sketch Map of Sadeng Dry Valley which correlate to pre-historic human inhabitants of Karst area in Gunung Sewu
(YOSHINO and YOSHINO, 1997:436)

4.2.2. Geology

Geologically, the study area is dominated by Miocene limestone of the Wonosari Formation, which consists of massive coral reef limestone in the south and bedded chalky limestone in the north (BALAZS 1968; VAN BEMMELEN, 1970; WALTHAM, SMART, FRIEDERICH, EAVIS, and ATKINSON, 1983; SURONO, SUDARNO, and WIRYOSUJONO, 1992; HARYONO, 2008). The development of a carbonate platform in Gunung Sewu was favored by several factors, namely stable tectonic conditions, a shallow marine environment, tropical or sub-tropical climate, clear water conditions and enough nutrients supplies for the growth of marine biota (SAMODRA, 2001). Geological formation of Karst Gunung Sewu carbonate rocks in the middle Miocene-Pliocene era have been studied and shown in Table 4.4, and the geogological Map in Figure 4.4.

Table 4.4. Geological Formations of Gunung Sewu in Gunungkidul Regency

	Formations	MacDonalds and Partners (1984)	Surono et al. (1992)
1.	Kebo Butak		
	a. Composition	Conglomeritic shale, tuffs	Upper part: alternating between sandstone, claystone, and thin layer of acid tuff; Lower part: sandstone, siltstone, claystone, shale, tuff, agglomerate
	b. Age	Early Miocene	Late Oligocene – Early Miocene
	c. Thickness	n.a.	> 650 m
2.	Semilir		
	a. Composition	Interbedded breccias, shales, tuff	Tuff, dacitic, pumice breccias, tuffaceous sandstone and shale
	b. Age	Early – Middle Miocene	Early – Middle Miocene
	c. Thickness	1200 m	> 460 m
3.	Nglanggran		
	a. Composition	Agglomerate, tuff	Volcanic brecia, agglomerate and andesitic-basaltic lavas, tuff
	b. Age	Middle Miocene	Early – Middle Miocene
	c. Thickness	750 m	530 m
4.	Sambipitu		
	a. Composition	Siltstone, shale, tuff, sandstone	Sandstone and claystone
	b. Age	Middle Miocene	Late early – Early Middle Miocene
	c. Thickness	150 m	230 m
5.	Oyo		
	a. Composition	Tuffs, tuffaceous sandstones	Tuffaceous marl, andesitic tuff, and conglomeratic limestone
	b. Age	Middle – Late Miocene	Middle Miocene
	c. Thickness	350 m	> 140 m
6.	Wonosari		
	a. Composition	Limestone	Limestone, marly-tuffaceous limestone, conglomeratic limestone, tuffaceous sandstone and siltstone
	b. Age	Middle Miocene – Early Pliocene	Middle Miocene – Pliocene
	c. Thickness	300 – 800 m	> 800 m
7.	Kepek		
	a. Composition	Marl	Marl and bedded limestone
	b. Age	Late Miocene – Pliocene	Late Miocene – Pliocene
	c. Thickness	200 m	200 m

Source: SUNKAR, 2008:57

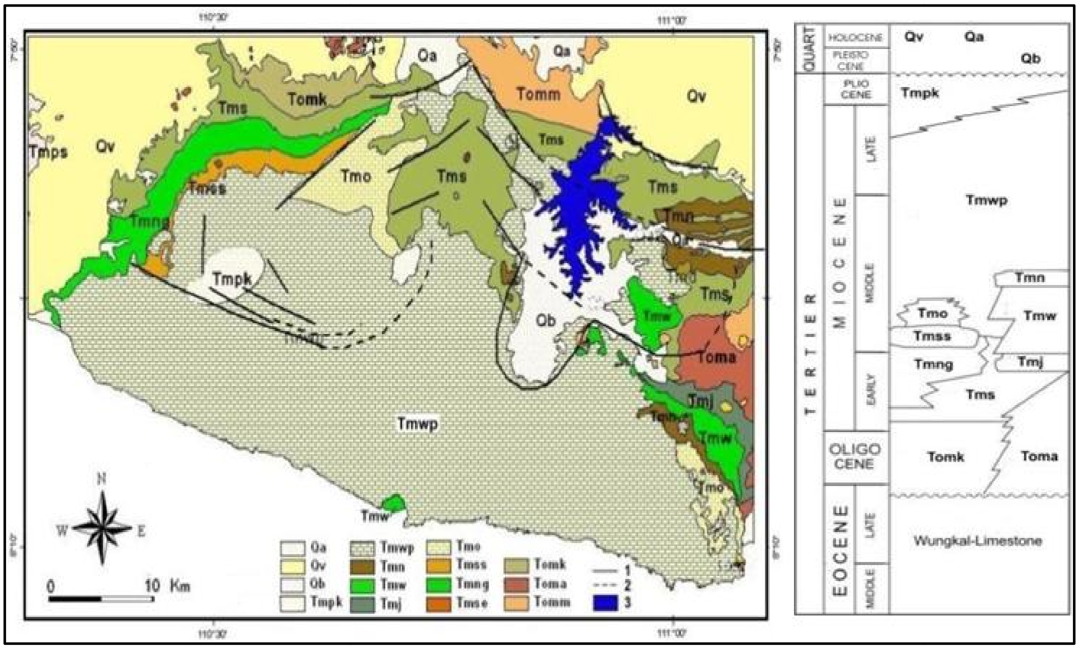


Figure 4.4. Geological Map of Gunung Sewu

Qa: Alluvium of Fluvial Deposits; Qv: Alluvium of fluvio-volcanic deposits; Qb: Alluvium of Baturetno Formation; Tmpk: Kepek Formation; Tmwp: Wonosari-Punung Formation; Tmn: Nampol Formation; Tmw: Wuni Formation; Tmj: Jaten Formation, Tmo: Oyo Formation; Tmss:Sambipitu Formation; Tmng: Nglangran Formation; Tms: Semilir Formation; Tomk: Kebobutak Formation; Toma: Arjosari Formation; Tomm: Mandalika Formation

(Compilation of Van Bemelen, 1970 Surono et al., 1992; and Rahardjo et al., 1995; cited in HARYONO, 2008)

4.2.3. Hydrology and Hydrogeology

Hydrological regions distinguish between areas where the hydrology is influenced only by inputs within the area (endogenous conditions), and those where the regime depends on external inputs or exogenous conditions (FALKENMARK and CHAPMAN, 1989:73). Exogenous inputs are surface run-off from adjacent sloping land within the same climatic zone. The concept of distinguishing between endogenous and exogenous conditions was considered critical to understanding the spatial interrelationships between hydrology and available water resources in different areas. People in rural Karst Gunungkidul recognize that their water resources are seasonally affected by climate and geologically by the parental rock's characteristic, locally called *watu gamping* (carbonate rocks) which shows no surface rivers.

Rain water directly infiltrates deep into the earth and emerges as underground rivers and springs. Figure 4.5. shows springs with forest surrounding the environment. Forested landscapes surrounding water sources correlate with evapotranspiration processeses.

Picture 4.5. Wonoseri Springs in Purwodadi village, Tepus sub-district

4.2.3.1. Karst Drainage System

Karst drainage is characterized by its subterranean nature and its dynamic evolution. Composition of the surface and subsurface rocks and the geomorphology of the area control the hydrology. The Karst area condition determines its specific hydrology system (Figure 4.6). This specificity is a function of the degree of karstification, number of catchments, depth to groundwater, geological complexity, facies and the like (SUNKAR, 2008). Surface elements such as soil, vegetation, regolith and closed depressions are included in karst drainage networks, which regulate the quantity and quality of water flows underground (GILLIESON, 1996).

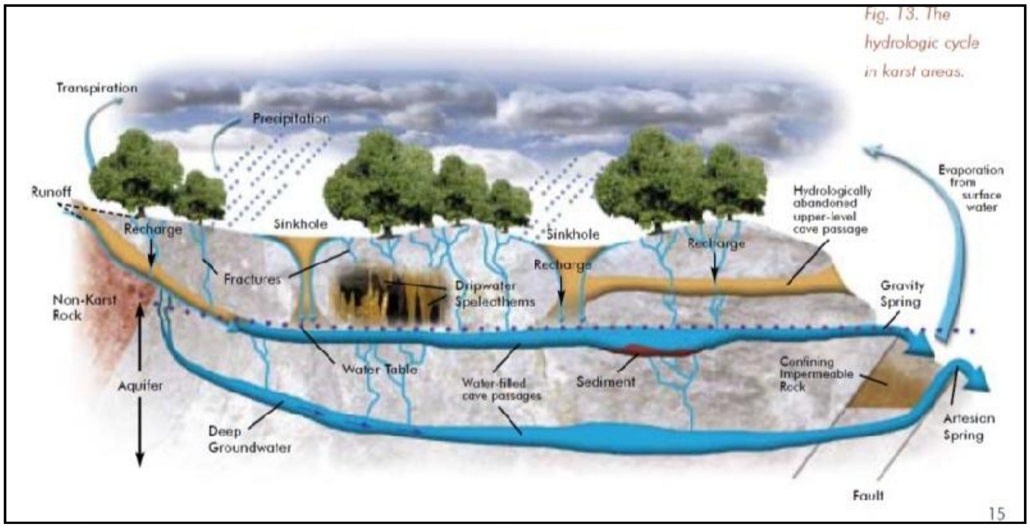


Figure 4.6. Hydrologic Cycle on Karst area

(Source : VENI, DUCHENE, CRAWFORD, GROVES, HUPPERT, KASTNING, OLSON, WHEELER; 2001:15)

Drainage system of Gunung Sewu karst varies in some localities. The properties of epikarst drainage is seemingly governed by lithology and geological structure. The variability of the drainage system is related to the stage of karst type, in addition to the control of lithology and geological structure. Karst area in Gunungkidul regency comprises three karst sub type, namely polygonal, labyrinth, and tower-cone karst (HARYONO, 2000). The relative amount of water occurrence in three different areas are (1) water pore in infilled material (2) water pore in rock, (3) surface runoff, (4) springs, (5) doline lake.

Hydrogeologic units of Karst Gunung Sewu can be distinguished into five systems 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 4.7 shows the hydrogeologic units of Karst Gunung Sewu from Gunungkidul Regency to the eastern part of Pacitan Regency. Understanding the hydrogeologic units leads to better management of water source and human activities on the surface.

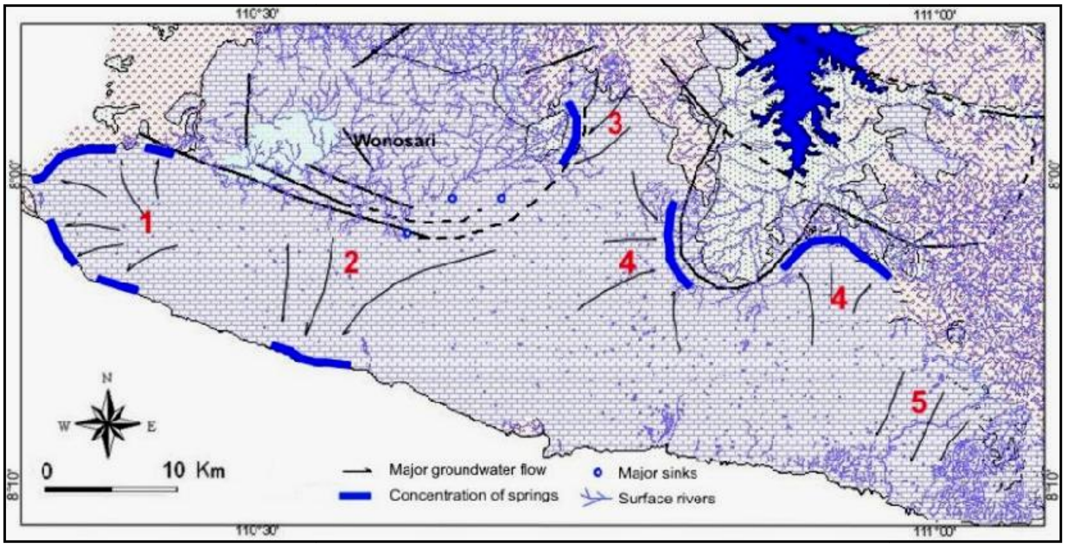


Figure 4.7. Hydrogeologic units of Karst Gunung Sewu
(source: HARYONO, 2008)

Hydrological conditions control water flows and this has not been considered yet in the local water and spatial planning in sufficient detail scale. Using analysis of the geomorphology, geology and hydrogeology characteristics together with community behavior on water and land management interaction will better portray on the cultural risk aspects.

4.2.3.2. Water Availability and Demand Behavior in Karst Gunungkidul

Water use patterns are affected by household activity types in each location. Water drawn from a field or open space surrounding a settlement or farm field, is common for the people in Gunungkidul Regency, including in Karst areas (SUDARMADJI, SUPRAYOGI, and SETIADI, 2012:118; field observation, 2012 and 2013). Water from ponds provided 90% of farming needs. Before the 1990s people still used the water to fulfill domestic needs as well. After a water piping network was established in 1993/1994, the Gunungkidul rural community, particularly in the southern part, have utilized it. Domestic needs are fulfilled from rain water tanks (cisterns), dug wells, springs, private water tanks and piped water from regional water company (Perusahaan Daerah Air

Minum/PDAM). Public hydrants (Hidran Umum/HU) are still used by small numbers of people drawing from water connections to Bribin, Seropan and Baron. Within a community sharing scheme, those who have no access to water sources or systems, can ask their neighbor. Social values play an important role in this issue, with water theft rarely occuring, despite the possibility of water conflict.

Such harsh area like Karstic area leads people to adapt to their environment. A research by SUDARMADJI (et. al. 2012) analyzed data based on questionnaires provided to 30 respondents using random sampling[4] regarding water sources for domestic use in the Karst area Gunungkidul in 2010. Domestic uses were cooking, bathing, ritual Moslem *Wudhu* (washing some parts of the body before praying), washing dishes, washing clothes, toilet needs, cattle needs, homegardening and other needs (cleaning motorcycle, car, etc.). Open site water sources like springs, *Telagas*, cave water, dug wells, and underground river mouth were the most utilized water sources for people. Each household with 3-5 persons on average needs 100 – 200 litres of water per day. Activities outside their home correlated with water consumption for household cooking and drinking. People have adjusted to doing the dishes or taking a bath only once a day to reduce water utilization. For some people in certain areas, taking a bath is quite luxurious due to water availability. During the dry season in particular, some people only take a bath once a day because water scarcity means they need to calculate the economic issue for other needs as well.

Most people in Gunungkidul are Moslem, therefore it is important to consider their need to use water for ritual prayers which are obligatory for them five times a day. On average, each person will require 18 – 20 litres per day. Sanitation is one concern related to water management and health. Indonesian people are used to use water in toilet to clean themselves instead of using toilet paper. In rural Karst Gunungkidul, however, people have developed such strategy to re-using water from washing clothes or dishes to flush the toilet.

[4] homogeneous population assumption

4.2.4. Climate Setting

The Earth's climate is changing despite the dispute on global warming. NASA scientists have analyzed data collected over the past 63 years by 1,000 meteorological stations from around the world to show that in some places the temperature is rising significantly[5]. The climate of Indonesia can be classified into three types: monsoonal, equatorial and local. "Monsoonal" areas experience clear dry and wet seasons, with the wet season occurring during the period from October to March. In contrast, "equatorial" areas are characterized as regions of minimal seasonality, with precipitation evenly distributed throughout the calendar year. "Local" climate refers to a few localities, particularly in the eastern equatorial provinces of Indonesia, which are neither monsoonal nor equatorial.

The predictability of seasonal to inter-annual climate variability is closely linked with the El Nino-Southern Oscillation (ENSO) phenomenon. The clearest, most predictable sign derives from the impact of warm ENSO (El Nino) events in the transition between the dry and wet seasons of the monsoonal areas, from July to October. A typical El Nino suppresses precipitation such that onset of the wet season is delayed. Forecasting the onset of the dry season is more difficult due to the "spring barrier" in predictability. The seasonal calendar local knowledge gives the early sign of seasonal changes.

JUNGHUHN (1845:157 and 1857:280) described the climate in Yogyakarta Province, including Gunungkidul Regency and the more famously known Gunung Sewu part of it; particularly rainfall and temperature conditions recorded at certain times; namely 8am, 10am, 12pm, 2pm and 4pm. JUNGHUHN (1857:348) described physiographic settings based on climate variations from the climate station at Wonosari. In the 1960s, Gunungkidul suffered from famine and diseases which correlated with climatological and biological conditions. The *Pegaber* era or *Jaman Pegaber* was known as the most severe condition people in Gunungkidul suffered in recent times (HOSSU, 2013; FGD 2012, 2013). The phenomenon occurred in 1963 during

[5] An animation visualizing 63 years of climate change derived from multiple temporal data from NASA to further open discussion about climate change and global warming arguments

extreme weather conditions in the Southern part of Indonesia (see Figure 4.8). In 1963, people suffered from hunger because the access to outside regions and the actors involve in development were very limited.

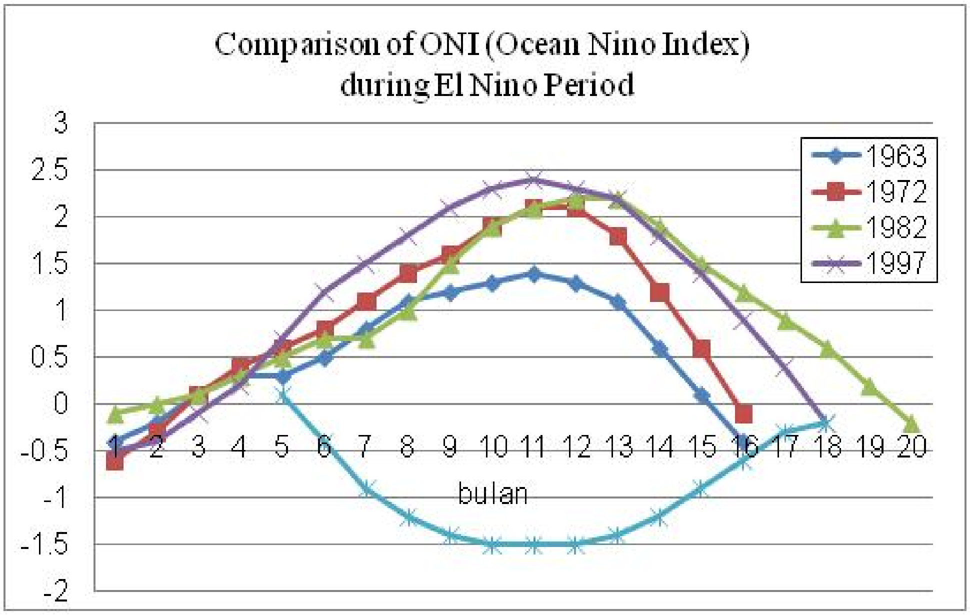


Figure 4.8. Comparison of Ocean Nino Index (ONI) during El Nino Period (Source: BMKG Yogyakarta, 2012)

Gunungkidul's climate characteristics are strongly influenced by the Northwest and Southeast monsoons, which produce a distinct wet season from October to April and a dry season between May and September which may be prolonged. The annual rainfall is about 2000 mm; records from 14 local rain gauge stations between 1960 and 1997 vary between 1,500 mm and 2,986 mm annually. An earlier mean annual rainfall, based on 33 years of record was quoted as 1809 mm and mean annual temperature is about 27°C (HARYONO and DAY, 2004:63).

4.2.4.1. Rainfall

Historical data indicate that ENSO years as experienced by the Island of Java are either much warmer than non-ENSO years or only slightly, if at all, warmer than normal (non-ENSO) years. A distinct oscillation is detectable within the ENSO warm event set of the cycle (defined as those years wherein the SO1 index is consistently negative) so that, in eastern Indonesia, hot-dry years are almost always followed by cooler wet years and vice versa. This pattern also extends to include the year immediately following the terminal year of an ENSO warm event set.

A severe drought occurred in Java in 1877 - 1878, which was the earliest ENSO-related (KILADIS and DIAZ, 1986), as shown by the first rainfall data collected in a systematic manner in Indonesia. Not surprisingly, rainfall during the dry season in Java (June-October) is negatively associated with annual temperature and in particular with that of the warmest month. Since regular warming can be detected throughout the available record, the character of a given year can be measured by examining the extent to which it departs from the secular trend. The length of the dry season (number of months with less than 100 mm rainfall) in central Java, Wonosari at Wonogiri (7^o58" South, 110^o30" East), a station having an almost continuous rainfall record since 1909, can be related to the Jakarta/Semarang temperature record (HARGER, 1995:1945).

Rainfall days and precipation events over a certain time period like one year can only be used to describe climatic events at that time. It will require serial data to establish significant changes and determine the pattern (see Figure 4.9 and Figure 4.10) There is an indication trends of climate variability based on temperature and rainfall (precipitaton) within 30 years from 1971 – 2001 (SUDARMADJI, SUPRAYOGI, and SETIADI, 2012). Compilation of climate condition in Karst Gunung Sewu have been done and analyzed in previous research by FAIDA (2012). Table 4.5 shows compilation data from 1934 – 2008.

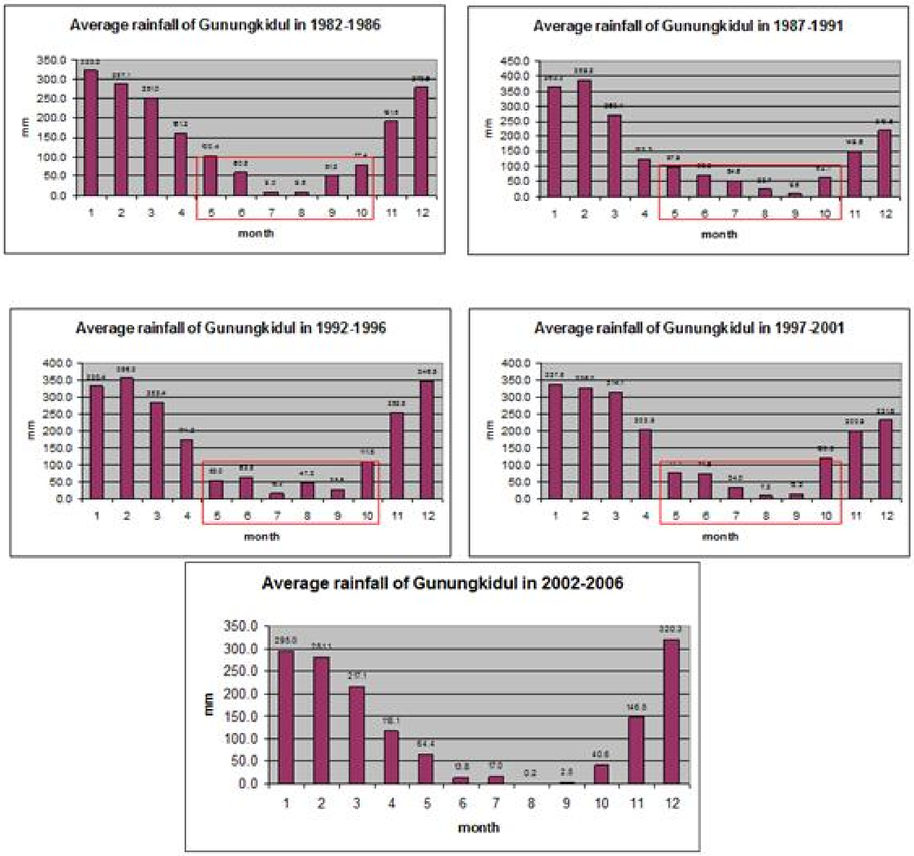


Figure 4.9. Rain fall pattern Gunungkidul Regency 1982-2006, clustered per 5 - 15 years (Source: Ministry of Public Works Indonesia, BMKG, IWRM Gunungkidul Project 2008-2013)

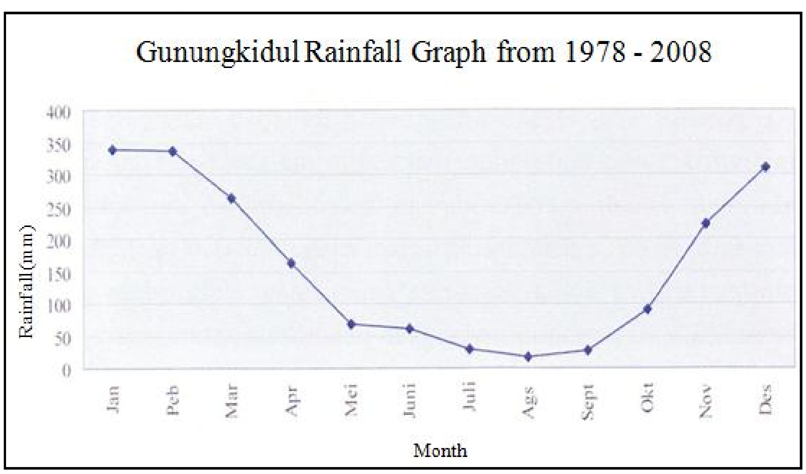


Figure 4.10. Rainfall pattern in Gunungkidul year 1978-2008 (SUDARMADJI, SUPRAYOGI, and SETIADI. 2012:56)

Table 4.5. Gunungkidul Compilation of climate data from 1934 - 2008

8 – 10 years interval	Value of Q Schmidt - Ferguson							
	Panggang	Saptosari	Tanjungsari	Tepus	Girisubo	Rongkop	Paliyan	Semanu
1934 - 1941	0.667					0.571		
1952 - 1960	0.200		0.143					
1955 - 1966							0.286	
1971 - 1980	0.222			0.222				
1981 - 1990	0.111			0.125		0.167	0.250	
1991 - 2000	0.333					0.143	0.667	0.286
2000 - 2008	0.500	0.111	0.833	0.375	0.667	0.250	0.600	0.833

Source: FAIDA, 2012:238

The strongest El Nino effects in Java island are experienced in Yogyakarta Province. The rainfall decreases significantly. The El Nino occurred every four to eight years before the 1940s, but has occurred every three to five years since 1940s. In the historical record of El Nino within the last 30 years (1970 - 2000) there are three severe events in 1972/1973, 1982/1983, and 1997/1998 (BMKG Yogyakarta, 2012).

Rainfall is one parameter that has been identified by rural people of Karst Gunungkidul in the seasonal calendar based local knowledge *Pranata Mangsa*. A parable is used to qualitatively visualize rainfall occurrence. The rain onset is the most observed parameter by people to start farming.

4.2.4.2. Temperature

Temperature is one parameter that indicates climate change. The mean temperature increase of the Earth's atmosphere was projected to be between 1.5 – 5.8 °C due to global warming (IPCC, 2007b). Within 30 years between 1976 - 2005, Gunungkidul experienced increase temperature between 1.4°C or 0.047°C per year, higher than the global increasing temperature 0.015°C per year (see Figure 4.11). In conclusion, Gunungkidul Regency has experienced increasing temperature or a greater global warming effect in this period (SUDARMADJI, et.al. 2012).

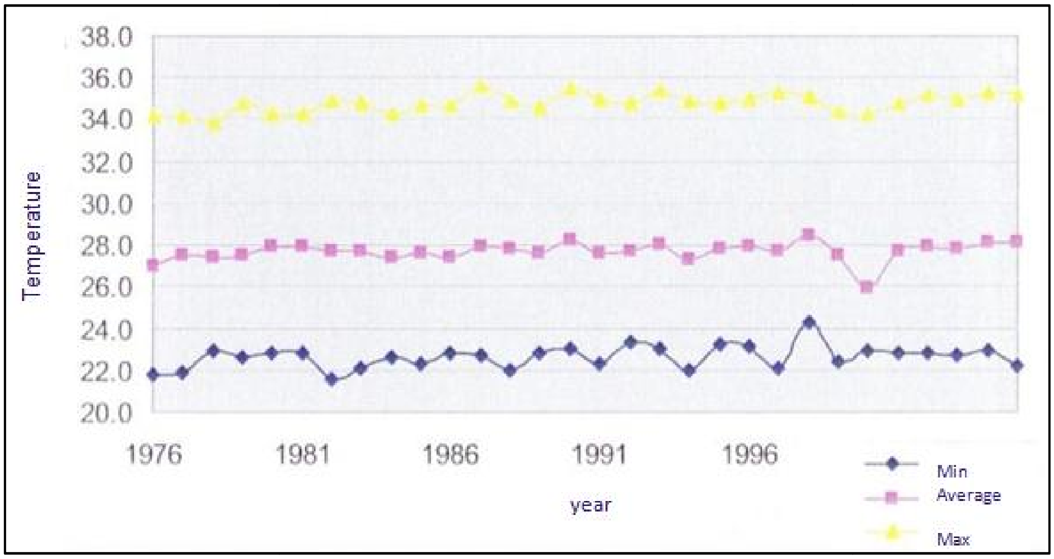


Figure 4.11. Graphic of Minimum, Maximum, and Average Temperature 1976 - 2005 (SUDARMADJI, et.al. 2012:51)

Evapotranspiration calculation by MACDONALD and PARTNERS (1984) showed the relation between rainfall and cropping patterns in Gunung Sewu (Table 4.6). A water surplus is needed to farm certain crops in (limited) available land. Evapotranspiration rates are also important consideration for developing and preserving water sources in open field, such as rehabilitating ponds or *Telagas*, springs and in-situ reservoirs.

Table 4.6. Evapotranspiration in Gunungkidul Regency

Months	Rainfall (R) (mm)*	Potential Evapotranspiration (PE) (mm)	Actual Evapotranspiration (AE) (mm)	Water Surplus R – AE(mm)
January	272	140	106	166
February	339	128	106	233
March	229	137	112	117
April	232	130	105	127
May	383	121	83	300
June	30	110	65	-35
July	0	119	67	-67
August	0	132	69	-69
September	0	142	74	-74
October	215	152	79	136
November	510	142	79	431
December	238	142	94	144
Annual	2448	1595	1039	1409

Source: MACDONALD and PARTNERS, 1984 (*rainfall data are averaged over seven stations across Gunungkidul)

Cement walled of ponds without shading green vegetation nearby have short periods of preserving water (see Figure 4.12). One needs to consider local evaporation, hydrogeological and the socio economic culture of nearby inhabitants when introducing new technology. Mal-adaptated water management programmes, increase water shortage conditions in the dry season, with cemented ponds in several locations drying up when most needed and no harvested rain water left.

Figure 4.12. Cemented wall Karst Pond in Tepus sub-district, which in turn shortens the rain water holding period

4.2.5. Soils

Investigating the soil information in Karst regions is important analysis for future prediction of water and vegetation condition. Soil information becomes input for modelling water balance to calculate comparative differences in recharge between locations and land uses (EDYE, MURPHY, CHAPMAN, MILFORD, MCGAW, MACLEOD, and SIMONS, 2001). Coupled with remote sensing tools, a phenology approach can be applied to assess vegetation growth and health. The soil of Karst Gunungkidul is mostly shallow or bedrock like Karst areas aroud the world. The parent material in a particular location influence the soil formation.

Thick soils in the Gunung Sewu systems are distributed in the closed depressions at the bottom of dry valleys with scattered cultivation using local adaptation. In Karst Gunungkidul Regency, soil depth varies from very shallow on the slopes to a few meters in the valley. A detailed soil survey conducted by the Research Centre for Soils and Agro-climate in 1994 identified major soils of Haplustalfs, Haplustolls, and Eutropept subgroups in Karst Gunung Sewu (see Figure 4.13).

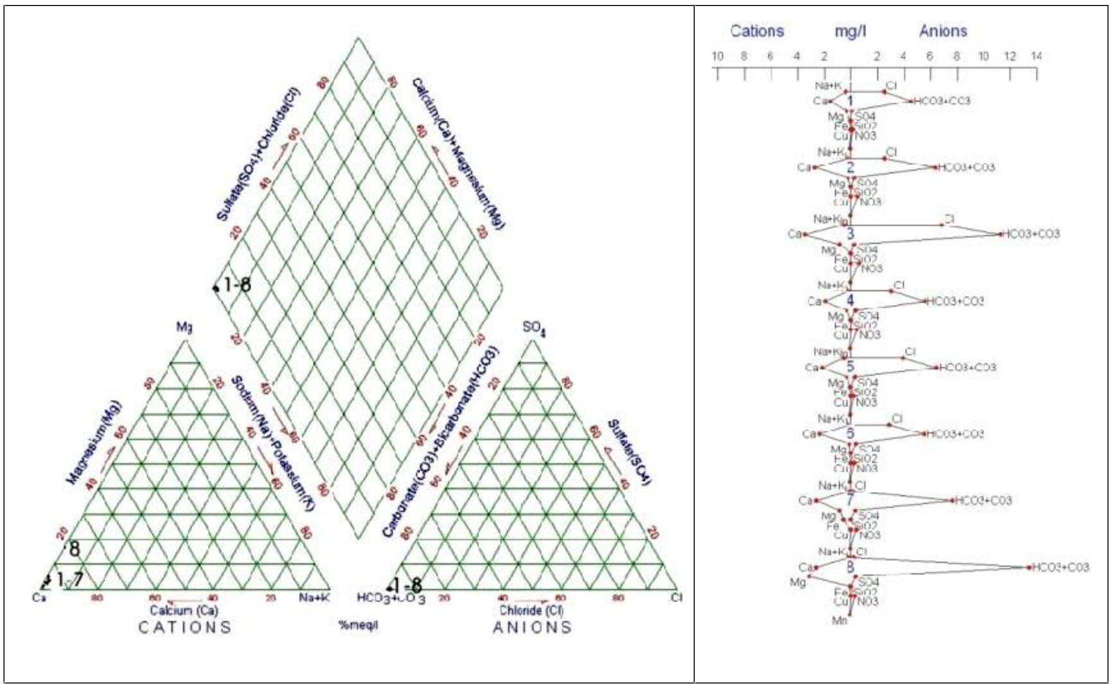


Figure 4.13. Piper and stiff diagram depicting typical bicarbonate water of Gunung Sewu Karst. Samples 1-4 are from surface rivers before sinking and samples 5–8 are from underground river (source: HARYONO, 2008b)

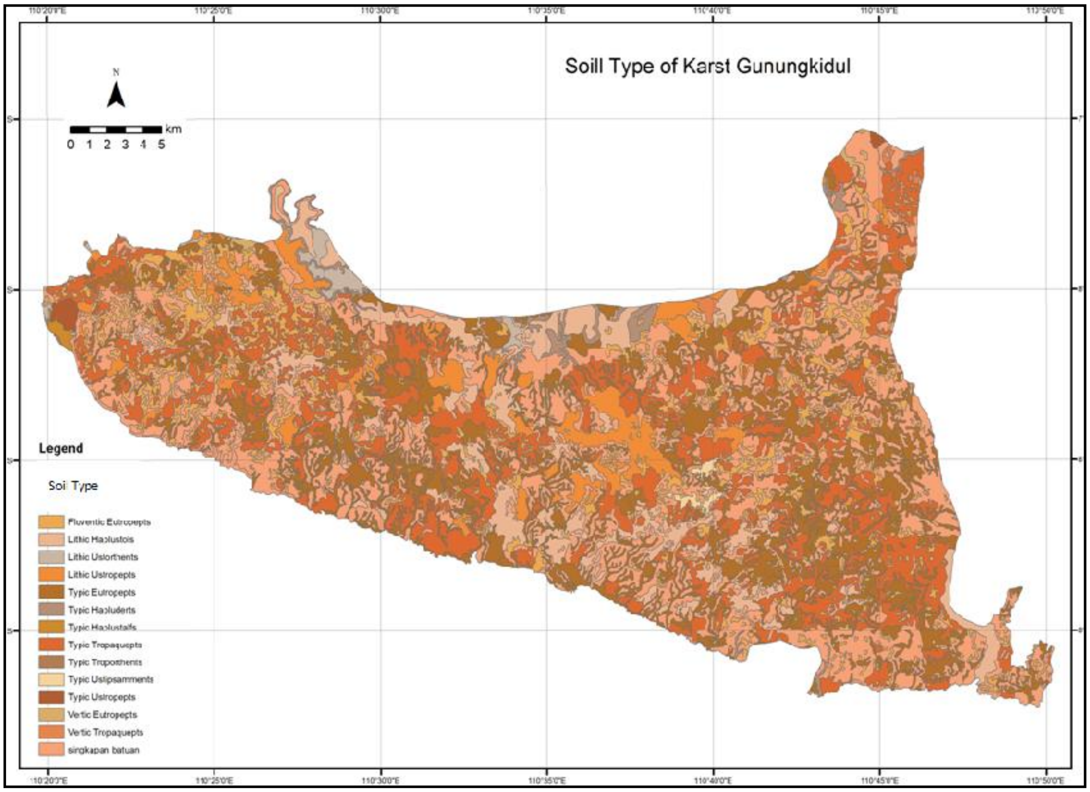
Most of cultivated lands in the Gunungkidul Karst are marginally suitable or not suitable both for seasonal and perennial crops (see Table 4.7). Only a small percentage of the land is marginally suitable, specifically that in the bottom of dry valley and residual cone Karst. The remaining area amounting to 92% of the total area are either permanently or temporarily not suitable for seasonal, perennial, or timber crops.

Table 4.7. Land Suitability Assessment of Major Soils in Gunungsewu Karst

SOILS MAP UNIT	Temugiring and Outcrops Complex	Outcrops and Gembol Complex	Sadeng and Ngrancah Complex	Mulo And Gembol Complex
Approximate area	52 %	40%	3%	5%
Seasonal crops				
Irrigated rice	N1s	N2s	S3np	S3wrn
Rainfed rice	N1s	N2s	S3p	S3fn
Maize	N1s	N2s	S3rp	S3n
Soybean	N1s	N2s	S3rnp	S2trf
Green soybean	N1s	N2s	N1r	S3rn
Ground nut	N1s	N2s	S3rp	S3rn
Sweet potato	N1s	N2s	N1r	S3fn
Grass	N1s	N2s	S3wnp	S3wfn
Perennial crops				
Banana	N1rs	N2s	N2w	N2w
Orange	N1rs	N2s	S3wrp	S3wrt
Mango	N1rs	N2s	N2r	N1r
Coconut	S3ns	N2s	N2w	N2w
Cacao	N2r	N2rs	N2w	N2w
Coffee	N2r	N2rs	N1r	N2w
Clove	N2r	N2rs	N2w	N2w
Sugar cane	S3rns	N2s	N1r	N2w
Timber cops				
Teak	N2r	N2rs	N1r	N2w
Mahogany	N2r	N2rs	N2w	N2w
Albizia	S3rs	N2r	N2w	N2w
Leucaena	N2r	N2rs	N2w	N1r
Acacia	N2r	N2rs	S3rp	N1r
Pine	N2r	N2rs	N2w	N2r

Source: Centre for Soil and Agro-climate Research 1994 cited in HARYONO, 2008b

Multiple seasonal cropping and multiple perennial crop utilization types have been employed for a long time and passed through many generations. Adaptation to the physical setting has been historically imprinted on the land utilization types. Soils assessment results which has been conducted by competent and related institutions should be considered into landuse and spatial planning to minimize the risk of poor water management. Certain types of soils might put buildings or vegetation into jeopardy when combining with other physical factors, e.g. geomorphology and hydrogeology. The type of soil in Karst Gunungkidul is presented in Map 4.2.



Map 4.2. Soil Types of Karst Gunungkidul (Source: BAPPEDA Gunungkidul Regency Spatial Plan 2010-2030, IWRM Gunungkidul Project 2008 - 2013, Author draft 2014)

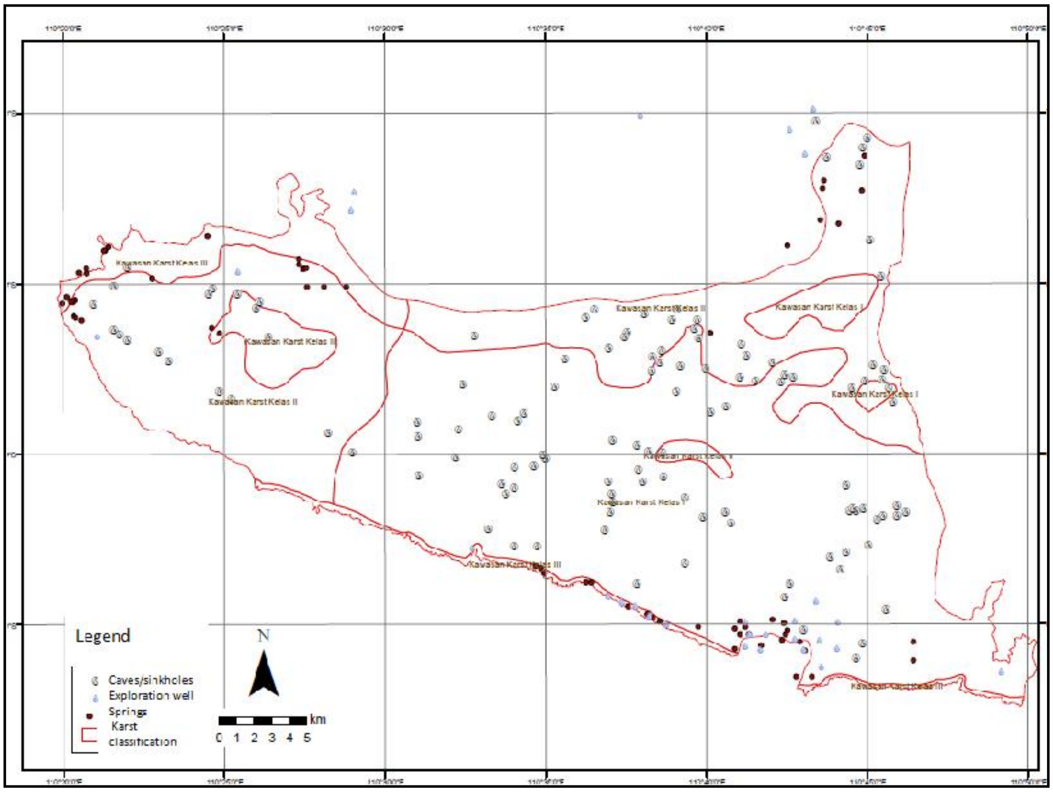
Soil type and structure correlates with erosion, sedimentation and land degradation rates. Gunungkidul's land degradation can be classified according to endogenous and exogenous factors. ENRYD (1998), calculated an erosion range for Gunung Sewu of 180 to 480 tones/ha/year using Universal Soil Loss Equation (USLE) and classified it as extremely severe soil erosion. NIBBERING (1991a), with data from three hamlets in Panggang Sub-district, found that total soil erosion was between 19.1 and 39.6 cm per annum (SUNKAR, 2008: 14). These facts show that Karst region in Gunungkidul as part of Gunung Sewu does pose a severe erosion hazard, and people have learnt through time to cope with it by developing stone terraces and reforesting or re-greening area near water sources.

4.2.6. Hazard in Karst Gunungkidul

Hazard is the probability of occurrence of potentially damaging events in certain areas and given time frame (VARNES, 1984 cited in PARISE 2009:155). The different between hazard and susceptibility relies on a spatial frame. Karst landscape is so unique in consideration of hydrologic, geomorphologic and hydrogeological condition that when coupled with climatic factors it becomes a fragile and vulnerable environment (FLATHE, and PFEIFFER, 1965; UHLIG, 1980; WHITE, 1988; FORD and WILLIAM 2007). Sinkholes are one possible hazard in Karst Gunungkidul (see Figure 4.14 and Map 4.3), underground river floods, quarrying in several locations, loss of Karst landscape, pollution from agriculture (see Figure 4.15), and mining activities. Underground river floods occur particularly during the peak month of the rainy season in Gunungkidul. For example in February and March 2006, a flood postponed the construction of the Bribin cave project at that time (the Jakarta post, 29 March 2006).

Figure 4.14. Sinkhole Occurrence near a settlement in Gunungkidul Regency[6]

[6] Governmental institution and local people gathered close to sinkhole which occurred after rainy days. It is hard to predict where a sinkhole might occur



Map 4.3. Map of Sinkholes (*Luweng*), Caves (*Gua*) and Springs (*Mata Air*), Karst Gunungkidul delineation (red polygon) (source: Gunungkidul Regency Spatial Plan 2010-2030 IWRM Gunungkidul Project 2008-2013, and Author draft 2014)

Karst regions are susceptible to soluble liquid, which becomes a concern of the Integrated Water Resources Management (IWRM) Project between Indonesian and German Government (2008-2013). Research has been carried out on the sanitation and waste water technology subjects by Karlsruher Institut für Technologie (KIT) team. Figure 4.15 shows a map of hazard and vulnerability due to pollutants from feces and fertilizers related to underground water flows. Detail of the figure contents are accessible through KIT electronic website or the team members.

Water scarcity is an annual occurrence in Karst Gunungkidul and people have considered it part of a natural cycle, although also admitted the hazard and risk of water scarcity is part of living with Karst. Table 4.8 shows the number of hamlets (sub-villages) which suffered from water scarcity in 1984 (MACDONALD and PARTNERS, 1984). The need for water during dry season has been gradually fulfilled by regional water company (PDAM) although at a slow pace (Author field observation, November - December 2012 and 2013). People recently feel the infrastructure development has increased the transportation and accessibility of their water supply from private water tanker companies. Lack of water during dry season has already been an accepted risk by understanding they lived in a Karstic region.

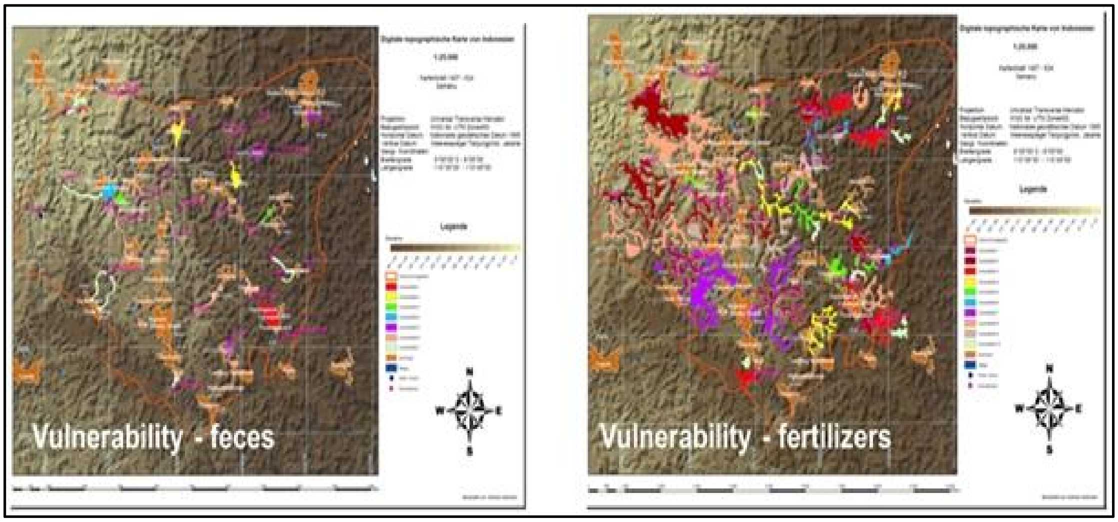


Figure 4.15. Hazard and Vulnerability Mapping due to pollutants, e.g. feces and fertilizer (Source: IWRM Project in Gunungkidul 2012)

Table 4.8. Commonly Water Scarcity (Geomorphological and Geological factors)

Sub District	Village	Number of Hamlets (Dusun)	Name of Dusun
Rongkop	Pucanganom	7	Slawu, Bongmanis, Kayuareng, Banombo A, Banombo B, Dengok, Tejo
	Karangwuni	3	Pampang, Tirisan, Ngerong
	Pringombo	5	Plalar, Ngebringan, Kweni, Sempu, Kayangan
	Semugih	5	Kemesu, Kemiri, Baranwetan, Bendorubuh,Semampir
Sub Total	4	20	
Girisubo	Karangawen	8	Kepuh,Tlasih, Langsep, Bandung, Pudak, Tegalrejo, Karangawen, Ngaglik
	Nglindur	5	Tekik, Wuni, Gangsangan Lor, Gangsangan Kidul, Ngepoh
	Jepitu	10	Janganmati, Pudak, Klumpit, Senggani, Jepitu, Nglaban, Pelem, Karanglor, Manukan, Pendowo
	Balong	6	Ngelo 1, Ngelo 2, Widoro, Kasihan, Piji, Balong
Sub Total	4	29	
Tanjungsari	Hargosari	9	Jambu, Jrakah, Klepu, Timunsari,

Sub District	Village	Number of Hamlets (Dusun)	Name of Dusun
			Mojosari, Pakel, Yaduhan, Ketos, Candisari
	Baleharjo	21	Jambu, Jarah 1, Jarah 2, Jarah 3, Sangen 1, Sangen 2, Keruk 1, Keruk 2, Keruh 3, Keruk 4, Ngepoh
	2	30	
Tepus	Sumberwungu	12	Karangtengah 1, Karangtengah 2, Bantalwatu 1, Bantalwatu 2, Karangtritis, Wunut, Klayu 1, Klayu 2, Gude 1, Gude 2, Karanggebang, Rejosari
	Giripanggung	8	Banjar, Gunungbutak, Kropak, Ngampel, Pringapus, Gupakan 1, Gupakan 2, Palgading
Sub Total	2	20	
Panggang	Girisekar	9	Krambil, Warak, Sawah, Waru, Blimbing, Jeruken, Pijenan, Bali, Mendak
Sub Total	1	9	
Grand Total		108	

Source: MACDONALD and PARTNERS,1984

4.3. Socio Economy, Demography and Human Habitation

4.3.1. Socio Economic Characteristics

The geomophological setting of Baturagung Range, Wonosari Plateau, and Karst Gunungkidul have shaped social and economic characteristics of the Gunungkidul Regency people. Most of the people in this regency depend on the agriculture sector. Agriculture is the main occupation for 75% to 90% of the population in Gunungkidul.

Indonesia´s statistical working age begins at 15 years old. Gunungkidul Regency statistics from 2009 show that more than 30% of workers are family workers. Agriculture is still the main living activity in all sub-districts, except for two villages of the Wonosari sub-district where the centers of government and trade are located. Dry field rice and cassava are the most popular crops in Gunungkidul Regency and contribute more than 50% of the region´s annual gross domestic product. Agriculture, cattle, and fisheries are major revenue for the regency. In the Karst sub-district, dry field cultivation and cattle are the main livelihood for the people.

Education is important to improve human resources and capacity, the economy and health. Regional government is obliged to provide better educational infrastructure. The education level in several villages of sub-districts in Gunungkidul Regency need to be boosted so that more people graduate higher than Junior High School (Author FGDs 2012, 2013). In good economy conditions, parents are eager to send their children to school for longer than own education. Social control also influences the opinion on getting higher education. Those who attend higher education will be highly respected. Higher formal education of the population is an investment in social capital to enhance community capacity building.

Health issues are related to water pollution and sanitary problems. An Integrated Water Resource Management (IWRM) project in Gunungkidul conducted an assessment on sanitary and waste management in the area of the Bribin water network (IWRM Indonesia-German, 2008-2013). A pilot project was initiated in Pucanganom and Dadapayu villages which required evaluation and monitoring. Health issues usually occur during the wet or rainy season, particularly when rainwater stagnates in non-doline ponds or *Telaga*, prompting water borne diseases. People in Gunungkidul are prone to kidney disease due to the water they consume which is chalky as they live in a Karst region. During FGDs and indepth interviews (2012, 2013), most serious illness is more related to age and changing life style as a result of increasing economic conditions.

4.3.2. Demographic Setting

In 1843, Gunung Kidul Regency housed around 12,310 people. The results of the 1930 census showed that the region was of a strongly agrarian character. According to Population Census in 2010, Gunungkidul Regency population was 688,145 people from a total of 18 sub-districta and 144 villages. This is 19.5% of a total population of 3,457,491 people in Daerah Istimewa Yogyakarta Province. The most populated sub-district is in Wonosari which is the capital sub-district in Gunungkidul Regency. Wonosari's population is 78,723 people. Geomorphologically, this area is relatively flat lied and lies on the Wonosari Plateau. The central business district and government is located in the Wonosari sub-district. Table 4.9 shows the population of Gunungkidul Regency by sub-district and gender in 2009.

Table 4.9 Population of Gunungkidul Regency by sub-district and gender in 2009

Sub-district	Male	Female	Total
Panggang	12,746	13,757	26,503
Purwosari	9,246	10,071	19,317
Paliyan	13,983	15,108	29,091
Saptosari	16,523	17,728	34,251
Tepus	15,181	16,697	31,878
Tanjungsari	12,330	13,315	25,645
Rongkop	12,964	13,915	26,879
Girisubo	10,511	11,610	22,121
Semanu	24,920	26,751	51,671
Ponjong	24,057	25,625	49,682
Karangmojo	23,477	25,200	48,677
Wonosari	38,476	40,247	78,723
Playen	26,301	28,083	54,384
Patuk	14,820	15,553	30,373
Gedangsari	17,228	17,920	35,148
Nglipar	14,422	15,268	29,690
Ngawen	15,345	16,159	31,504
Semin	23,697	25,174	48,871
Total	326,227	348,181	674,408

Source : Population Census Beareau Statistic (BPS) of Gunungkidul Regency 2010

The female role in decision making at household level is related to water and land management indirectly. Farmer labourers are usually female aged between 20 - 45 years old. In accordance with inherited seasonal based local knowledge, it is mostly males who receive the knowledge. A disparity of knowledge transfer still exists and knowledge equality needs to be improved for female participation. However, the challenge arises from local values, require men to be the decision maker. Table 4.10. shows total population in Gunungkidul sub-districts which are included in the Karst area.

Table 4.10 Population of Gunungkidul Regency by sub-district

Number of Population											
No	Kecamatan (sub-district)	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
1	Girisubo	27872	27813	23625	23775	27879	23707	23770	23258	23873	22188
2	Paliyan	31423	31677	29730	29894	32076	29859	29937	29291	30065	29083
3	Panggang	27919	28081	26032	26065	28389	26431	26500	25929	26615	26509
4	Ponjong	50274	56166	50506	50624	56789	51012	51143	50038	51358	49803
5	Purwosari	21483	21707	18879	18982	22157	18702	18751	18348	18833	19361
6	Rongkop	32017	32254	28619	28772	32495	28837	28912	28289	29037	26901
7	Saptosari	36496	36717	35484	35756	37196	35340	35431	34666	35582	34270
8	Semanu	41668	57889	53985	54370	58818	53473	53611	52454	53840	51737
9	Tanjungsari	21945	28120	33381	33459	28638	26318	26387	25819	26501	25698
10	Tepus	38514	38614	26176	26264	39034	33625	33714	32990	33863	31889
	TOTAL 2001	162016	359038	326417	327961	363471	327304	328156	321082	329567	317439

Source: Gunungkidul in Figures (*Gunungkidul dalam angka*) 2001 - 2010

The Gunungkidul Regency government's spatial plan assigns each sub-district a function in regional development. Sub-districts which are close to the capital center, show dense population in their regions. For example Wonosari the center of business and government, Karangmojo, Ngawen, and Semin have the greatest population density in rank order (see Figure 4.16), although other factors like topographic setting also influence the population density of a sub-district.

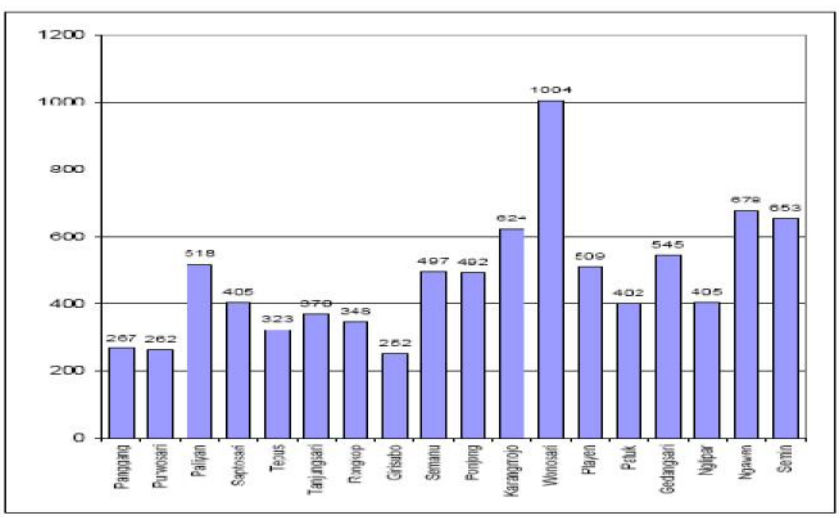


Figure 4.16.
Population density (people/km²) by sub-district in Gunungkidul Regency in 2009

The pyramid of population in the Karst region of Gunungkidul Regency from 2001-2010 shows that the productive age ranges between 20 - 65 years old (see Figure 4.17). High expectancy life age in Karst Gunungkidul is indicated at the pyramid from age 65 years old or higher. The dependency ratio, which consider productive population (self support) at age 15 - 60 years old, is still tolerable. It means that people at age 60 years old or higher can support their live (Author field observation, 2012 and 2013). Within four decades from the 1970s to 2010, the 65 years old population number is increasing. On the other hand, the productive age is not fluctuative from 2000 - 2011 (HOSSU, 2013:153). During 1971 - 1980, government programs was boosting and encouraging young people or the productive age (20 - 45 years old) to migrate from Gunungkidul and find other promising livelihood.

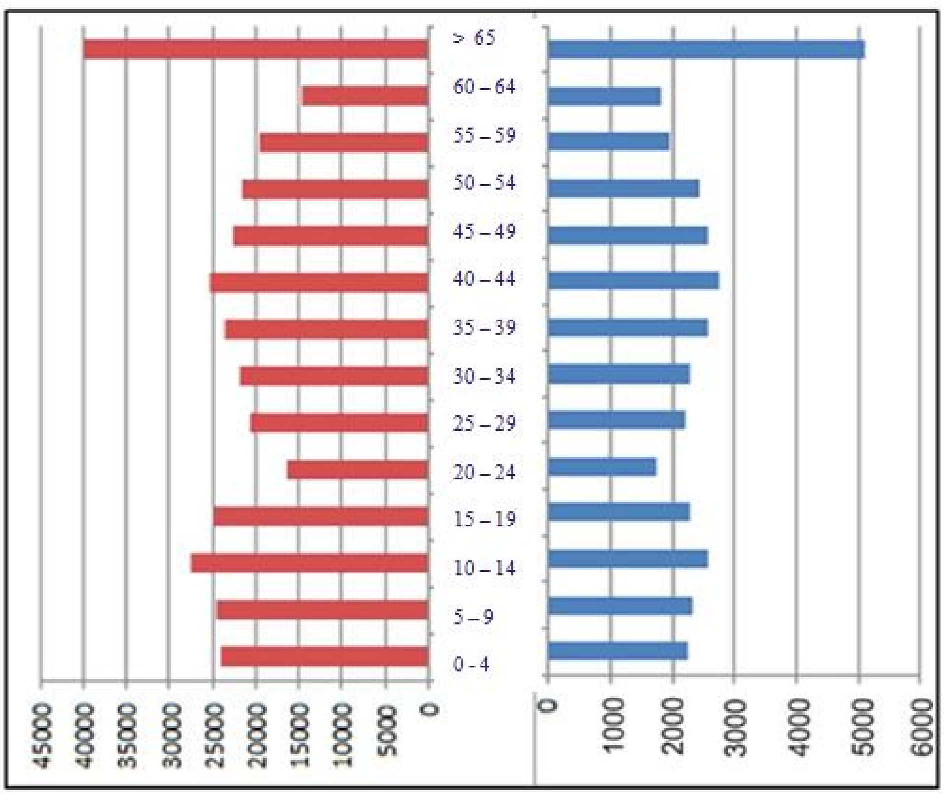


Figure 4.17. Population Pyramid in Gunungkidul

(source: BPS Gunungkidul 2001-2010 for the 10 sub districts in the Karst region)

People need water for religious activities, i.e. Moslem people wash five times a day for daily praying which takes at least 5 litres per day on average from the available water resources regardless of water availability during the dry season in the Karst region. Table 4.11 shows population numbers by religion. It is important to considera each person's basic needs for water including for their religious activities and other public infrastructure needs. Understanding the demographic characteristics determines the way people manage their resources.

Table 4.11. Population based on religion in Karst sub-districts Gunungkidul

Year	Moslem	Christian	Catholic	Hindu	Budhist	Others	Total
2002	369665	4896	2865	590	578	503	379097
2003	353575	3580	1157	576	365	0	359253
2004*	0	0	0	0	0	0	0
2005	354073	3475	1824	1778	2366	0	363516
2006	356541	4156	1641	1358	510	0	364206
2007	355547	4156	1641	1358	510	0	363212
2008	359770	4209	1922	1761	625	0	368287
2009*	0	0	0	0	0	0	0
2010	335711	7711	2179	1281	980	0	347862
2011*	0	0	0	0	0	0	0

Source: BPS Gunungkidul (note: in 2004, 2009, 2011 no available data)

4.3.3. Agriculture

Karst Gunungkidul is well known for its rain-fed agriculture, producing paddy, cassava, corn, soya bean and ground nut. The crops follow seasonal calendar cultivation, either following the inherited seasonal calendar *Pranata Mangsa* or following the cultivation calendar created by government institutions. Both calendars are applied in Gunungkidul's farming system with modifications or adaptations to field phenomenon. Agroforestry is also conducted as an extension of agriculture and forestry.

Agriculture was first boosted during the New Era (*Orde Baru*) with self sufficient paddy (*Swasembada Beras*) program in correlation with the green revolution of the 1970s until the 1980s to feed the increasing population. Development of rice production in Indonesia since the green revolution has until 2008, involved many actors and stakeholders, with a rising number of critics (HOSSU, 2013:107). Development in Gunungkidul has concentrated on agriculture until the present time.

Irrigation paddy fields can only be found in Wonosari Plateau (*Basin Wonosari*) and those part of Karst sub-districts namely Ponjong and Semanu, which lied between the boundaries of Wonosari Plateau, Panggung Massive and Karst. Water availability is different, with some parts of Ponjong and Semanu capable of cultivating wet paddy using irrigation model or nursery seedlings. The southern part of Gunungkidul Regency relies on rain-fed agriculture which requires certain adaptations of the government's program of agriculture and forestry due to Karst physicalf constraints. However, the inherited "artifacts" of green revolution and *Swasembeda Beras* exist, including the type of paddy introduced and cultivated up to present like IR 64 and Ciherang (FGDs and in-depth interview 2012, 2013).

Inter or mixed cropping, known as *Tumpangsari*, is the farming system applied through generations, but the methods have undergone "field-experimention" by farmers in application to their land and the government's instruction. The cultivated and mixed crops are paddy, corn, groundnuts, soya beans and cassava; in rotation with annual seasonal changes adapting to locality characteristics. Paddy in rain-fed fields is cultivated only once per year and the production is increasing, but only sufficient for local to regional demand (BPS Gunungkidul 2001-2010). The production of groundnuts, corn/maize, and cassava are increasing, but soya bean production is decreasing (HOSSU, 2013:188). Government policies to support farmers's production correlate with farmers' decisions to plant easy cash crops with less operational cost.

4.4. Historical Background of Gunungkidul Regency

4.4.1. Gunungkidul Pre-historic Time and Human Habitation

Physical features of Karst in Gunungkidul region during the pre-historic time has shaped the landform and inevitably determined early human habitation. The region has experienced a long history of settlement. In the first stage of karst landform development, human habitation was on open sites along surface riversides. During the late Pleistocene (40,000 BP until 12,000 BP), there was some cultural change. In this period, habitations moved to caves or rock shelters from those previously found along the riverside adapting to Karst environment at that epoch time period (HARYONO, YUWONO, and FAIDA, 2008). This change had a great impact on cultural development. Life in temporary camps which had previously tended to be nomadic changed to a more settled life in the caves. This condition facilitated opportunities for innovations. Some typical characteristics of the late Pleistocene are 1) exploitation of caves and rock shelters for habitation and other activities, 2) exploitation of various kinds of rocks for tools, 3) subsistence by hunting, and 4) hominid culture bearers belonging to the species of Homo sapiens (SIMANJUNTAK, 2002).

The neolithic of Gunung Sewu karst displayed unique characteristics with regards to its geographical orientation, technological aspects and chronology. In the beginning, neolithic technology was still located in caves and shelters, representing a continuation of the pre-neolithic culture. Subsequently, neolithic sites shifted to open sites on plains and hill slopes. The shift from cave to open sites was apparently related to technological development. The plains and hill slopes where cert, was easy to get for adze manufacturing, were selected as locations for settlements and workshops, rather than caves. Advancements in technology made it possible to exploit trees to build simple houses around the workshop. Neolithic culture is presumed to start from 4,000 BP up to 2,000 BP (SIMANJUNTAK, 2002; SUTIKNO and TANUDIRDJO, 2007; YUWONO, 2004).

The prehistoric time of Gunung Sewu Karst ended in paleometalic era. In this era, pottery making became more advanced, characterized by the use of the paddle and anvil, combined with the use of potter’s wheels and polishing technology. The time span covered by Palaeomethalic culture was shorter than that of Neolithic. This culture still existed 700 years ago. (SIMANJUNTAK, 2002).

Gunung Sewu prehistoric time culture was prolonged, when the lowland areas and volcanic areas experienced a Hindu culture. Gunung Sewu Karst region continued with a pre-historic culture until better access was opened from the lowland surrounding areas Present traditions related to human habitation in the Gunung Sewu Karst are closely associated with agricultural culture. One of the important traditions for people is festivity, the so-called *Rasulan*, that is held annually after harvesting time. This cultural tradition is related to seasonal based activities before planting starts, post harvesting, or events due to extreme weather occurrence. The recent agricultural practices will be artifacts in the future which can be important as paramater to determine cultural and the environment changes.

4.4.2. History of Gunungkidul Regency Administration

The settlement history in Gunung Sewu is related to the Mataram Kingdom, established in Java during the 8th and the 9th centuries (SUNKAR, 2008). Between 16th and 18th century, Gunungkidul was time known as *Wukir* or *Redi Kidul*. Gunungkidul was established as an administrative region in 1831, a year after the Diponegoro war ended, according to R.M Suryodiningrat's book *"Peprentahan Praja Kejawen"*, confirmed by ROUFFAER (1931) in *de Vorstenlanden.* The establiment of Gunungkidul Regency was together coincided with other regencies in Yogyakarta, on *Jumat Legi*, 27 May 1831 (or in Javanese calendar 15 *Besar Je* 1758). Yogyakarta Province legalized Gunungkidul Regency with Wonosari as the capital, in National Enactment 15 (*Undang-Undang*) 1950 and *juncto* government Act 32 (*Peraturan Pemerintah*) also in year 1950. The date of Gunungkidul Regency's establishment is supported and legalized by the Head of Gunungkidul Regency decree No. 70/188.45/6/1985, signed by Drs. KRT. Sosro Hadiningrat the head of the regency at that time. The history of Gunungkidul Regency is close to Yogyakarta Monarchy up to present time. There is a saying *'Adoh Ratu celak watu*", means far from the King but close to rock resources, thus people explore carbonates rocks of Karst.

V. Water and Land Management in Gunungkidul: an Understanding from Seasonal based Local Knowledge

"*The need to treat water as an economic good has been recognized as an essential component of sustainable water management. Integrated Water Resources Management (IWRM), a globally endorsed concept for water management, identifies maximizing economic value from the use of water and from investments in the water sector as one of the key objectives along with equity and environmental sustainability* (Global Water Partnership 2000).

Water is life, sanitation and hygiene, and to some cultures water represents dignity and status. The water post-2015 *Development Agenda* revealed that water-related natural disasters have shown devastating impacts to people, livelihood, and the environment. Access to sufficient quantity and quality of water needs to be accessible for everyone to mitigate risks from water related hazards (UN Water, 2013). It is urged to develop climate resilient water and land management. This research tries to synthesize climate-resilient management by understanding seasonal based local knowledge and its bio-indicators combined with physical features derived from keen observation or *ilmu titen* inherited through generations known as *Pranata Mangsa*.

5.1. Spatial Approach to Spatial Planning and Land Management of Karst Gunung Sewu in Gunung Kidul

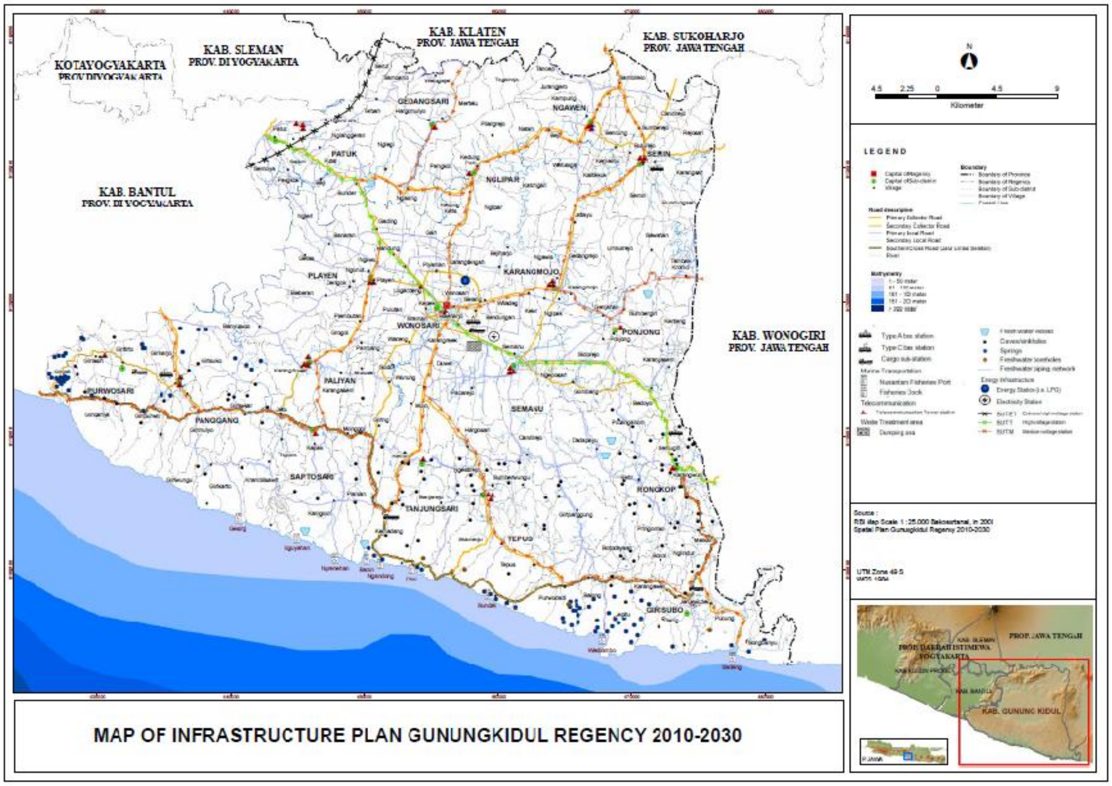
Land use and land cover are compiled in the spatial plan from a national to a local level in Indonesia. Spatial planning accommodates various interests and strategic activities with potential conflict. Being a agricultural country, the government issued constitution assures that potential farming land is preserved and no conversion for other purposes is allowed. National Government Act 41 (*Undang-undang*) in 2009 aims to sustain food security in the long term vision at national level. The legal constitution is followed by the regional government, where Gunungkidul Regency issued a regulation that protects 5,505 Ha of farming land from conversion, either for non-farming activities, or non-food commodities.

Water and culture challenges spatial planning to integrate and incorporate local (traditional) knowledge into planning agendas in order to reduce risk. In Karst region Gunungkidul, spatial planning needs to consider drought or water scarcity risk. Karst communities' perspective on water resources management and spatial planning are typically ignored (FGDs 2012, 2013). The method which has been used in spatial water management to create local support for regional and national planning issue is as follows:

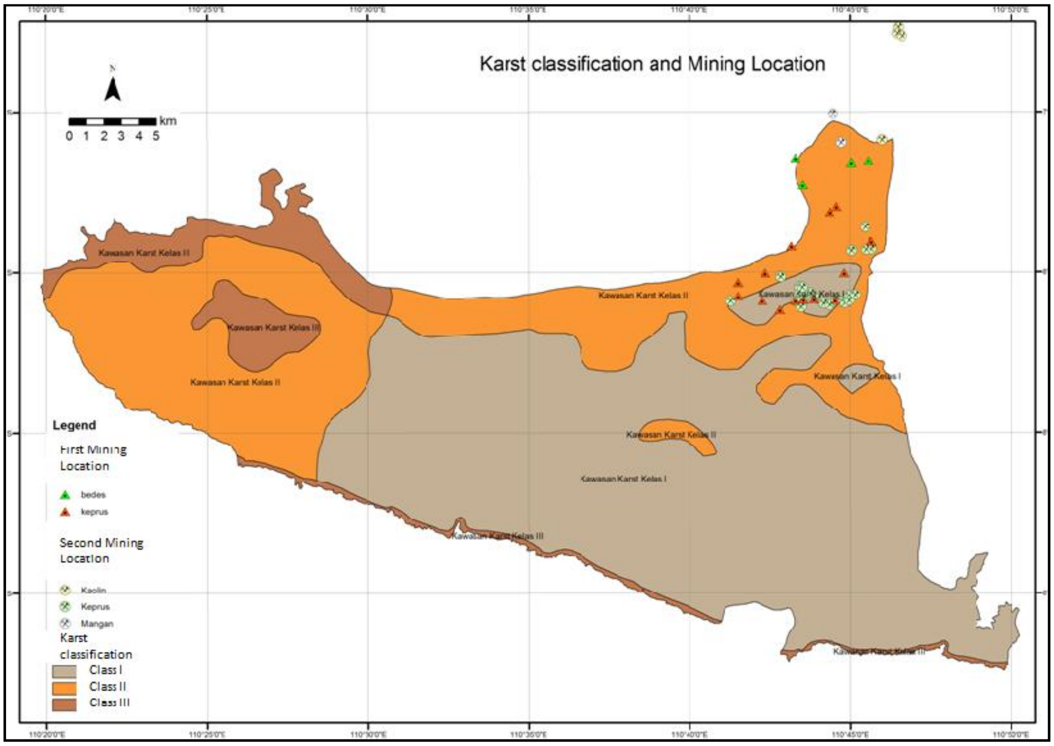
1. An inventory of spatial water management projects.
2. Analysis of the general characteristics of the state of spatial (planning) water policy and implementation.
3. Selection of projects for in-depth analysis .
4. Development of a check-list of potentially important conditions for success.
5. Analysis of case studies through interviews and review of background material.

The spatial plan is issued from national to local level and is reviewed every five years. The latest *National Spatial Plan Indonesia* was issued in 2007 and considered hazard and risk reduction issues in managing available space. The water catchment area is prone to landscape change and in such a climate sensitive region managing landuse is crucial and critical regardless of political interests. At the regional level, the Gunungkidul Regency's latest Spatial Plan was issued in 2010 and covers the period up to 2030 with possibility of a review every five years. Spatial approaches in the planning agenda are correlated with the development program and government elections, which are conducted every five years, with change of representation common.

Arrangement of space or landuse in Gunungkidul Regency shows the distribution of rain-fed agriculture and water infrastructure for fresh water (see Map 5.1). The southern part of Gunungkidul Regency is Karst ecosystem, and it is confirmed that people in the Karst region understand the difference of their environment to the middle and northern part of the region regarding the physical features and adaptations needed (FGDs and interview, 2012, 2013). However, governmental and institutional programs induced decision making on local or households level.



Map 5.1. Potential water sources are mapped on the Region Infrastructure Gunungkidul Regency Spatial Plan 2010 - 2030



Map 5.2. Karst Classification and Mineral type (*Bedes, Kaolin, Keprus, Mangan*) being mined on Karst Gunungkidul (Source: Gunungkidul Regency Spatial Plan 2010-2030)

The Karst ecosystem in the Southern part of Gunungkidul Regency is classified into three different categories (see Map 5.2) based on Ministerial Decree of Energy and Mineral Resources number 17 issued in 2012, as the renewed regulation of previous decree number 1456K/20/MEM/2000. The Ministerial decree supports the regional spatial plan to manage the Karst ecosystem. Map 5.2 shows carbonate rocks (mineral) type being mined in Gunungkidul, namely *Bedes, Keprus, Kaolin*, and *Mangan*.

A local-level spatial plan is applied in Ponjong village in Ponjong sub-district. Ponjong village lies between *Panggung Massive* (North part) and the Karst area (South part). The village is one of the catchment areas for Bribin cave where IWRM project built, in cooperation between German and Indonesian government, a pump to drill and bring up groundwater for a fresh water. The distribution of the water is then managed by regional water company (PDAM).

Human resources in Ponjong village local government are reliable, actively proceed with planning and management and represent good model of governance and institution application. They built a detailed spatial plan supported by the Minister of Settlement and Infrastructure (see Figure 5.1). A participatory spatial approach was initiated and operates to manage water and land resources. The initiation was started from the local government human resources, and then socialized to the whole villagers.

Figure 5.1. Scale Model of Ponjong village (Author, 2013)

5.2. Land management

The Millenium Development Goal (MDG) agendas related to land management goals are to eradicate extreme poverty and hunger and ensure environmental sustainability. Agriculture is one of the most dependable sectors for more than 2.6 billion people in the world (POULSEN, 2013) but soil degradation is keeping emerging due to anthropogenic factors which related to climatic factors and landscape changes. The first land management system in Indonesia was initiated by force by the Dutch government in 1832 known as *Cultuurstelsel* or cultivation system. The system had no affect on Gunungkidul landscape yet, as seen by JUNGHUHN who visited Gunung Sewu in 1836. The next agrarian law, applied in 1879 was known as *Agrarische Wet*, which was revised after Indonesian's independence and became *Undang-undang Agraria* (Agrarian Act) in 1960. Agrarian Reform between 1915-1965 brought changes to what people had to plant on the land based on colonial law. Tobacco, chocolate, coffee, and clove trees from the colonial era plantations can still be found in certain locations around Gunungkidul Regency, particularly the fertile areas. It represents the landscape during a different period of time with different climatic factors. Constitutions, laws and acts that regulate land and related issues in Indonesia are mainly agrarian or spatial planning related (national and regional spatial plan, detail spatial plan and building block code).

The land and water governance fact sheet[7] showed that: the New Order (*Orde Baru*) government emphasized economic growth in the hope that equitable distribution would be achieved. Land was considered a state asset necessary for capital investments for economic growth. This attitude was adopted by autonomous local governments in a decentralized approach. They consider land belongs to the local governments, enabling them to compete with other local governments in offering land to attract investment or revenue. Such thinking is possibly inherited from the past where the Dutch acknowledge the right of land already settled and cultivated by local populations. However, most of the land area was retained as state land, to be reserved for large plantations.

Land resources are a source of food, shelter and economic development. Managing land resources sustainably is crucial to ensuring they continue to provide important ecosystem services such as watershed protection, biodiversity conservation and carbon sequestration. Land resources challenges in Indonesia are:

1) transformation of productive land into critical land.
2) marginal land.
3) conversion of paddy rice land.
4) land fragmentation.
5) infrastructure development of optimal irrigated area.

Land issues on Karst areas in Gunungkidul Regency, mainly related to land scarcity (availability), erosion, possibility of sinkhole occurrence, no risk

[7] http://www.landgovernance.org/system/files/Indonesia%20Factsheet%20landac%20april%202011.pdf, accessed 3rd April 2013.

taking with new innovations in agriculture and forestry without good evidence. Following the philosophy of Confucius, the way to get wisdom is by imitation and experiences. By knowing and understanding farmers' motivation to use certain farming systems or to practice such soil and water management systems as they currently use and the knowledge they get and apply, a knowledge of local management can be built to reach what UNCCD (2013) called sustainable land management, to protect, sustain, and restore land resources.

Land is inevitably related to water in Karst Gunungkidul Regency. Local land management is applied following the inherited seasonal calendar known as *Pranata Mangsa* (FGD October 2012 to February 2013, and in-depth interview November to December 2013). However, the inherited knowledge faces challenges due to shifting climatic factors for farmers who rely on the rainy onset to start cultivation. To preserve sustainable, long lasting agriculture land and ensure food security, the National Government issued *Undang-Undang* number 41 in 2009, followed by Ordinance *Peraturan Pemerintah* number 1 in 2011, Provincial Government regulation *Peraturan Daerah Provinsi Daerah Istimewa Yogyakarta* number 10 in 2011, and then Gunungkidul Regency issued *Peraturan Daerah Kabupaten Gunungkidul* number 23 in 2012. These ordinances are meant to regulate agriculture or cultivated land conversion, yet so far there is no correlation with water (management) ordinances.

ENRYD (1998) conducted a study on the capability of land within Sleman Regency and Gunungkidul Regency. The study assessed land management regarding crops and vegetation management, soil management, and mechanical method (ENRYD, 1998:19). The Gunungkidul land use system needs to meet the welfare of people without harming the land reinforce an attitude toward conservation that sustains their resources. Land sensitivity to erosion defines the farmers' keen observation to conserve land and water resources. The introduction of new varieties of rice during the Green Revolution was easily accepted, as it produced a higher yield within a shorter time-frame. The attitude and perception of farmers to new innovation and technology related to land management, particularly agriculture or farming systems, induces socio economic changes individually or communally. An experimental farm field which shows good crop yields sufficient to meet farmers' livelihoods in adaptation to uncertainty climate variability without jeopardizing their harvest will encourage them to develop sustainable land management practices. In correlation to Sauer's work and other scholars on land ethics, people and particularly farmers, maintain their land management to meet subsistence needs and welfare in the medium to long term. Farmers' sensitivity to land and soil as adaptation to limited available resources on Karst regions, imprint on the land management practices, and describe socio-cultural relationship between land owner and farmer labours (see Figure 5.2).

Figure 5.2. Crop Rotation on second crops (ground nut, soya or mung bean) after harvesting paddy in Tileng, Girisubo (Author, 2013)

5.2.1. Land Management with Limited Land and Water Source Availability

Green Revolution was a major achievement for many developing countries and gave them an unprecedented level of national food security. However, the Green Revolution did have negative impacts on the environmental which still need to be resolved, including the livelihood of economically poor farmers with less access to resources (HAZEL, 2009). One of the impacst in Indonesia is the use of chemical fertilizer to boost crop yields in line with Government programs. Farmers in Gunungkidul usually use manure fertilizer. Farmers have realized one effect of chemical fertilizer use is that their soil becomes harder during ploughing. In 2010 the regional agriculture institution introduced organic fertilizer mixed with chemical products because the depleted soil already needed for certain minerals from it (Indepth interview, November to December 2013).

Soil conservation technology introducted include building terraces with ditch and duct, terraces braced with vegetation, perennial vegetation, ground cover planting, and organic matter utilization in Ponjong, Munggur, and Bedoyo Kulon villages in Ponjong sub-districts all show promising physical soil improvement properties. The technologies coupled with local knowledge of soil properties build embedded knowledge management. During the fallowing period, farmers can cultivate *Crotalaria juncea* (see Figure 5.3) to protect the soil surface, whilst the leaves can be used as animal feed and bio or organic fertilizer. This practice ceased after the 1980s because farmers considered it un-economic when the government program introduced chemical fertilizers. During field observation (October 2012 - January 2013; October 2013 - January 2014), use of Sunn hemp was not evidant.

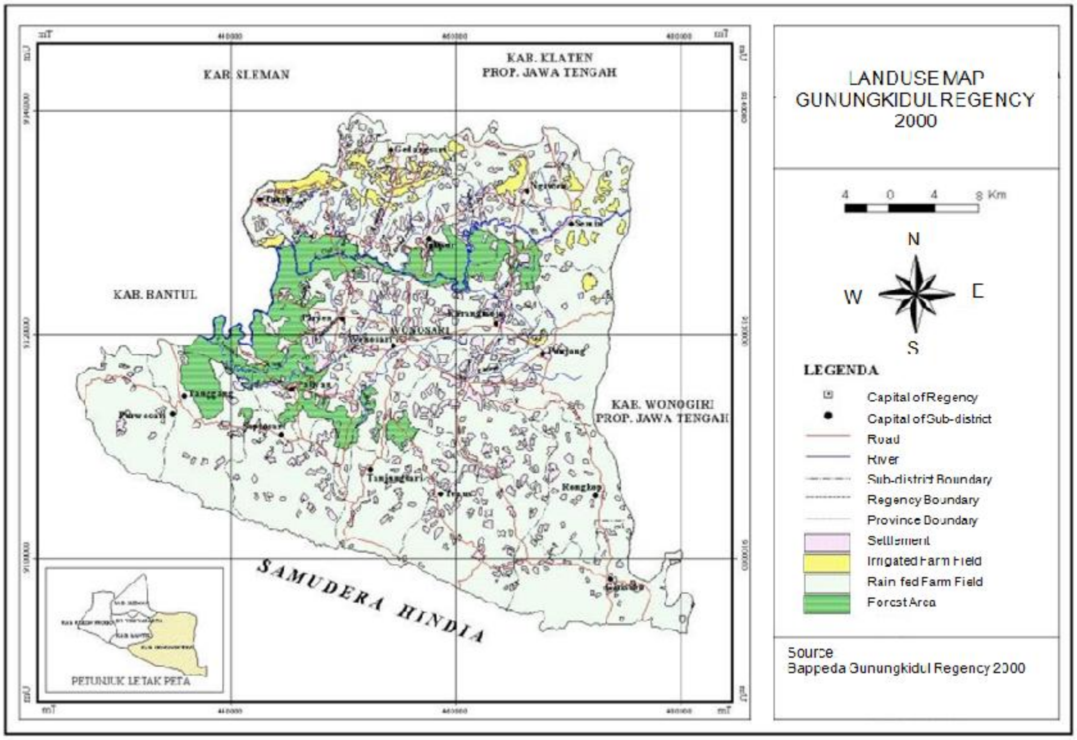
Figure 5.3. Sunn hemp or *Crotalaria juncea*

Farmers cultivate their land with consequences of Karst characteristics, particularly the shallow soil solum with rocks occurrence, which hamper the ploughing and putting seeds. Farmers have adapted to limited land resources and manage the cultivation season. Figure 5.4 shows that farmers utilize stone (rock) pockets to put corn seeds and in other part of the field they put cassava stem.

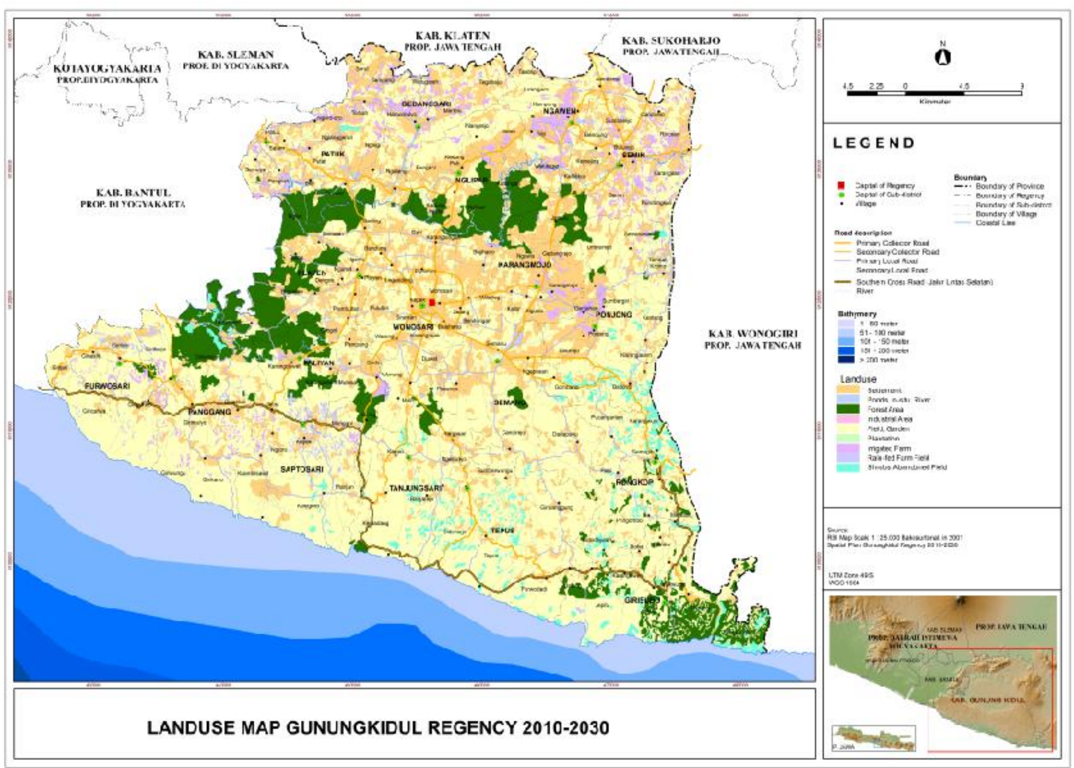
Figure 5.4. Optimizing Limited Available Land in Tepus Sub-district (source: Suryanti, 2010)

Agroecology has actually applied in Karst Gunungkidul region with serial adjustment along with evolving and flourishing knowledge from the people. In other parts of the world, inter-cropping, multi-cropping, or crop rotation are being introduced to cope with climate related vulnerabilities and susceptibilities, while Gunungkidul's people, in particular farmers, have already nurtured and construed their land and water management based on local knowledge. However, in a rapidly changing of climate factors, they are challenged to be more diligent in managing limited resources for their livelihood. Improvement of agriculture methods, techniques and innovation needs to address locality issues in consideration of the global threat of climate change.

Comparing landuse map issued by the Gunungkidul Regency government (see Map 5.3 and Map 5.4) to the landuse (see Figure 5.5) drawn by DAMES (1955:23), it is clear the location of preserved (protected) forest is slightly expanded. The protected forest locations are mainly found in the region close to surface water sources and in the border of geomorphologic units. The protected forest is sometimes overlapping with smallholder plantations area.



Map 5.3 Landuse Map Gunungkidul Regency 2000 (source: BAPPEDA Gunungkidul Regency 2000)



Map 5.4 Landuse Map Gunungkidul Regency of the Spatial Plan 2010-2030

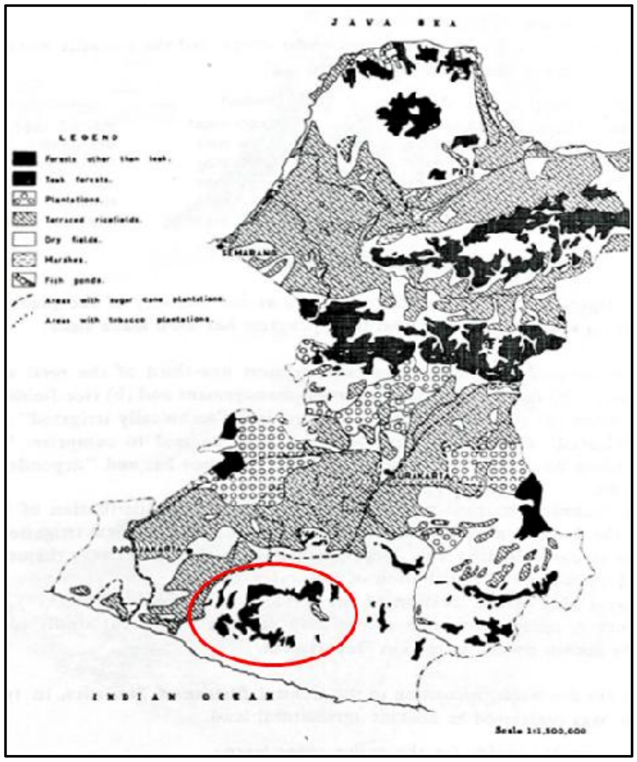


Figure 5.5. Landuse Map depicting part of Gunungkidul Regency with Teak Forest (red circle) on DAMES (1955:23)

A study from WARDHANA, BOMANTARA, and SUGIARTO (2012) using satellite images, shows that smallholders' plantation areas are increasing (see Figure 5.6). Large scale re-greening campaigns were started by the national government in the 1970s and encouraged farmers to grow trees at large scale. Due to farmers' skill and experimental planting, the most common species grown were teak, mahogany, *A. auriculiformis*, *Cassia timoriensis*, *Sesbania grandiflora*, mostly on the hillsides. The species chosen were fast growing species for wood or fodder and the ready availability of seedlings. Meanwhile, fruit trees such as *Gnetum gnemon*, *Ceiba pentandra* and *Musa paradisiaca* (banana) were grown and still exist today, mostly in the valley bottoms and home gardens.

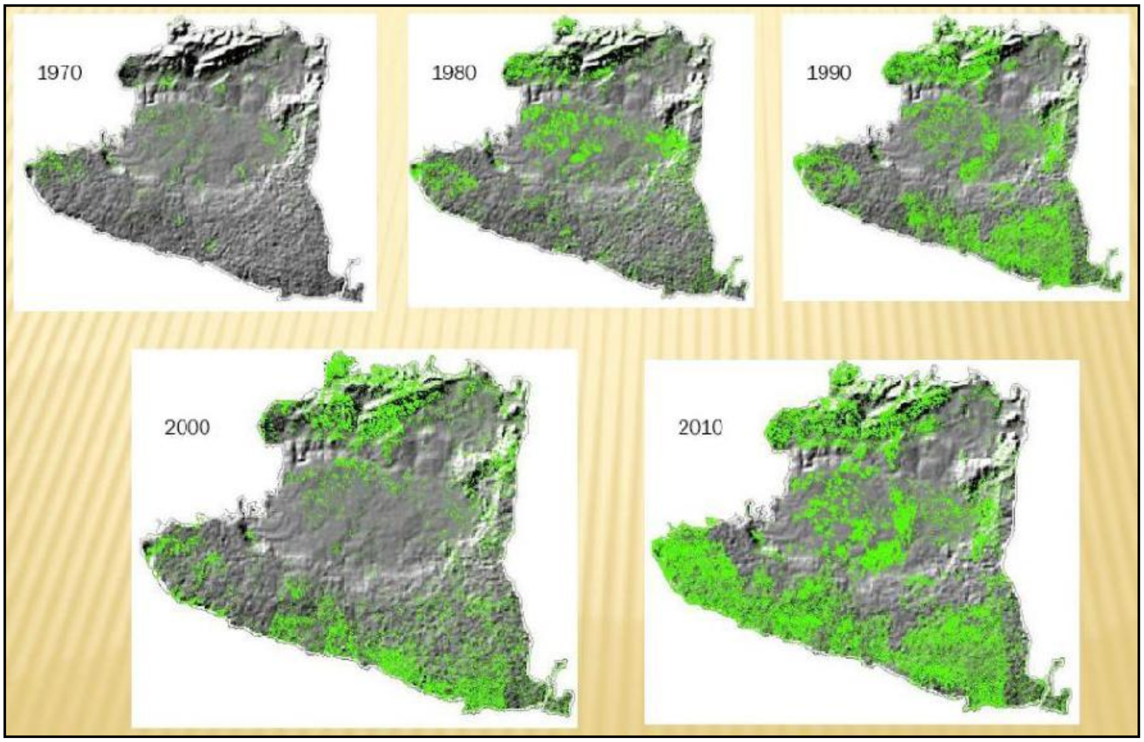


Figure 5.6. Historical expansion of smallholder forest plantations (green color) in Gunungkidul Regency (source: WARDHANA, BOMANTARA, and SUGIARTO, 2012)

Agroforestry (see Figure 5.7) has been introduced to farmers to maintain economical and ecological consideration. Agroforestry aimes to support farmers who grow timbers like teak and mahogany and prevent deforestation. During the Japanese occupation the forest in Gunungkidul suffered greatly. Deforestation occurred for cultivation and charcoal production (1940-1970), which contributed to soil erosion. Agricultural production was susceptible to droughts and the crop rotation followed the seasonal changes (NIBBERING, 1991b:118). NIBBERING's study (1991a,b) revealed the spatial preference of land management, within social economic pressure. In that study, people with large land holdings let their relatives or other farmers cultivate by sharing the harvest or other agreements, which are still practiced nowadays (FGD 2012, 2013). Forest plantation on Karst areas are important to secure conservation and preservation of groundwater discharge on the catchment area.

Figure 5.7 Paliyan Agroforestry (Author, 2013)

DAMES (1955:73) discussed about "*labuhan*" as the time in seasonal calendar *Pranata Mangsa* when people start to cultivate, as rain starts to fall in the first half of west monsoon. The cultivation mentioned involved upland rice, ground nuts or soya beans, intercropped with maize or millet and others, such as castor, pigeon peas and sesame. At that time, terracing using low stone walls was already common, although inadequate for soil protection using available resources. During the dry season the land remains fallow, in the 1930s hillsides in Karst Gunungkidul were cultivated for two years and fallowed for two or three years (NIBBERING, 1999:69). This fallowed period has shortened due to population growth. The fallowing period today is only during peak dry season and in *Pranata Mangsa* calendar known as *Mangsa Katiga*.

5.2.2. *Tumpangsari* as Climate and Water Sensitive Cultivation System on Rain-fed Field Karst Gunungkidul

Ecological farming (adaptation) to meet and build sustainability on Karst Gunungkidul region, can be derived from understanding the seasonal calendar with some adjustment in facing erratic climate patterns. *Tumpangsari* is an inter-cropping system which can be considered as local adaptive land management to meet the limited availability of land and water in Karstic regions like Gunungkidul. The knowledge was firstly developed by farmers to cope with the uncertainty of changes in climate and environment, to manage land and water scarcity. Farming knowledge evolves through time, but optional crops still consist of at least three different species following the seasonal cycle. The knowledge evolution involves innovation at each step of land management, such as seed nursery, ploughing, dunging or fertilization, and pest control.

Soil characteristics are identified by farmers regarding the fertility, selected by color and texture, based on their observation and experiences. Dark soil is regarded as more fertile than the red soil, and this keen observation is based on experiences which then transfer through generations orally (FGDs, 2012 and Indepth interview, 2013). Manuring was extensive on hills with red soils. Cut and burn was also practiced in expectation of bringing nutrients when rain water flows (NIBBERING 1991b:114) and let natural succession works. The identification of soil properties correlates to water-sensitive cultivation. On the red soil, people cultivate corn, ground nuts, soya or mung bean, which is known as *palawija*. Whilst on the dark soil, paddy is preferable and most suitable.

Farmers whose land belongs to someone else, including their parents' land, are unable to make decisions about the cultivation activities and the crop selection. Farming is also considered the very last optional occupation. Thus, it takes a certain approach and effort to encourage a farming system. Farming is not giving any benefit economically for those who choose to have another job. Government programs and projects seem in no way to support an increase the farming, but end up creating dependency on seed, fertilizer and modernize equipments (Indepth interview, 2012). Participation in land policies is needed with support by government policies to assure regional development.

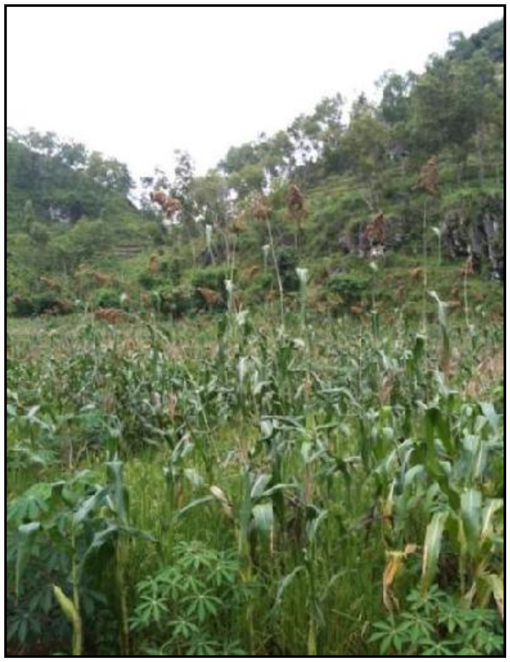


Figure 5.8. Millet between corn, dry fed paddy, cassava in T*umpangsari* cropping system in Kenteng village, Ponjong sub-district (Author, 2013)

Tumpangsari is an adaptation of agriculture which related to agrogeobiodiversity and lead to in-direct impact on food security (see Figure 5.8). *Tumpangsari* helps to sustain germplasm which is adapted to local characteristics. The crops are cultivated in orderly time frame following annual season changes. Thus, support farmers for their food security. Optional crops which are cultivated on the same field depend entirely on the land owner. Figure 5.9 shows economically market oriented dragon fruit tree, beside paddy, corn, and banana trees. Farm labourers are paid and hired to help nurse crops for the land owner. An economically market oriented farmers do not apply seasonal calendar *Pranata Mangsa*, but they still use the knowledge from it. These farmers wait for the rain onset, then starts growing the economically market plants.

Figure 5.9. Farm labour *(buruh tani*) in Kukup coastal area, Kemadang village, Tanjungsari sub-district (Author, 2013)

Home gardening also supports food security at the household level, not necessarily for economic purposes, for example by growing fruits and vegetables. Figure 5.10 shows home gardening with (rain) water tank nearby to support water demand for the household for the average three to five month-long dry season. Water use efficiency when applied in agriculture or plant cultivation correlates to an improved water footprint.

Figure 5.10. Rain Water Tank (left), and Home Gardening (left and right) (Author, 2013)

The ecological continuum study of rice cultivation systems in Southeast Asia stated that dry upland rice appears in three ecosystems: shifting cultivation (*padi ladang*) by dibbling, swiddening, in-land rotation; dryland-rice on permanent arable land (*padi gogo*, in-crop rotation) on open fields, or intercropped under tree-cultivation, and other annuals (UHLIG, 1984:16). The landscape of rice systems reflect the ecosystem service for humans, particularly to feed the hungry population, in adaptation to geo-ecological and physiological factors.

BURKARD (2004) showed that socio economic process in Java differ spatially, exemplified in the highland region Gunungkidul, Java. In the highland rural society, no exclusionary contractual arrangement exists between the land owner and the marginalized wage workers. GEERTZ (1963) discussed the degree of human and environment relations, in an ecological approach into ecosystem, as an analytical system. The study revealed the characteristics of agriculture patterns in Indonesia per island, and described the landscape by exploring the ecology and environment characteristics "any form of agriculture represents efforts to alter a given ecosystem in such ways as to increase the flow of energy to man: but a wet rice terrace accomplishes this through a bold reworking of natural landscape; a swidden through a canny imitation of it (GEERTZ, 1963:16)". Scholz (1988) described the agriculture of Sumatra island which is influenced by local characteristic, and the challenges in the farming system .

The condition of farmers in upland Java has seen improving since the 1980s-1990s with the main concern overcoming food shortages (NIBBERING, 1991b:122). Nowadays, it is not food shortages, rather it is to maintain the assets or wealth to mitigate such stress situations as water scarcity and pests for Gunungkidul farmers. Government institutions have improved their program regarding land management through implementation of rules, regulation and standard guidance to improve farmers' knowledge and skill, without suppressing local characteristics. However, it is the farmers themselves who finally decide how to develop local adaption to their environment. Plant and water conservation through *Tumpangsari* increase food security through agrogeobiodiversity, reducing the impact of failure on harvest time and adapting to climate variability climate with resilient water and land management. Crop rotation options are paddy, groundnuts, corn/maize, soya or mung bean and cassava.

Government institutions which are responsible and correlate to land management are the agriculture and forest department, with the ministry operating at the national level and a board or agents at the regional and local level as representatives of the ministry. In cooperation with other government departments or agents, some efforts have been developed to increase farmers' knowledge, skill and related capacity. The agriculture department has introduced *Sekolah Lapang Pengelolaan Tanaman Terpadu* (Integrated Cultivation Management Field School), *Sekolah Lapang Pengendalian Hama Terpadu* (Integrate Pest Control Field School), and *Sekolah Lapang Iklim* (Climate Field School) to accommodate the climate challenge.

5.2.3. Integrated Crop Management Field School (*Sekolah Lapang Pengelolaan Tanaman Terpadu*/SLPTT), Integrated Pest Management Field School (*Sekolah Lapang Pengendalian Hama Terpadu/*SLPHT), and Climate Field School (*Sekolah Lapang Iklim*/SLI): Institutional Sharing to Develop Land and Water Knowledge Management

SLPTT and *SLPHT* were initiated around 1997 and continue to the present day, together with *SLI* which was initiated around 2009 in cooperation with the Bureau of Meteorology, Climatology, and Geophysics (BMKG) Indonesia. The climate field school (*SLI*) aims to build farmers's knowledge into a more adapted, adjusted and prepared to cope with uncertainties approach to climatic factors changes (BOER, 2009). There are now at least 290 Climate Field School operating in regencies or districts throughout Indonesia, Gunungkidul regency is one of them.

The Climate Field School (*SLI*) in Gunungkidul Regency was first established in 2007 in Wareng Village, Wonosari sub-district. Discussions during the field school activities involve the experiences of farmers, particularly in application of *Pranata Mangsa* from their keen observation of changes. Some of the participants received the knowledge sharing from the school field, yet still consider to apply *Pranata Mangsa* for their farming guidance. Others, consider *Pranata Mangsa* as old fashioned and rely on the calculation of government institutions and the first rain fall to start cultivation. The village is not part of Southern Karst Gunungkidul, but a lesson that can be drawn here id to compare and further analyzed the homogeneity and heterogeneity of seasonal based local knowledge. The "schools" are institutional media to develop water and land knowledge management.

5.3. Water Management in Karst Gunungkidul

The Kingdoms era in Indonesia showed that the Kings have already considered the value of water to boost their region, while also taking into consideration the natural hazards of water. Early 1930's Indonesia was still occupied by Netherland who has established a modern water law called *Algemeene Water Regelement*, general water law (HARYANI, ANSHORI, DJUWANSAH, and HEHANUSA, 2007).

5.3.1. Watershed Approach

A watershed approach for Karst landscape needs to take into consideration surface water flow from catchment areas and flows as groundwater to arrange a planning and management scheme in such geographicly-driven hydrology issues. A coordination framework for environmental management involves public and private sector efforts to address the highest priority problems. In a region where coupling climate and physical characteristics lead to water scarcity annually, sustainable water resources and efficiency land management are everyone's and every sector's business. Water management for agriculture determines farmers behavior towards available resources and meets their needs to achieve better yield harvests. Innovation for farming with modern technologies is likely to meet agriculture and water management needs against water stress and drought (VALERO, 2011: 34).

Managing the watershed can be used to assess, evaluate and monitor environment degradation or disturbances. Under uncertainty changes, in correlation with climate and environment, inhabitants in Karst region Gunungkidul, have developed water management at the local level and household level. At the higher level, namely regional and national level, water management is ruled by government institutions. Figure 5.11. shows the water supply zone in Yogyakarta Province with different physical settings in each region, and Gunungkidul karst area is part of it. Each region apply water policies using national standards while considering locality aspects. Karst in Gunungkidul (in yellow) can be considered as one big watershed (ecosystem) which correlates to the retention or catchment area on Baturagung Range and Wonosari Plateau.

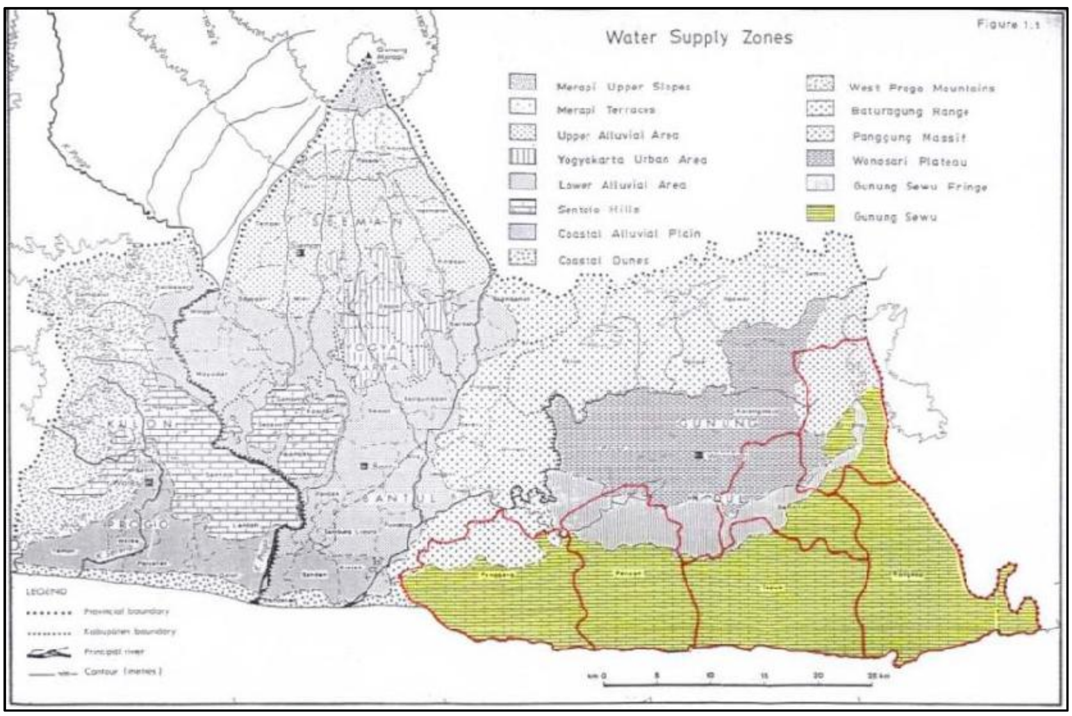


Figure 5.11. Water Supply Zone in Greater Yogya
(Source: MACDONALD & PARTNERS, 1984)

5.3.2. Water Issue

Adapting to climate uncertainty changes from diverse water resources management appears in *The Rio Declaration* 1992, *Rio +20* and *Agenda 21* and brought the issues on environmental development as adopted by many countries on Earth to global awareness. MDGs targets by 2015 include 77.2% of the population in Indonesia having accessed safe drinking water and at least 59.1% of the population in rural and urban setting having appropriate sanitation as stated in Indonesian´s MDGs 2009. These percentages might have been accomplished, but they are in a scattered spatial pattern in some parts of Indonesia, particularly rural areas with harsh physical settings prone to environmental changes from climate variability. In some parts of rural Indonesia, safe drinking water and good sanitation are not accessible for life support.

This study considers that sanitation strategy for municipality or regency can be applied through water management based on local culture, which consider actual data, scale arrangment made by the local community supported by regional government and the development of a real decentralized approach without neglecting government authorization and obligation. Local government in many communities needs to be able to map local characteristics, obstacles and the potential water resources, sanitation needs and land or space utilization. Those who know and own the knowledge of water and landscape and the power shall rule the development and the less knowledgeable people. Social awareness, knowledge and capital are required to effectively manage water resources, involving many parties or related stakeholders globally and locally.

5.3.3. Indonesia's Water Resources Policy Reform Process

Complex investment and management challenges have been faced by the Indonesian government regarding the water and irrigation sectors. Indonesia has drafted a national resources policy action plan 1994 - 2020 (see Appendix 1), which mentioned water resources management, socio-economic and finance, environmental management, and legislation and administration. The policies are to:

1) Provide allocation and utilization conducive to economic and social development and environmental sustainability;
2) Improve the effectiveness and efficiency in the utilization of water;

3) Provide levels of quality in Indonesia’s water resources which are conducive to economic and social development and environmental sustainability;
4) Develop water resources under the national water resources development plan based on river basin planning;
5) Enhance private sector and community participation in financing of water resources development;
6) Establish a sustainable budget system for water resources management;
7) Create a water resources management structure consistent with integrated management objectives.

Indonesia is one of respondent countries to the sanitation and safe drinking-water UNICEF/WHO program that indicated to have developed and implemented water safety plans or other preventive risk management strategies (Figure 5.12).

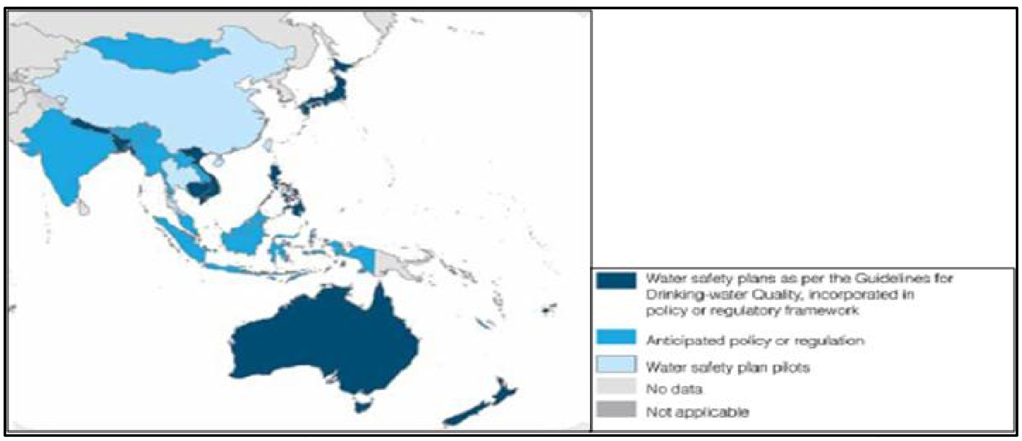


Figure 5.12. Southeast Countries in Asia with developed and implemented water safety plans or other preventive risk management (source: GLASS, 2012)

The use of financial systems for water related system development in rural areas of Indonesia include partial support for drinking-water, sanitation, and hygiene promotion at the local level. Development and implementation of water related policies are mostly carried out in the Western part of Indonesia, rather than in the Eastern part of the country with certain conditions. Some unique physical and socio-culture rural areas need to be recognized for optimizing local water related resources. SUNKAR (2008:190) hypothesized that water is a basic essential for life, therefore people will choose to live in areas close to water. The IWRM, by means of technology and supported by good accessibility, provide water to those who live in quite a distance from a water source.

During Dutch colonialism in Indonesia, the first water irrigation institution was known as *waterschappen*. It became the embryo of *Dharma Tirta* in Central Java and regulated in the constitution of Dutch East Indies (MAKSUM 2007, cited in AGUSTINA and SUBARI 2011). The constitution was changed by the Indonesian Government gradually over the years: *Peraturan Pemerintah* (*PP*) number 77 in 2001 (Irrigation), *PP* number 20 in 2006, *Undang-undang* (*UU*) number 11 in 1974 (Water), *UU* number 7 in 2004 (Water Resources). Water institutions at the field level are culturally different between traditional institutions on irrigation of West Java, Middle Java, and East Java; with different application of the water constitutions.

5.3.4. Integrated Water Resources Management (IWRM)

An agreed consensus on a new national water management strategy was named 'integrated water resources management and water efficiency' (IWRM and WE). The IWRM and WE develop available water in a sustained way, considering water and land ethics (HARYANI, ANSHORI, DJUWANSAH, HEHANUSA, 2007). The World Water Forum proposed in 2001 an integrated approach in managing water resources and The World Summit on Sustainable Development in Johannesburg 2002 recalled all countries to start to develop an IWRM plan and Water Efficiency Strategy incorporating multiple sectors (see Figure 5.13).

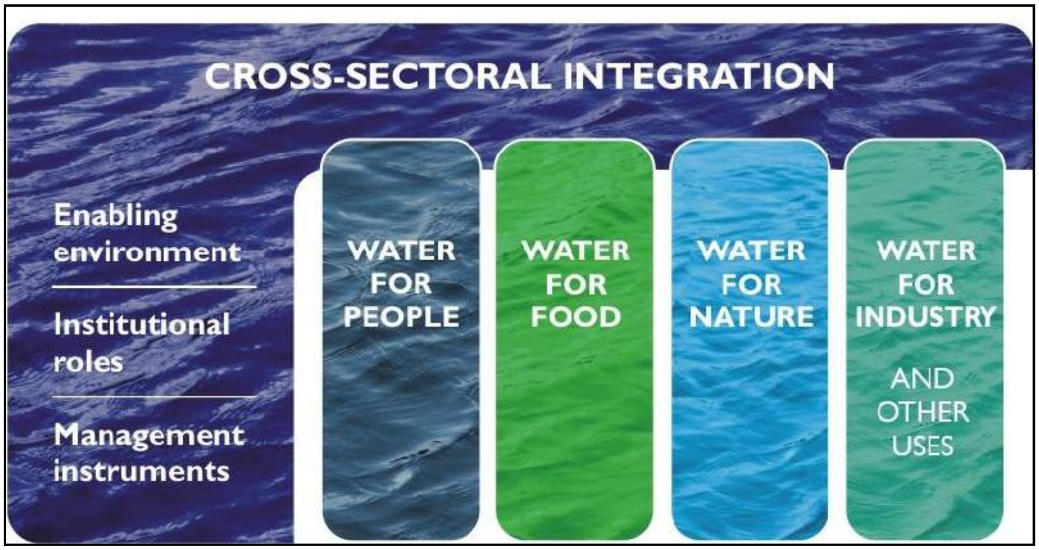


Figure 5.13. IWRM and Its Relations to Sub-Sectors[8]

Seasonal based local knowledge teaches the nature cycle within such ecological balance. Understanding the ecological balance ensures capability to manage resources in pro portion to the anthropogenic factors affecting the natural cycle. Therefore, technological innovation needs to be developed. Technology and innovation do not always require sophisticated form. They need only be applicable for rural livelihood, particularly to manage water and land an create a water land system which contributes to a safe and clean environment.

Water management and knowledge between authorities, non-governmental organizations and communities needs to be shared to reach sustainability for multiple interests including nature itself within environmental ethics. Integrated water resources management in Karst Gunungkidul, applies a proposed technological innovation to solve water scarcity problems during the dry season (DITTMANN, FACH, FUCHS, HOSSU, NESTMANN, and OBERLE, 2011). Reducing water-related risk efforts aim to accelerate achievement of strategic planning and reach the MDG's targets. A resilient environment, including the cultural environment, need to be enhanced to face the potential hazard in the Karst area.

[8] Global Water Partnership program on IWRM and the relation sectors

5.3.5. Case Study of Integrated Water Resources Management (IWRM) in Gunungkidul, Indonesia

IWRM as defined by Global Water Partnership is a process promoting the coordinated development and management of water, land, and related resources in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems. Gunungkidul Regency is an example of a IWRM project conducted for Karst ecosystems in Indonesia with the German Government (see Figure 5.14). The project is not expected to change local social culture in a short time, rather it chooses practices with a good chance of success, and appropriate alteration adjustments.

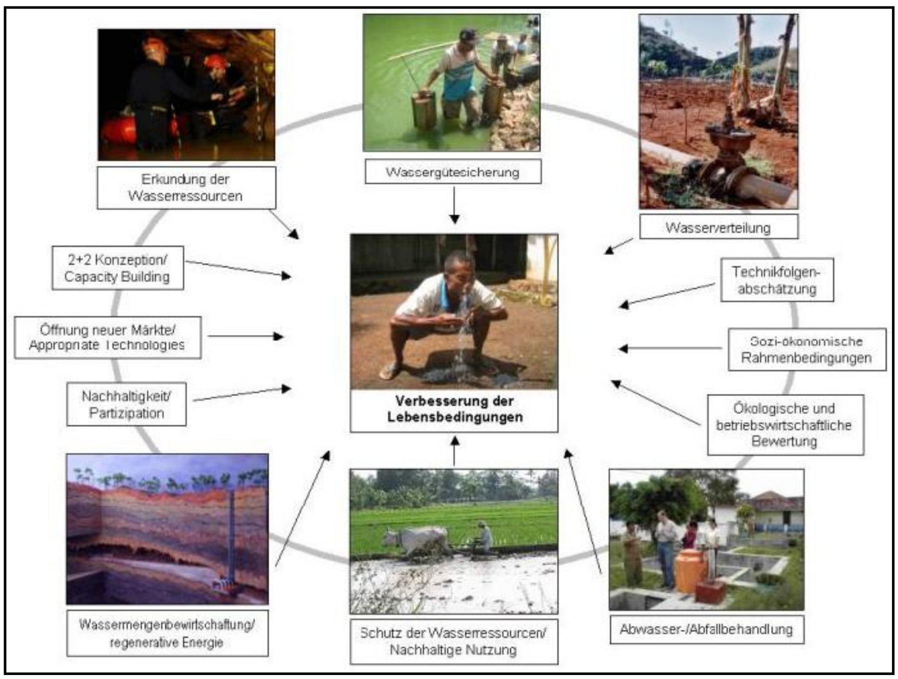


Figure 5.14. Scheme of Integrated Water Resources Management Project in Gunungkidul, Indonesia[9]

The regional Government of Gunungkidul has cooperated with other stakeholders related to water management for the Karst ecosystem. The realization of the IWRM concept in Gunungkidul must follow the framework of a joint research project with 18 institutions (project partners) of the

[9] a scheme describing how the IWRM project conducted in Gunungkidul, Indonesia as pilot project for other Karst region

Karlsruhe and Giessen Universities, the Karlsruhe Research Centre, as well as several industry partners in cooperation with Indonesian partners. It was defined from all technical disciplines of the FuE-demand based on the super ordinate work packages. The concept was developed for the realization of the key activities in the region with the following aims:

1) Water supply;
2) Water quantity management;
3) Water distribution, water treatment and water quality assurance;
4) Wastewater treatment and treatment of waste;
5) Ecological and socio-economic evaluation / technological impact assessment;
6) Capacity-Building.

The technology IWRM introduced and deployed in Gunungkidul's underground river system water are generally not accessible to local communities (FGD, 2012). The regional government still needs to improve the communicating system. The social network among beneficiaries of IWRM has not worked virtuously as an information sharing network, this in favor of the study conducted by SAMMADDAR, MURASE, and OKADA (2014). Their study revealed the role of social networks in disaster prevention technology dissemination, particularly introducing rainwater harvesting tanks to cope with the risk of water salinity in the coastal area. Individuals and communities tend to share information within the same cohesive affiliation. This also occurs in the case of IWRM Karst Gunungkidul. The competent institutions has not applied public communication to introduce the scheme to the people, or even that the water supply is available.

In terms of Disaster Risk Reduction, IWRM is relevant for managing both excess water (i.e. floods and landslide mitigation) and water scarcity (i.e. drought management). IWRM is broader approach seeks to integrate conservation, development and optimal utilisation of available water resources at watershed or river basin level (GUPTA and NAIR, 2012). From this approach, we can propose an early warning system, preparedness and mitigation strategies to cope with natual threats and human induced activities, by combining sustainable ecosystems with over-all-landuse planning and management for the Karst area in particular, starting from local knowledge keen observation or *ilmu titen* of seasonal changes coupled with physical features changes.

LASCO and BOER (2006) conducted an assessment on watershed areas in the Philippines and Indonesia based on landuse and climatic condition. The study described vulnerabilities and community capacity building to reduce the impact of climate change. Vulnerability in Karst Gunungkidul is related to socio-economic factors. The success story of IWRM in Karst Gunungkidul is determined by complex mutual relations between multiple sectors.

5.3.6. Water Management Characteristics in Gunungkidul Regency

Gunungkidul water management needs to follow the hydrology, geomorphology and relief characteristics. There are three different (ground) water zones which determine water availability and the supply zone, namely Baturagung range, Wonosari Plateau, and Karst region. Water supply zones in Gunungkidul are mainly located in the Karst region. In the Karst region itself, geological study revealed that there are three different gravitational groundwater system. Hydrological Sub-System (SSH) Panggang, SSH Wonosari Baron, and SSH Sadeng (KUSUMAYUDHA, 2005). Figure 5.15 shows springs in Sadeng coast (SSH Sadeng) which pump-up and distribute water to other Karst regions in the Southern part of Gunungkidul, mainly nearby villages. Underground water exploration is regulated, by Gunungkidul Regency regulation number 17 in 2012. However, it is the local government which then determines the application of the regional government law. In Purwodadi vilage, the head of the village issued a regulation that any private mobile water tank exploiting the village's water sources, must contribute a share of profit and cease operation when the Purwodadi villagers suffer severe water shortage (FGD and Indepth interview, 2012).

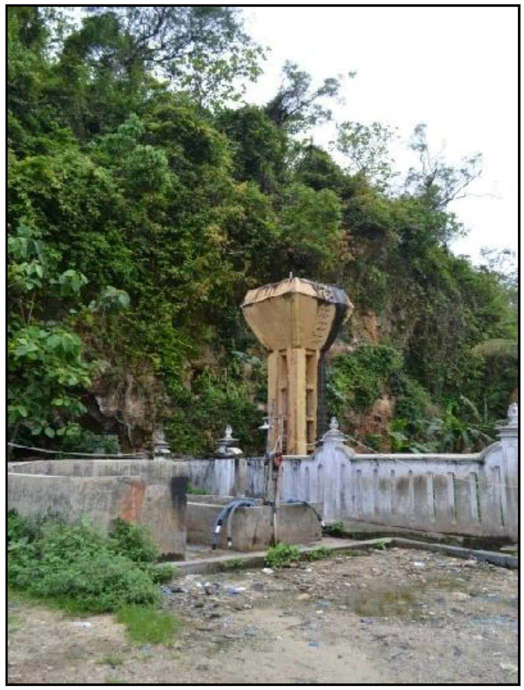


Figure 5.15. Water Sources for Water Tank Pumping in Sadeng coast (Author, 2013)

Gunungkidul's regional water company, known as PDAM *Tirta Handayani*, has installed several main water pipes in strategic locations (see Table 5.1). The PDAM water pipe in Gunungkidul Regency was installed more than 20 years ago and needs to be renewed due to its usage-limitation age. The piping network relies on gravitational methods to distribute the water and is divided into several zones of water tanks, with result of lack of water to the customers taps (FGDs and indepth interview 2012, 2013).

Tabel 5.1. Tap Water Infrastructure Location in Gunungkidul Regency

Location	Source capacity (L/sec)	Pumping capacity (L/sec)	System capacity (L/sec)	Distribution system	Number of installed	
					SR	**HU**
1. Panggang - Banyumeneng - Giritirto	15	10	4	Pumping	433	7
2. Paliyan	10	6	3.8	Pumping	835	
3. Saptosari - Ngobaran - R (I) - R (II) - R (III) - R (IV) - BP (7)	180	80	46	Pumping	6.322	155
4. Tepus - Wilayu I - Wilayu II	9	7.5	6	Pumping	254	26

Location	Source capacity (L/sec)	Pumping capacity (L/sec)	System capacity (L/sec)	Distribution system	Number of installed	
					SR	HU
- Hargosari						
5. Baron				Pumping		
- Rejosari	800	30	20		894	57
- Kemadang						
6. Rongkop				Pumping		
- Saban	6	7.5	5		839	6
- Sawahan						
- Songbanyu						
- Pucung	10	7.5	3.5			
- Trayu	8	7.5	3.5			
7. Semanu				Pumping		
- Munggi						
- Gunungsari						
- Seropan	950	150	90		8.920	145
Bribin						
- R (I)	759	80	65		5.960	417
- R (III)						
- BP (I)						
- BP (II)						
- BP (III)						
- BP (IV)						
8. Ponjong/Payak Trengguno	8	7.5	5.5	Pumping	329	
9. Karangmojo/Branjang				Pumping		
- Grogol	4	5	3.7		211	
10. Wonosari				Pumping		
- Hargobinangun	60	50	33		6.996	87
- Ngembel	70	1				
- Gelung	20	75	5			
- Tawarsari	25	22	17.5			
- Gempur	28	20	16			
- Siyono	20	20	15			
11. Playen				Pumping		
- Tompak	6	5	1		932	6
- Gading	10	5	3			
- Bunder						
- Ngleri	5	5	5			
12. Nglipar	15	15	7.5			

Source: Draft of Sanitation (Draft Buku Putih Sanitasi), Gunungkidul Regency 2010

The social department through their representatives in Yogyakarta Province and Gunungkidul Regency are also involved in water issues, mainly during the dry season, distributing water using mobile water tanks and giving financial or non-financial aid to manage water shortage, for example by building rain water tanks (see Table 5.2).

Table 5.2. Rain Water Project in Gunungkidul built by Social Office (*Dinas Sosial*)

Year	Sub District	Village	Unit
2004	Ponjong	Kenteng	11
2005	Panggang	Girikarto	10
	Tanjungsari	Banjarharjo	10
	Tepus	Purwodadi	10
	Rongkop	Bohol	10
	Girisubo	Nglindur	10
2006	Paliyan	Karangasem	8
		Mulusan	7
		Giring	8
		Grogol	7
	Saptosari	Ngloro	10
		Krambilsawit	10
		Monggol	10
	Purwosari	Giriasih	10
2007	Ponjong	Tambakromo	8
		Sawahan	7
	Purwosari	Giriasih	10
		Giritirto	10
		Giricahyo	10
		Giripurwo	10
2007	Gedangsari	Sampang	7
		Watugajah	8
	Patuk	Ngoro-oro	10
		Terbah	10
		Nglanggeran	10
		Patuk	10
	Panggang	Girikerto	10
	Ngawen	Kampung	6

Source: Dinas Sosial (Social department)Yogyakarta, 2007

The major challenge of access to safe water in dry season is the most common hazard in Gunungkidul Regency, particularly in the Southern part located on Karst systems. A study on the water supply plan was conducted in 1984 by MacDonalds and Partners. They visualized the network of water supply to optimize local water resources. The variety of water sources used is a way to broaden accessibility for economically poor people in the rural water management area. Potential water resources in Gunungkidul come from: (1) springs water in the Karst region, (2) cave water, (3) doline ponds, (3) rain harvesting tank, (4) perched aquifer only in certain location (see Figure 5.16), and (5) irrigation in Gunungkidul only available in the Baturagung range and Wonosari Plateau. The exploration of caves for rural water supplies have also recommended by WALTHAM, SMART, FRIEDRICH, and ATKINSON (1985).

Figure 5.16. Used to be a perched aquifer water source (the arrow indicate rain water surface run-off flows to the point source) (Author, 2013)

MACDONALDS and PARTNERS' study (1984) had taken into consideration the cultural landscape of water resources and space occupation in the Gunungkidul Karstic area, thus they proposed that variation of water utilization not only depends on the tap piping system but also requires improving doline ponds and the rainwater harvesting system. The Gunung Sewu Integrated Rural Water Supply Plan (see Figure 5.17) combined a mix of sources and technologies initated and proposed by MACDONALDS and PARTNERS (1984), and confirmed by LUKAS and STEINHILPER (2005), as suitable for managing water in Karst Gunung Sewu, particularly Gunungkidul Regency. The mix includes pumping stations tapping underground rivers and remote springs; improved cisterns or PAH (rain harvesting tanks), rehabilitated doline ponds or *Telagas* (following the characteristics of Karst drainage system) and additional water tankers when needed.

Participants in the focus group discussions and indepth interviews (Author, 2012 and 2013) agreed that the mix of water sources represented adaptative behavior by people in Karst Gunungkidul as a coping mechanism to uncertain water availability during dry season. Innovation or technology should not create dependency on only one resource, but rather should enhance an individuals or community's ability to cope with uncertain phenomenon by capacity building to enhance the access to water resources in Karst regions.

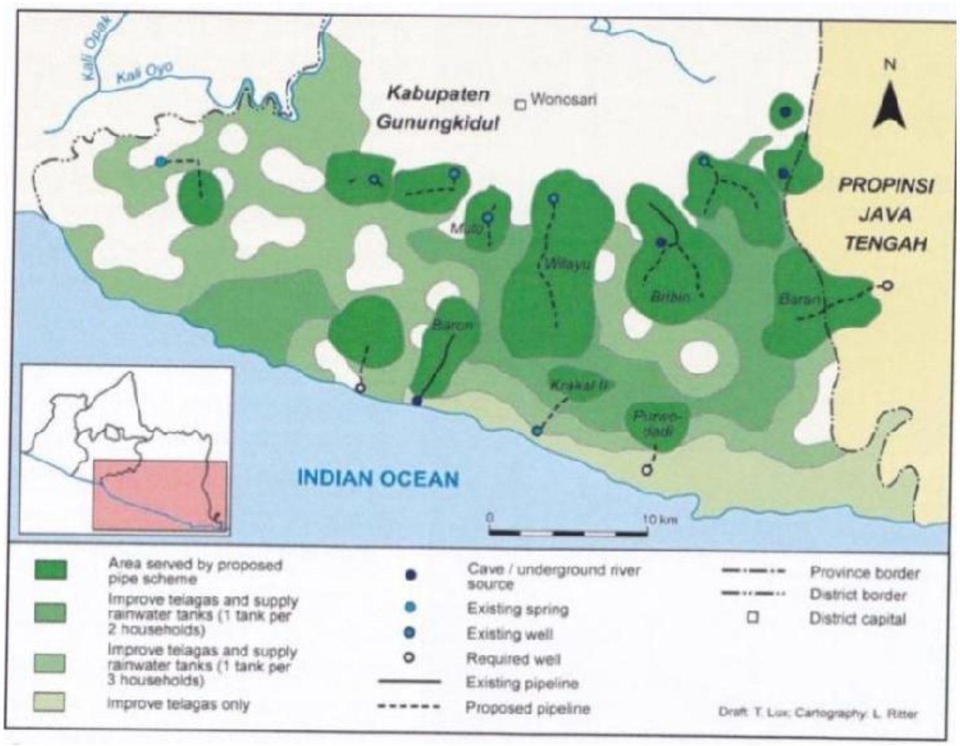


Figure 5.17. Gunung Sewu Integrated Rural Water Supply Plan (GSIRWSP) proposed by MACDONALDS and PARTNERS (1984) in LUKAS and STEINHILPER (2005:101)

Accessibility to water resources is difficult, meanwhile local institutions lack water management capability. Figure 5.18 shows potential springs which have been used to pump-up water without enhancing distribution. Springs occur some distance from settlement without good road access, which is different to doline ponds. Due to gravity flow and fluidity, coupled with geographical features of Karst Gunungkidul, mechanical challenges are unavoidable in lifting underground water vertically. People used to get water manually using traditional vessels to overcome such problem. Human modify water's availability and how it influences human decision making and organization. Thus, in this study local water management is a set of technical adaptations to landscape or environment that can be measured and evaluated empirically, lending scientific method and associated rigor to cross cultural comparison.

Figure 5.18. Springs in Wotunggal, Tepus (Author, 2010)

Characteristics of water resources and infrastructures in Gunungkidul mainly as follows:

1. Water supply and demand characteristics

Minimum daily domestic water needs in Karst Gunungkidul are about 100lt/day/person (KUSUMAYUDHA, 2005:3) for many activities, including owning cars or motor cycles and livestock. SUDARMADJI, SUPRAYOGI, and SETIADI (2012) conducted a survey in 2010 with 90 respondents representing Gunungkidul people and concluded that water demand for each person is 6.89 lt/capita/day. UNESCO in 2002 stated that the basic needs of water per person is 60lt/day, which then adapted by Indonesian Enactments *Undang-undang* number 7 in 2004, Home Affairs Ministry Decree number 23 in 2006, and the Ministerial of Public Works which differentiated water needs by region (rural to metropolis).

In Indonesia, only about 9 million people are connected to 400 PDAMs throughout the country based on data from Indonesian Water Supply Association (*Perpamsi*). The network covers only 42% of Indonesia's urban area and 11% of rural areas. Water tap rates vary from one location (region) to another. Water management is defined as society's interruption and redirection of the natural movement or collection of water, by having ponds, canals, wells and rain water tanks (cisterns), which allow us to determine, assess, and evaluate individual or communal landuse practices and behaviors (SCARBOROUGH, 2003:39; Author fieldwork 2012, 2013). In 2007, only 43.8% of Gunungkidul people have received water from PDAM *Tirta Handayani*. Table 5.3. describes the Water System throughout Gunungkidul Regency. The villages which are served or not served by the PDAM piping network is shown in Table 5.4. The villages which are not served suffer geographical conditions considered too difficult to reach by gravitational methods and would likely cost too much to extend the piping network installation. Map 5.5. shows the network stations distribution of tap water by PDAM (2006/2007) in adaptation to MACDONALDS and PARTNERS' (1984) research. The difficulties arise from topographical features affecting the water flows that force the company to shift distribution to villages.

Tabel 5.3. Service Distribution of PDAM Gunungkidul 2007

No	Sub System Working Unit (Location)	In the Sub-district	In the Village	In the hamlet	Type of Installed Customer Unit					installed SR	Total installed unit	Served (Persons)
					RT	Inst	Niaga	Soc	HU			
1	Wonosari	2	10	78	6202	102	116	168	95	6588	6683	63112
2	**Seropan**	6	36	219	7803	48	13	283	85	8147	8232	72193
3	**Bribin**	5	26	249	5869	12	1	76	411	5958	6369	80739
4	**Paliyan**	1	3	15	808	14	0	13	0	835	835	6198
5	**Ponjong**	1	2	9	339	3	0	16	2	358	360	3184
6	Karangmojo	1	1	5	203	0	0	3	4	206	210	1768
7	Playen	1	7	28	747	7	0	24	13	778	791	7332
8	**Baron**	2	4	32	779	5	14	19	57	817	874	11924
9	**Tepus**	1	6	17	242	8	0	4	26	254	280	4652
10	**Rongkop**	1	10	41	545	4	1	9	73	559	632	11245
11	Nglipar	1	5	13	554	8	5	18	7	585	592	5449
12	**Panggang**	2	3	13	440	0	0	7	7	447	454	3690
13	**Ngobaran**	5	21	142	6232	31	2	102	155	6367	6522	59592
Total		29	134	861	30763	242	152	742	935	31899	32834	331078

Source : PDAM Gunungkidul, 2007

Water demand during the dry and rainy seasons shows no reliable recorded data, but respondents confirmed that they have no difficulties with water supply quantity, but do experience poor water quality due to sedimentation

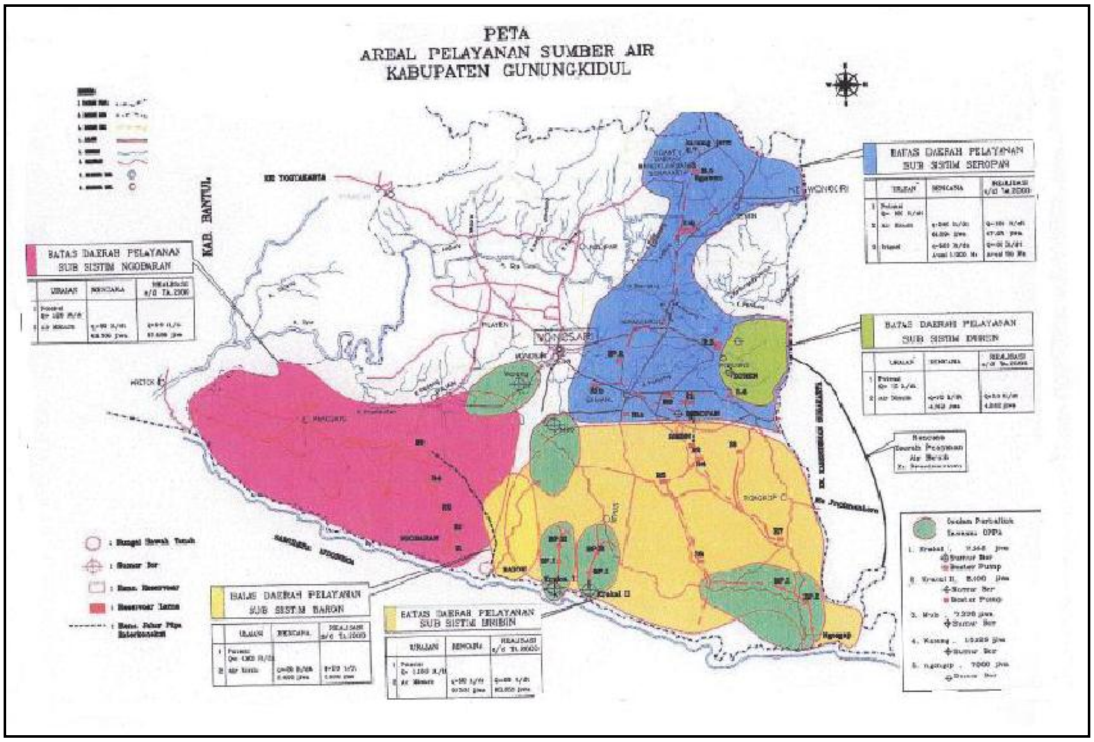
(FGDs, Interview in 2012, 2013). People use their rain water tank during both the dry and rainy season. However, during the dry season the water tank is used to keep the water they buy from private mobile water tankers. Therefore, nowadays people put their rain water tank (cistern) close to transportation access, where previously it stood near the kitchen at the back of the house.

Tabel 5.4. Villages cover by PDAM piping network

No	Kecamatan	Served villages	Un-served villages
1	Gedang Sari	0	7
2	Girisubo	8	0
3	Karangmojo	9	0
4	Ngawen	6	0
5	Nglipar	4	3
6	Paliyan	6	1
7	Panggang	6	0
8	Patuk	3	8
9	Playen	4	9
10	Ponjong	9	2
11	Purwosari	5	0
12	Rongkop	8	0
13	Saptosari	7	0
14	Semanu	5	0
15	Semin	10	0
16	Tanjungsari	5	0
17	Tepus	5	0
18	Wonosari	11	3
	Jumlah	101	43

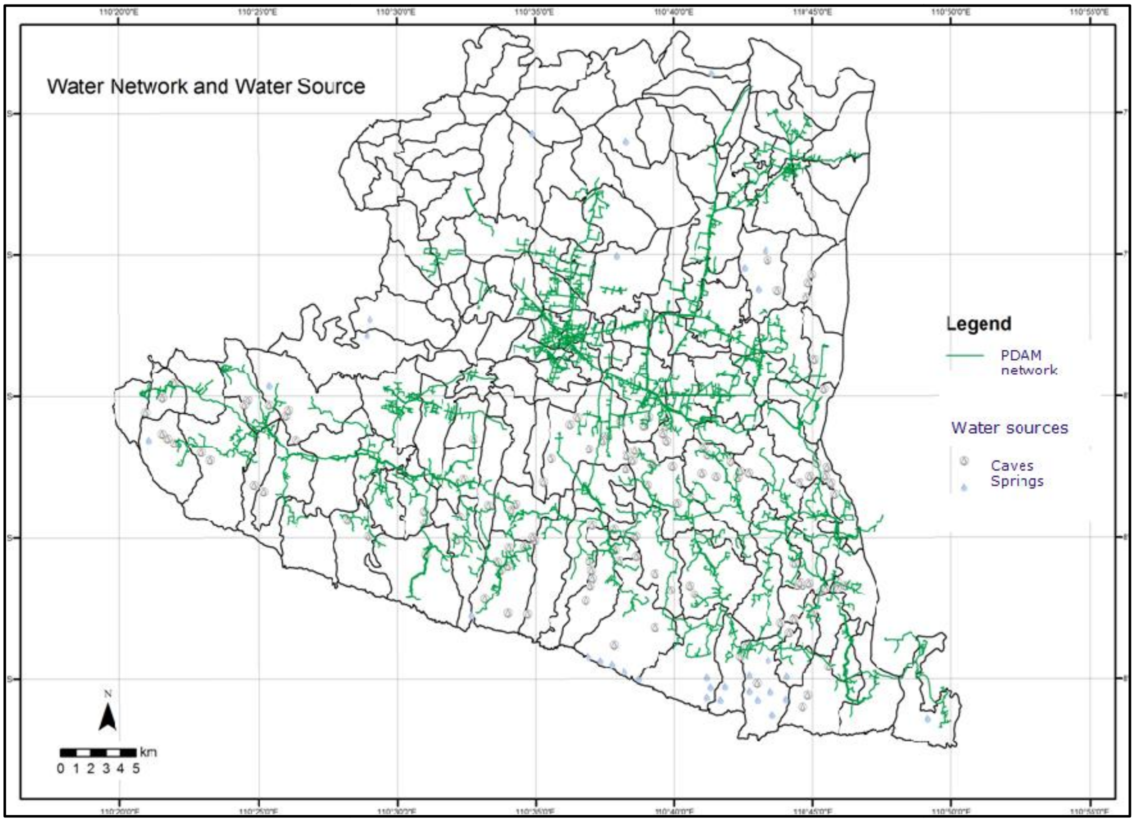
Source : PDAM Gunungkidul (2007)

According to Bappeda Gunungkidul (1991) in KUSUMAYUDHA (2005:137), the amount of groundwater discharge in Gunung Sewu, from boreholes and groundwater rivers is around 50 million m^3/year. The amount is only 26% of the total amount of 190 million m^3/year. Theoretically, the amount should be enough to support water needs in Gunungkidul Regency. SUNKAR (2008:116) described water sources for different utilization per villages. Rain water tanks (cisterns) are still favoured during the rainy season and mobile private water tanks during dry season, as mentioned also by LUX (2004) and confirmed by the author's field survey (2012, 2103).

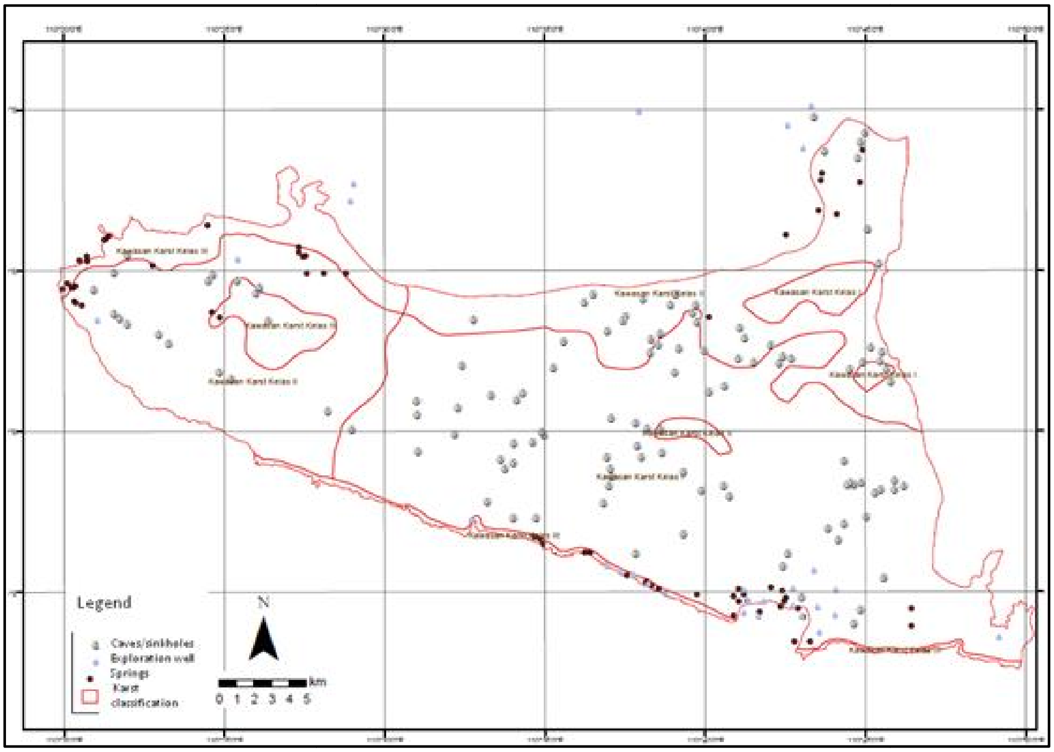


Map 5.5. Water Pipe Station Distribution by Drinking Water Regional Company (PDAM, 2006, 2012)

The Environmental Impact Management Agency (*Kapedal*) in Gunungkidul Regency has issued a map of ponds and a map of caves and springs together with PDAM network, which then collaborated into Gunungkidul Regency Spatial plan (see Map 5.6 - Map 5.7). Short period ponds become indicators of a decreasing hydrologic system on a water basin system due to sedimentation processes, and erosion in upper locations. Conservation culture and efficiency of water consumption to cope with an increasingly uncertain environment and climate factors changes are challenging nowadays. Water use efficiency for Karst's people in Gunungkidul have met with historical difficulties due to limited availability. Since communication technology was introduced to the people, accessibility along with good transportation for those who live in quite remote settlements has made access to private water tanks possible (In-depth interview 2012, 2013).



Map 5.6. Lake Ponds (doline) within PDAM (water network) in Gunungkidul Regency (source: Gunungkidul Regency Spatial Plan 2010-2030, IWRM Gunungkidul Project 2008-2013 and Author draft 2014)



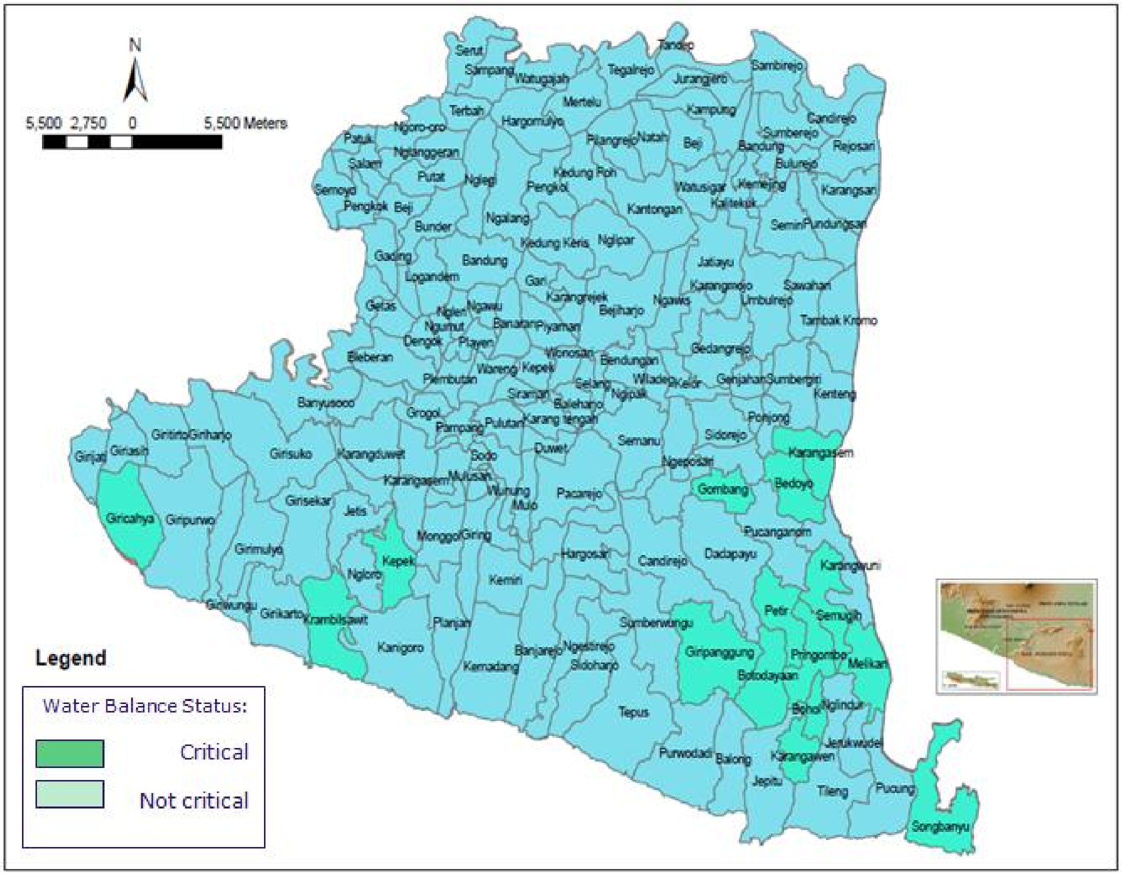
Map 5.7. Springs (see dark dots) and Caves/sinkholes (water drip symbol) in Karst Gunungkidul (source: Gunungkidul Regency Spatial Plan 2010 - 2030, Author draft 2014)

There are around 288 shallow and small surface water lakes between the conical hills Karst Gunungkidul, however only 38 of these *Telagas* are perennial. Regional Panning office (*Bappeda*) and the Environmental office (*Kapedal*) have listed dried-up ponds in Karst Gunungkidul with the possibility of increasing numbers (see Table 5.5).

Table 5.5. Dried Ponds in Gunungkidul

Kecamatan	Number of Ponds	Dried
Purwosari	31	19
Panggang	22	12
Tepus	32	29
Tanjungsari	27	26
Semanu	42	37
Ponjong	21	14
Rongkop	49	36
Girisubo	27	22
Saptosari	21	15
Paliyan	10	7
Total	282	217

Source: Bappeda Kabupaten Gunungkidul, 2012

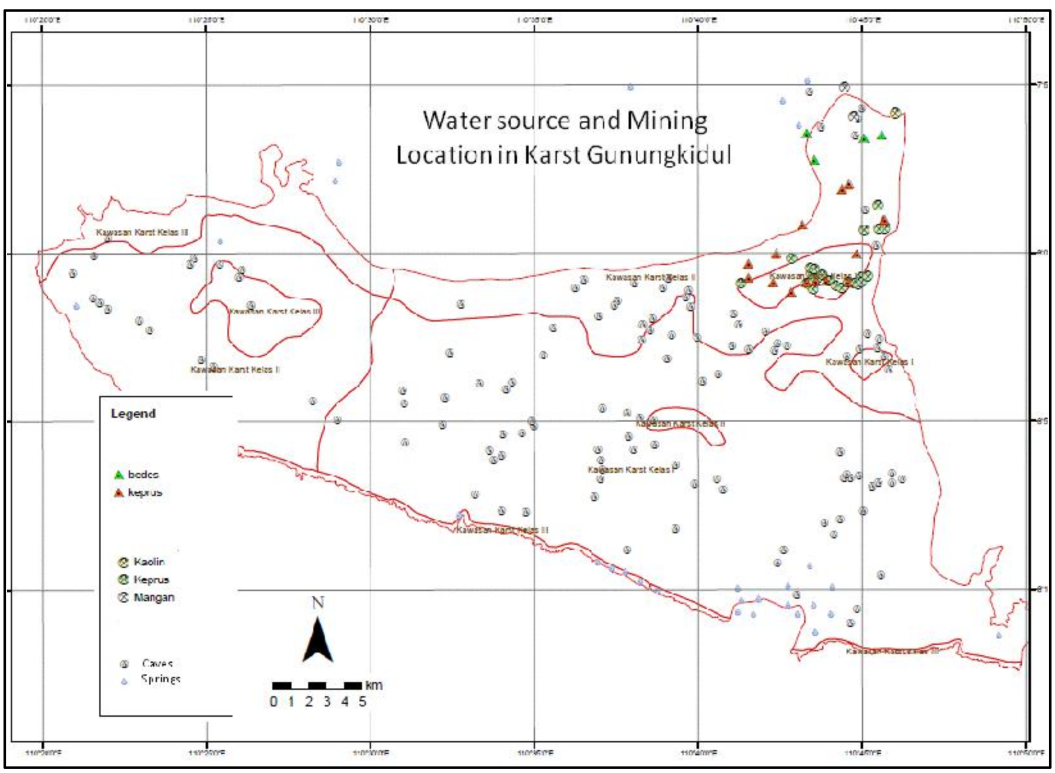


Map 5.8. Water Balance Budget in Gunungkidul Regency
(Source: *Kapedal* Gunungkidul 2007, IWRM Gunungkidul Project 2008-2013, Author draft 2014)

The authorized institution on water management in Gunungkidul Regency has calculated and forecast water supply and consumption from several potential water sources. Potential static groundwater in the sub-district from unconfined and confined aquifers was still enough for domestic needs in 2007, 2010, and 2015 (see Map 5.8), with no anomaly from extreme weather occurrences assummed. The bureau calculated a water availability from rain harvesting of 50 m^2 from rooftops for domestic needs in all sub-districts up to 2015 will be in deficit if no back-up supply available. Water pumping from groundwater, springs and short period ponds in some sub-districts could meet water demand for themselves and possibly back-up other sub-districts. This follows the idea of mixxed method water supply by MACDONALD and

PARTNERS (1984) which still the baseline reference of water management in Gunungkidul Regency and Yogyakarta Special Province.

Mining water, using aquifers as underground storage basins in Karst terrain feature (doline, polyje, etc.) during the wet season, is analogous to using underground water cisterns or artificial aquifer. It requires such sophisticated engineering methods which are unlikely and not easy for a rural Karst area in Gunungkidul Regency. It has been of high concern that the Karst area has been mined for carbonate rocks for a decade because these activities tend to fail safe environmental regulation standards. Meanwhile, Karst Gunungkidul as part of Gunung Sewu has been proposed as a World Heritage and Geopark to UNESCO. The hydrological function of Karst Gunungkidul have mapped. Map 5.8 shows water sources distribution and the location of some identified Karst mining. It has not been any record of the influence of Karst mining on water discharge, however the study of HARYONO (2000), and ADJI and SUDARMADJI (2008) support the importance of Karst hydrological functions in correlation and application of ecosystem services.



Map 5.9. Water sources distribution and mining location on Karst Gunungkidul (Source: Gunungkidul Regency Spatial Plan 2010-2030, Author draft 2014)

2. Institutional (policy) on spatial plan and water management

The role of local institutions in adaptation to climate variability and environment changes (AGRAWAL, 2008) is important because it is local people who suffer adverse impact. Climate effects on Karstic region processes like dissolution lead to appropriate policy and planning only when multiple institutions understanding their capacity. In accordance with payment for Hydrological Ecosystem Services, people are willing to pay water tariffs as long as they have water supply regularly. Some cases reveal that individuals who can access water using household connections (*Sambungan Rumah*/SR) get to the point where they feel reluctant to share their resources with their neighbors although they will pay the cost.

The annual expenditure of Gunungkidul Regency on providing water to villages prone to water shortage is increasing every year, for example from 2012 - 2014. The increasing expenditure raises question, whether the water and environmental management is inefficient or if landscape changes have boosted water shortage occurrences in an annual event in an area already affected by climatic factors.

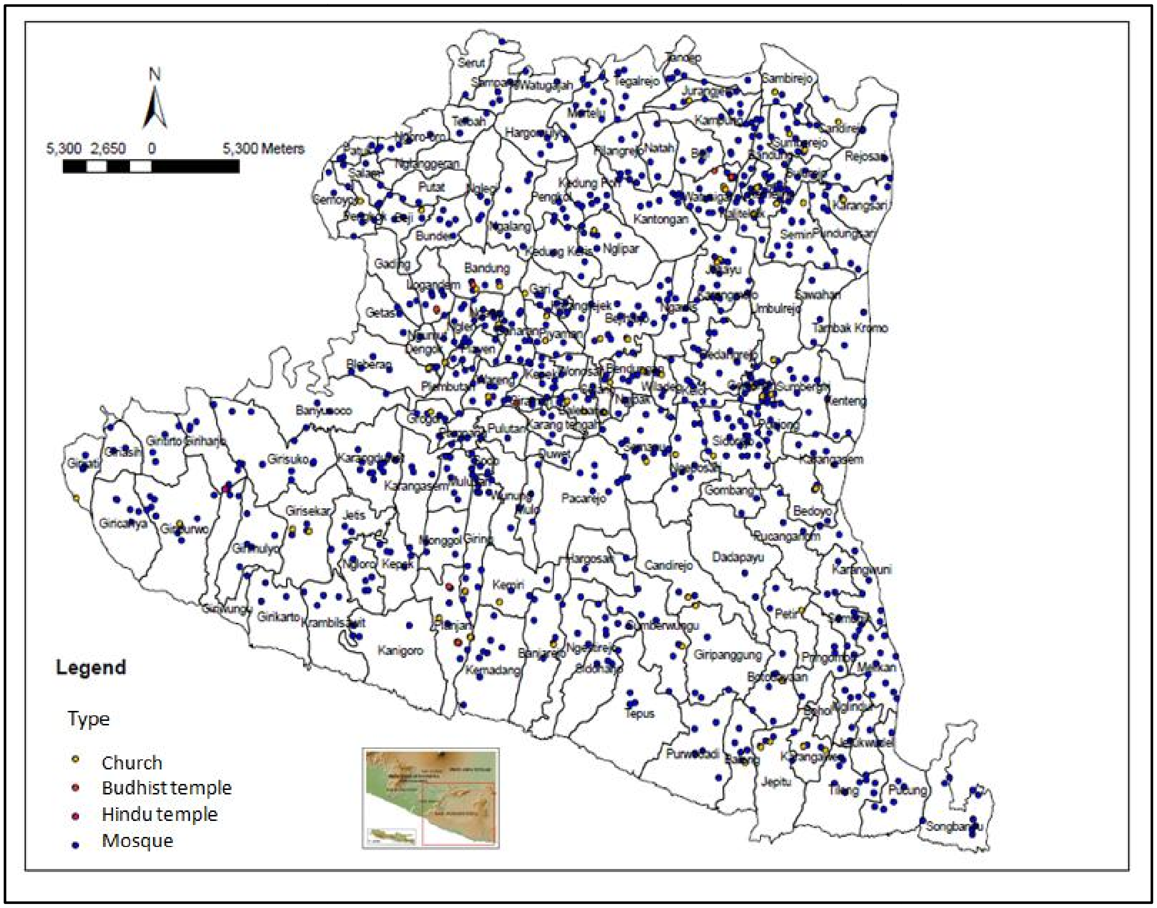
Law enforcement requires explicit actions in specific regions regarding environmental destruction due to certain activities as a result of spatial planning deviation, i.e. mining and quarrying, excessive water pumping and land conversion. Karst Gunung Sewu, a potential listing as the World Karst Heritage, requires "scientific" study and regulation to protect, conserve and reduce the risk of environmental destruction due to land or space utilization. The essence of spatial planning regulation, environmental laws, and other related development planning have cross cutting issues. Sectoral institutions have different point of views and approaches which should be developed into comprehensive knowledge management for regional development planning. The deputy head of the Gunungkidul Regional Company of Drinking Water (PDAM) said that the mining and quarrying activities so far had not yet affected the water sources PDAM managed, but believe that the activities would eventually affect water discharge supply in the future. Springs are one of water sources that some communities might lose due to intensive mining or quarrying. No recorded data is available yet, only the communitites' awareness that during dry season the water discharge decreases (Indepth interview, 2012, 2013).

Water infrastructure and other supporting infrastructure for rural Karst communities needs to consider that unique Karst environments are dynamic, not static. Regulations which are adapted to Karst environment are needed for water management and space utilization. Gunungkidul institutions have been advised to take good care of the Karst hills and turn them into tourist attractions and educational services, which would be more sustainable and profitable, as learnt from Karst regions in China and USA. It demonstrates how one sectoral planning activity may affect the sustainability of other sectors, which leads to environmental disturbance and increases people´s risk. The ecological politic from government institutions are represented on the policies implemented. The spatial plan of Gunungkidul Regency 2010-2030 covers the Karst ecosystem, water related subjects and land use.

A poor water management system coupled with climate change and human induced deterioration will extend the decline of the water system affecting future water reservoirs. Water management systems in Indonesia regulate and operate from a national level to regional level. Implementation is the responsibility of the regency government through PDAM. Water value in Indonesia is stated in the *Water Law 2004* that stated water has social, environmental and economic value. Literally, nobody owns water, anyone might take benefit from water resources, but must also take responsibility for the effect of using that water. PDAM takes responsibility for public drinking water at household level and the regional government establishes the regulation. The Environmental Impact Management Agency (*Kapedal*) takes part in assessment, monitoring and evaluation of water resources, and pollution occurring by water use or consumption, besides other environmental issues occurring at the regional level. The Regional Planning and Development Board (*Bappeda*) manages coordinating planning and programs between multiple institutions, including water and land institutions. The role of multi actors in regional development Gunungkidul's Regency, includes water and land issues, that have been explored in HOSSU (2013).

Governmental and non-governmental institutions have worked hand in hand and on cross-cutting issues to manage Gunungkidul's development.

The vital value of water to Karst Gunungkidul people is undeniable important. It determines their livelihood and for majority of the people water correlate to their religious ritual. Map 5.10 shows the distribution of mosques that need to provide water to support ablution activities called *Wudhu* for muslim people before praying, five times in a day. Other religions embraced by people in Indonesia, namely Christianity, Hinduism, and Budhism also use water in ceremonial or ritual activity. The majority of people in Gunungkidul regency are moslem (90%), but they have already adapted to the limited water availability during the dry season without neglecting the obligation of the religion. According to the Moslem people, they are allowed not to use water under certain circumstances. Besides religious buildings, other public infrastructure which require water supply, such as hospitals, community health centres (*Puskesmas*) and schools, require the government institutions to consider the distribution of that water supply. People have adjusted to annual seasonal changes to meet their daily need of water for domestic and religious use.



Map 5.10. Location of Religion Buildings

(source: Gunungkidul Regency Spatial Plan 2010 -2030, Author draft 2014)

3. Community and individual (households) water management

Community engagement on water resources management in Karst Gunungkidul needs to be carried out from regional to local scale and take into account the utilities and priorities for each community. Rural communities which rely on agriculture for their livelihood have developed the ability to recognize the pattern of climatic conditions which support their life system (YOSHINO and YOSHINO, 2009). The relationship between humana and the environment changes in adaptation to climate and environment variability cycles. Rural Karst communities and households in Gunungkidul have been optimizing their inherited knowledge and evolved their knowledge by continuous observation, learning and experiencing the changes, which imprint their understanding and behavior on water and land management. This cultural behavior adaptation helps them to reduce the risk of severe disaster that might occur, for example installing rain water tanks (cisterns) individually or communally (see Figure 5.20). Communal water tanks are usually utilized during the dry season to collect and distribute water aid delivered by the regional government or other volunteers. The relationship among people during water crises is interesting to analyze in terms of managing the possibility of conflict.

Figure 5.19. Communal Water Tank in Purwosari (Author, 2013)

The seasonally based calendar being practiced by rural Karst Gunung Sewu communities, is proof that some communities adapting to annual climate variation in the Karst environment, mainly for agriculture. However, people have understood that in certain months they will face water scarcity based on their inherited knowledge and their experiences, usually from May in the Gregorian calendar or *Mangsa Mareng-Terang* in *Pranata Mangsa* calendar. Karst Gunungkidul communities in some locations have developed local institutions to manage water resources from their surrounding area to tackle water scarcity.

5.3.6.1. Community based Water Management Optimizing Ground River, Springs and Caves Water Sources

Community based water management reflects cultural behavior adaptation and a good inter-relation between community elements. Local institutions for community-based water supply management are called SIPAS (*Sistem Perpipaan Air Minum Sederhana*). A simple water tapping system, has been practiced in several locations around Gunungkidul regency, namely:

1) SIPAS Serut, Gedangsari sub-district.
2) SIPAS Ngalang, Gedangsari sub-district.
3) SIPAS Sumber Cermo Tegalrejo, Gedangsari sub-district.
4) SIPAS Patuk, Patuk sub-district.
5) SIPAS Sumber Bendo Nglanggeran, Patuk sub-district.
6) SIPAS Beji, Ngawen sub-district.
7) SIPAS Giriharjo, Panggang sub-district.
8) SIPAS Jepitu, Girisubo sub-district.
9) SIPAS Sumber Playen, Playen sub-district.
10) SIPAS Ngunut, Playen sub-district.
11) SIPAS Dengok, Playen sub-district.
12) SIPAS of boreholes water source in Bulak Mulo, Wonosari sub-district.
13) SIPAS Sumber Ngleses Banjarejo, Tanjungsari sub-district.
14) SIPAS Pacarejo, Semanu sub-district.
15) SIPAS Sawahan, Ponjong sub-district.
16) Self supported systems of fresh water infrastructure (*Sarana Air Bersih*/SAB) in Bleberan, Playen sub-district.
17) Self supported systems of fresh water infrastructure (SAB) in Goa Plawan, Giriasih, Purwosari sub-district.
18) Village water supply system (*Sistem Penyediaan Air Minum Perdesaan*/SPAMDes) in Semin sub-district.

There are three SPAMDes which have been built by utilizing in-situ source. One of them is located in Karangsari village with 10 liter/sec capacity, capable of supplying 10,000 persons, or 800 to 1,000 household connection or *Sambungan Rumah* (SR) reaching to Rejosari and Pundungsari village. However, only 430 households received the water supply. The rest still need to wait for another piping network deploying Pakel's in-situ water source. Households which have received water supply are obliged to pay IDR[10] 3,500/month for 11-20 m^3, IDR 4,000/month for 21-30 m^3. SPAMDes development utilized Provence's Revenue and Expenditure Budget (*Anggaran Pendapatan dan Belanja Daerah/*APBD), Regency's APBD, in coordination with Directorate General of Human Settlements of the Ministry of Public Works (*Direktorat Jenderal Cipta Karya Kementrian Pekerjaan Umum*) for infrastructure construction. SPAMDes is managed by local communities at sub-district level. The challenge arises when the fuel price is increasing because the operational machine is using 15 litres of diesel per hour.

The Head of Purwodadi village in Tepus sub-district published village ordinance to regulate and control their water sources, namely Mendolo and Bundel, which are pumped up and distributed by private mobile water tank owners. The village government asked them to sign an agreement on the water pricing when the tank owners distribute the water to Purwodadi villagers which should be different from other villages. The regulation is *Peraturan Desa* number 3 issued in 2007. Water pricing is determined by the distance and accessibility to reach the location where the villagers live.

5.3.6.2. Community Based Water Management Optimizing Sea Water Desalinization

A Reverse osmosis (RO) Seawater System was established in Drini coast sub-district Tanjungsari and Gesing coast sub-district Panggang. In Bolang hamlet, Girikarto village, sub-district Panggang, the community based water supply is known as *Poksambal Tirto Mulyo* and in Drini coast called *Poksambal Tirto Samudro*. The generator machine in Girikarto village can produce desalinized water up to 600 lt/hr (see Figure 5.20). Challenges lie with the fuel cost to operate the machine which faces unequal production

[10] US $ 1 = IDR 12,000

costs without governmental subsidy and on the marketing related to transportation and packaging material (FGDs, 2012).

Figure 5.20. Desalinization Unit in Bolang hamlet, Girikarto village, sub-district Panggang[11]

Water cooperation among community is one thing related to the awareness that they live in a harsh Karst area particularly during the dry season. Conflict does emerge when equality of water accessibility does not meet individual need. Conflicts over water are resolved by values and beliefs among community but still suffer from the resource's limited availability (FGDs 2012, 2013). Water users are already practizing communal water management by applying their own rules and traditions, unless an incident occur which is unacceptable. Community based water and land resources management are crucial to local livelihood within seasonal changes uncertainty and susceptible environment to vulnerable household who have limited access to resources.

5.3.7. Lesson Learnt of Water Management from Subak System in Bali

One lesson learnt of water management based on community and their cultural behavior is *Subak* in Bali. *Subak* has been a central pillar of Balinese traditional society and culture and part of their identity as agricultural

[11] Water from desalinization process is hoped to be consumed for institutional (office) supply to support the community water management, due to marketing and operational cost challenges, http://jogja.tribunnews.com/2012/07/06/seaqua-segera-jadi-air-wajib-di-kantor-pemkab-gunungkidul/, accessed on 6th April 2014

communities. Balinese farmers succeeded in creating an efficient and ecologically sustainable rice-growing culture and also in producing one of the most esthetic bodies of art and culture in the world. *Subak* is a system of water sharing to farms, with local farmers making up the membership of the *Subak* organization. The system was developed more than 1,000 years ago and has become a vital Balinese agricultural system. It involves the wisdom of the Balinese concept *Tri Hita Karana* philosophy (see Figure 5.21) on the relationship between humans, the Earth and the Gods, as the heart of the traditional ecologically sustainable irrigation system. However, the *Subak* system is facing challenges, as land conversion from agriculture to other utilities increases unabated. The paddy fields cultivated with the *Subak* system are disappearing as housing and tourism development continous.

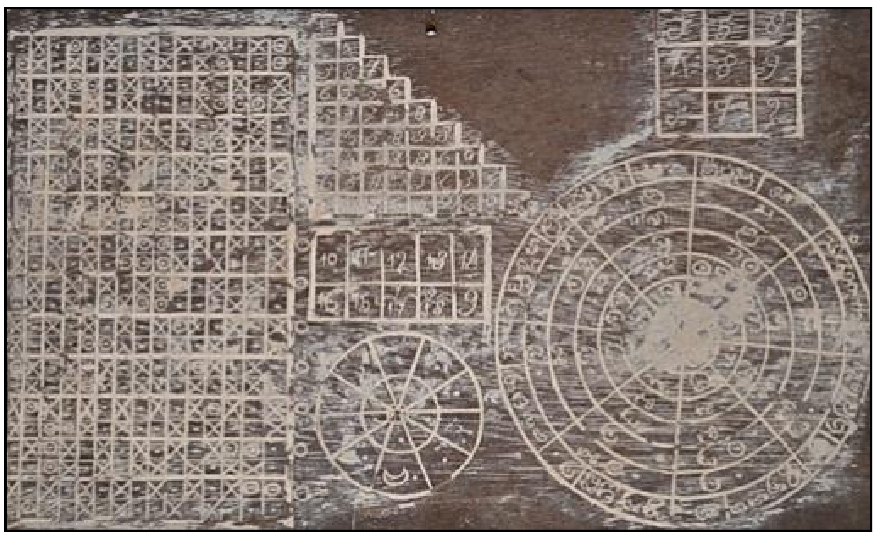


Figure 5.21. The *Tika* is an ancient mathematical system of discovering auspicious rice planting days in Bali (the Jakarta Post, 2013)

A *Subak* museum was established to preserve Bali's heritage in 1981. Some farmers in Tabanan still apply the system and stated that the system is still strong because they have traditional law *awig awig* and the agreement of the villages to protect 187 hectares of their rice fields which inherited from their ancestors. The Bali Legislative Council has prepared a bylaw to ensure the conservation and protection of the *Subak* system. The *Subak* system has also been recognized as one of World Cultural Landscape Heritage by UNESCO (see Figure 5.22). Irrigation water management by community organizations on Bali has proven to be effective, efficient and durable.

Figure 5.22. *Subak* system has been recognized as one of World Cultural Landscape Heritage by UNESCO (Source: UNESCO's photos)

5.4. Integrated Water Resources Management Coupling with Integrated Water and Land Management

Land and Water integration is an ecological based approach in this study using seasonal based local knowledge, initiated as knowledge to develop management tools in water and land management, in accordance with hydrosolidarity through Integrated Management (FALKENMARK and ROCKSTROM, 2005:219). Human rights, fairness, equity and equality principles explicitly described on seasonl calendar *Pranata Mangsa* are in line with the term hydro-solidarity, but need to consider the nature of rights, water and land rights exemplified. The geographical and social environment of water and land characterized by rural individual households and communities in Gunungkidul Kart region requires thoroughly understanding of the development of water and land related issues, such as the green and blue revolution and green and blue water.

5.4.1. The Green Revolution and Blue Revolution

The green revolution arose between 1940 - 1970s. Indonesia adopted the green revolution by boosting up the rice yield, introducing new varieties resistant to disease and short time cultivation with less water consumption developed by International Rice Research Institute (IRRI). IR 8 and IR 64 are the most common and popular cultivated paddy throughout the Indonesian islands, up to recent years. However the government was also boosting chemical fertilizer use which has adversely impacted upon soil properties (In-depth interview, 2013). Indonesia's rice consumption in 2010 was more than 139 kilograms per capita per year and is among the highest in the world[12]. This fact is related to an inherited governmental program since New Era (*Orde Baru*), under President Suharto, which made rice the main staple food throughout Indonesia. Certain physical landscape in Indonesia are not suitable for growing paddy, and local people have adapted their diet to location with crops like corn, cassava and millet or some combination of these. A socio-cultural change has occurred in correlation with government programs since then.

The green revolution was followed by a blue revolution, the water equivalent of the green revolution. It primarily refers to the management of water resources that can steer humanity towards achieving drinking water and crop irrigation security. However the most popular aspect of the blue revolution is aquaculture. Indonesia has the world's fourth longest coastal line with potential aquaculture to develop and manage, large marine and fisheries industries. The Indonesian government tries to boost the fisheries sectors from aquaculture within an uncertain global environment. The idea of farmers as agent of changes to develop best practices at the field level has been initiated through ecology friendly agriculture on a local knowledge basis, which then needs to be equipped with evolving knowledge on eco-friendly technology and innovation on processing and other value adding agriculture and aquaculture product.

[12] http://irri.org/our-work/locations/indonesia, accessed 17th August 2014

5.4.2. The Green and Blue Water

To feed hungry populations and reach food security, the execution of land use to produce sustainable stock, requires water which is also needed for others. Rainwater is partitioned into green and blue water flows which sustain freshwater functions in four eco-hydrological domain (FALKENMARK and ROCKSTROM, 2005:67). The use of water for food production can also be explored using a water footprint approach (HOEKSTRA, CHAPAGAIN, ALDAYA, and MEKONNEN, 2009 and 2011) in correlation with ecosystem services or millennium ecosystem approach (MEA).

The green water approach was first highlighted in 1995 during Food and Agriculture Organization (FAO) conference. Landscape plays a crucial role in this approach, particularly in the arid, semi-arid, or dry land where the hydrological cycle dominates. Water resources management focuses on blue water, where potential conflict is high due to multiple users of water. Landscape changes in specific regions, such as the Karst region Gunungkidul, affected the green and blue water approach in accordance to Integrated Water and Land Management (ILWRM). Cropping and vegetation systems on Karst landscapes require monitoring from a crop per drop approach in consideration of limited water availability, which meet the idea of water foot print approach (see Figure 5.22). The water footprint approach is one of method to assess water scarcity with the concepts of blue, green and grey water (ZENG, LIU, and SAVENIJE, 2013:443).

The water footprint on Karst Gunungkidul commences with Phenology embodied and embedded in the local knowledge. Phenology within seasonal based local knowledge represents the growth of crops or vegetation which are proxies to water consumption of plants, evapotranspiration and carbon sequestration on Karst landuse/landcover. Figure 5.23 shows water footprint in the islands of Indonesia, where Yogyakarta province is among those with the lowest number for its water footprint, meaning that the levels of water per head of population is still considered low. However, this condition also correlates to socio-economic cultural behavior and could reach a high level. Capacity building on green and blue water needs to be continuously introduced.

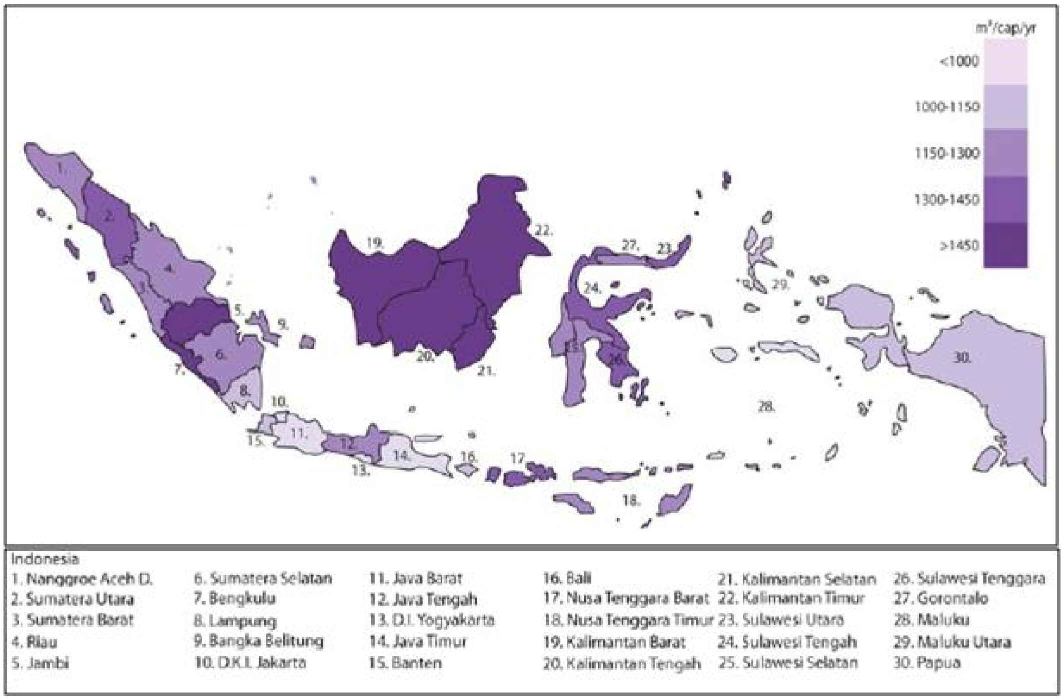


Figure 5.23. Water footprints of Indonesian provinces per capita related to crop products for the period 2000 – 2004 (BULSINK, HOEKSTRA, and BOOIJ, 2009:21)

5.4.3. Coupling and Integrating Intelligent Water and Land Management

In the 3rd World Water Forum in Tokyo 2003, solutions for the critical shortage of drinkable water that the UN estimates 2.7 billion people will face by 2025 need to be conducted at the field level and monitored. Land use or land cover correlates with their role in green and blue, even gray water partitioning and affect groundwater recharge in Karstic regions. Learning and interpreting ecological (balance) criteria from *Pranata Mangsa*'s phenology or bio-indicators makes possible the assessment of ecosystem health, local protection and secure long term resilience of livelihood. Green water flow on Karstic regions is crucial, for human and other inhabitants and for nature itself. When using or withdrawing water, the effect or disturbances cause by it should be considered in planning and managing ecology.

During the New Era (*Orde Baru*) under Suharto in 1980's, Indonesia once claimed itself an agrarian land. Agricultural land use was categorized into paddy fields, household gardens and orchards, rainfed and drylands, open grass, brackish and fishponds, swamps, and state and private plantations. Agricultural land in Indonesia is decreasing more than 20,000 Ha/year and in 2025 might left only two million Ha (Ministry of Agriculture and Statistical Bureau, 2013). Vast dryland and non-irrigated areas existed in Indonesia, and the Southern part of Gunungkidul Regency on Java island is one such region that depends on rain for agriculture.

The main input for agriculture is water, coupled with knowledge and skill of the people to manage it. Rain water supplies surface water and groundwater as resources for input to agriculture and other activities. Total water storage capacity throughout Indonesia unevenly distributed due to different geo-physical settings, thus water and land management take into consideration available resources. Incorporated water and landuse planning needs to consider the hydrogeological role of the Karst region where water affects the Karstification process. Some regulations have been issued by national and regional governments related to water use, particularly groundwater exploration and landuse. Gunungkidul Regency issued Regional Ordinance 17 in 2012 which regulates permission for groundwater exploration and utilization, and Regional Ordinance 23 in 2013 which regulates protection of agricultural land for sustainability, and Regional Ordinance 6 in 2011 on spatial planning of Gunungkidul for 2010-2030. These regulations are the basic steping stones to develop (regional) Integrated Water and Land Management.

Figure 5.24. Green belted pond (Author, 2011)

BAUER (2006) described the correlation between landuse and the protection of groundwater. Land utilization near water sources have an impact on water availability storage. For example ponds with a green belt of surrounding vegetation and not fully cemented wall can still provide water (although the quantity decrease) during dry season (see Figure 5.24). Green belted doline ponds represent green and blue water approach, in consideration of evapotranspiration. Local people knowledge play significant role in maintaining their environment.

5.5. Human Eco-adaptation Culture

Humans tend to modify their environment to fulfill their need and turn the environment into a cultural landscape which reflects human adaptation or coping mechanisms to nature. Such natural processes might force humans to bow to the environment, be it the ground, the rocks, the availability of water, the flow of water or the altitude. But intensive development puts too much pressure on the environment. A framework for linked social-ecological system analysis (see Figure 5.25) is required to better understand the eco-adaptation culture of Karst Gunungkidul people, supported by phenomenological hermeneutics and anthropological approaches.

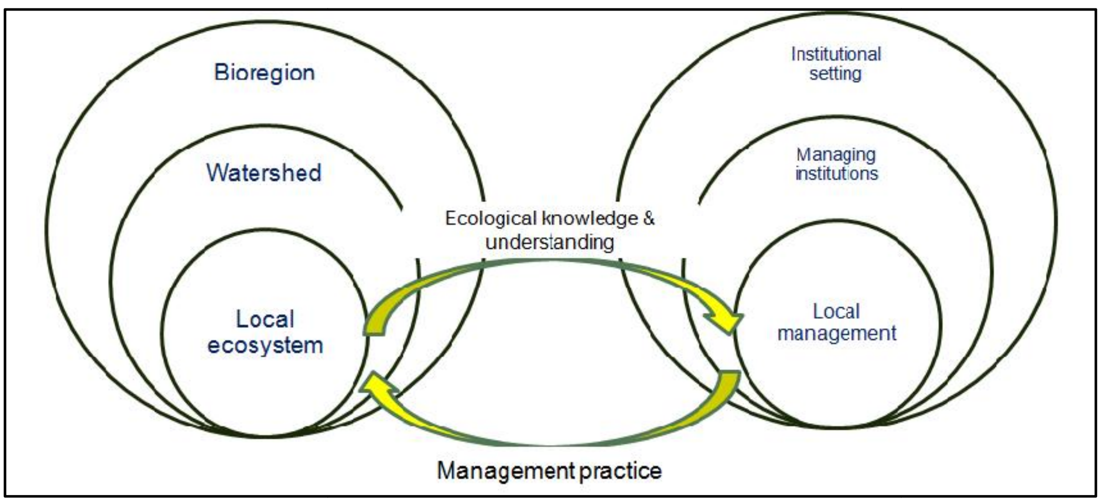


Figure 5.25. Conceptual framework for linked social-ecological system analysis (BERKES and FOLKE, 2002:124)

Water shortages that must be endured by rural karst Gunung Sewu communities during the dry season have been coped with for centuries along with geomorphological Karst processes (SIMANJUNTAK, 2002; SUNKAR, 2008; HARYONO, YUWONO, and FAIDA, 2008). The process of environment adaptation and outside influences, have created a thriving cultural dynamic, ranging from the Paleolithic style, Pre-neolithic, Neolithic, until Paleometalic during proto-history. Available resources, namely good qualified rock for equipment, water, fauna and flora became the backbone of life in the range of hundreds of thousands to millions of years (FAIDA, 2012).

Culture plays an important role in mediating human responses to environmental change (HEYD and BROOKS, 2009) or environmental processes. Culture may serve as a resource in two ways, in relation to the "management" of the non-human sphere and in relation to the development of governance processes that conclude that a deeper understanding of the cultural mediation of responses to environmental dynamism may be of significant value in the development of resilience to accelerating environmental change. Culture is considered as comprising the ways of living that involves values, beliefs, practices and material artefacts that condition the production of tangible as well as intangible goods and services needed for the satisfaction of human groups' needs and wants. Particular cultural patterns among human groups may play a crucial role in the ability to cope with environmental changes (HEYD and BROOKS, 2009).

Variation of water use consumption reflects the environmental ethic of the people on Karst environments, yet economic reason still lies behind the actions. Fallowing the land during the dry season gives the soil/land a break. During May - August the land is occupied by the last crop, mainly cassava. The crops that have adapted to Karst Gunungkidul environment evolve through time during trial and error by the people. Meanwhile, scientists also develop models to tackle the harsh condition of dry area or region on Earth that require climate-resilient crops. Knowledge that circulated among "local scientists" such as the farmers and "global scientists" meet in the knowledge management eco-adaptation culture.

Human eco-adaptation culture is imprinted on the landscape. The strategies the Karst people of Gunungkidul continuously do are to balance water for human needs and the natural cycle. Water and land serve the people, an understanding of ecosystem services and ecological balance from local knowledge *Pranata Mangsa* incorporate one another. Eco-adaptation starts from policy/planning, awareness, information management (in this study called knowledge management) and livelihoods or resources management.

VI. Local Knowledge of Seasonal Calendar and Phenology in Karst Area Gunung Kidul

Climate variability and the correlated risk have been experienced by people on Earth, who then developed diverse coping mechanisms due to their knowledge based on geographic and other physical settings. Some coping mechanism are also based on socio-economic and demographic factors. Rural communities have already acquired understanding of their shifting micro climate through observations and experiences. They have fostered thorough knowledge of many aspects surround their daily lives. People know what varieties of crops to plant, when to sow and weed, and how to maintain their environment in a state of equilibrium. However, the uncertainty of climate they have experienced in the past decades has disrupted their inherited and experienced seasonal based knowledge. The disruptio gets worse when governmental institutions and programmes related to the climate issue are introduced and fail. This causes a lack of trust when another program is introduced to replace the previous ones.

Current local practices, processes, systems and infrastructure which are less suitable given the uncertainty of climate change, need to be resolved, while sensitive to the fact that local perception and interpretation of climate change can be different. This study seeks to explore the seasonal calendar based on local knowledge as a foothold to awaken and regain the rural community's awareness of the environment and ecological values, which can be a basis for water and land management. Correlating seasonal calendar knowledge with the work discussed in the previous chapter on water and land knowledge management in Karst region Gunungkidul will hopefully mobilize human ingenuity to cope with seasonally limited water and land availability on the region. The value of water and land individually and communally differ, yet they both inevitably face water scarcity during the dry season. Thus, it is interesting to know how people nourish their keen observation of seasonal and physical environment changes as local knowledge to manage the resources in a changing climate environment.

6.1. Local Knowledge of Seasonal Calendar

Indigenous, traditional and local knowledge systems are transmitted and renewed by each succeeding generation and ensure the well-being of people around the globe by providing food security from hunting, fishing, gathering, pastoralism or small-scale agriculture, as well as healthcare, clothing, shelter and strategies for coping with environmental fluctuations and external forces of change (WARREN, SLIKERVEER and BROKENSHA 1995; SILLITOE, DIXON, and BARR, 2000; NAKASHIMA and ROUÉ, 2002). Knowledge is the expression of understandings, thus understanding local seasonal knowledge reflects local human expression of the nature cycle. UNESCO (2005) promotes knowledge for development and the emergence of knowledge societies. UNESCO emphasizes on an open, integrating and different conceptualization of knowledge in its definition (HORNIDGE, 2012:30). Local knowledge is the human capital of urban and rural people. It is their main asset in the struggle to survive, produce food, provide shelter or achieve control of their own lives. Local knowledge is developed and adapted continuously to a gradually changing environment, passed down through generations and closely interwoven with people’s cultural values which also change.

In correlation with cultural changes arising in 21st century global communication era, many local knowledge systems are at risk of extinction. The increasing variability in climate has led farmers to seek scientific weather forecasts (RENGALAKSHMI, UNEP), but in practise farmers chose the one most suitable for them based on their locality. The Anthroscape context or human reshaped landscape (KAPUR, ESWARAN, and BLUM, 2011) requires the topographic, vegetative, landuse, demographic and socio-economic attributes combine with the information on local, traditional, or indigenous technologies to develop a holistic sustainable water and land management agenda. In other word, a combination of indigenous technologies and scientific know-how.

6.1.1. Practices and Lesson Learnt from The Seasonal Calendar as Local Knowledge in Some Part of The world

Local knowledge in this study refers to a uniquely given culture of society, community and individual. Local-level scale decision-making basis in agriculture, health care, food preparation, education, natural resource management and a host of other activities in rural communities may be related to a common practice seen in communities that are indigenous to a specific area. Or, the focus might be on the long history of the practice, in which case it is often called traditional knowledge (UNESCO, 2002). This knowledge has been promoted as an alternative way to reach rural communities seeking development progress (BRIGGS, 2005). Local knowledge of agricultural systems demonstrate considerable sympathy with the environment and its ecological aspect, though economical values also important. Some part of the world practice seasonal based knowledge for their daily activities, and also agriculture, for example:

1) Bauernkalendar

   Germany had the *Alter Bauernkalendar* also known as *Mandlkalender* which was applied to the agricultural sector in 1800s. The old calendar was fully of illustrated as a simple ‘book’ to help the illiterate rural people at that time understand the weather forecasting and to work on agricultural activities, i.e. sowing, reaping, harvesting, and the day length between sunrise to sunset. The *Mandlkalender* was previously printed or carved on rods or wood and evolved into a book with some adjustments and improvements, while keeping its traditional design, size. The new farming calendar or *Neu Bauernkalender* nowadays is reformed and referring to the Gregorian calendar accordingly. Symbols are still used to represent weather, agriculture and daily life activities (see Figure 6.1).

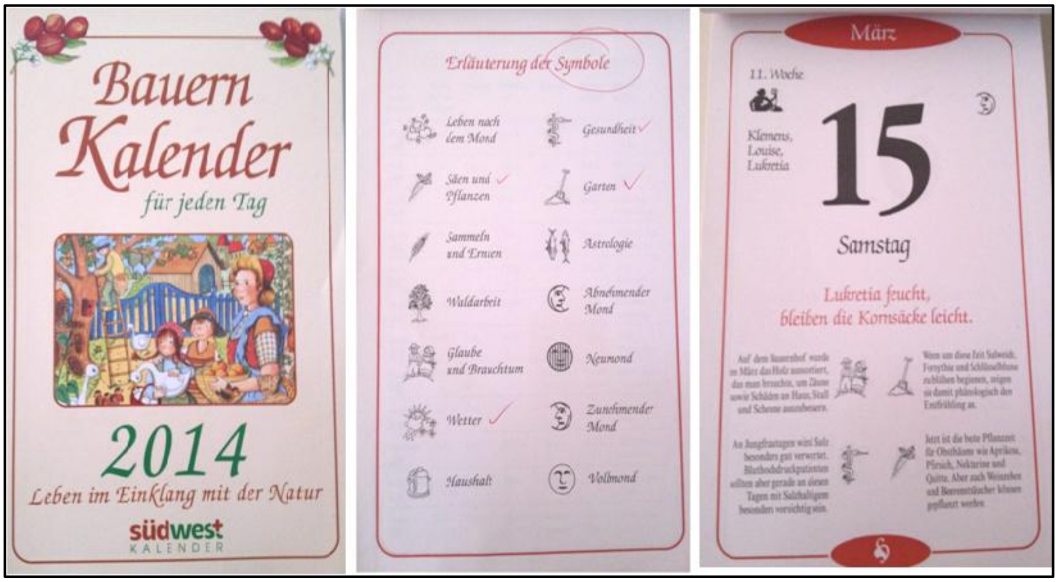


Figure 6.1. New Bauernkalendar (Author, 2014)

2) Weather lore from Vietnam

The Mekong river system in Vietnam system is a complex river and channel network which creates floodplains and contributes to the wetlands and ecosystem in the delta. The cacthment area is highly populated, comprising 22% of Vietnam's total population. Rural populations along the river have adapted their livelihood strategies to the water and flood regime in the area. Local farmer in the Mekong Delta Vietnam said that their ancestors found a method to observe and research by experience and continous learning to forecast flood occurrence. This type of local knowledge plays an important role regarding the seasonal water resources management which determine the traditional rice cultivation in Mekong Delta.

Local farmers and fishermen have observed within the last decade that there have been environmental changes, with no distinct weather periods between dry and wet seasons (BIGGS, 2004; EHLERT, 2012). Farmers' and fishermens' awareness of environmental changes are scaling up due to the increasing irregular precipitation periods (ADGER, KELLY, and NINH, 2001), and the increasing frequency and magnitude of storms hitting the Delta. It is the exquisite apability of farmers and fishermen to observe and interpret weather events on the basis of local weather lore and make use of the science-based meteorological forecast to adapt to the changing environmental for their agricultural lifestyles and decision making. Local knowledge hybridization serve as an adaptive strategy to encounter environmental change which not accommodated by top-down system environment management.

3) Arctic (Inuit) case

In environments like the Polar Arctic, the local seasonal calendar is so crucial in determining people's life due to food security and sustainable livelihood. Their culture is facing challenges in relation to climate variability and cultural intervention because the younger generations of Inuit find themselves caught between traditional and contemporary cultures. Their diet has been slowly compromised by outsiders' food products, leading to increased obesity and diabetes levels.

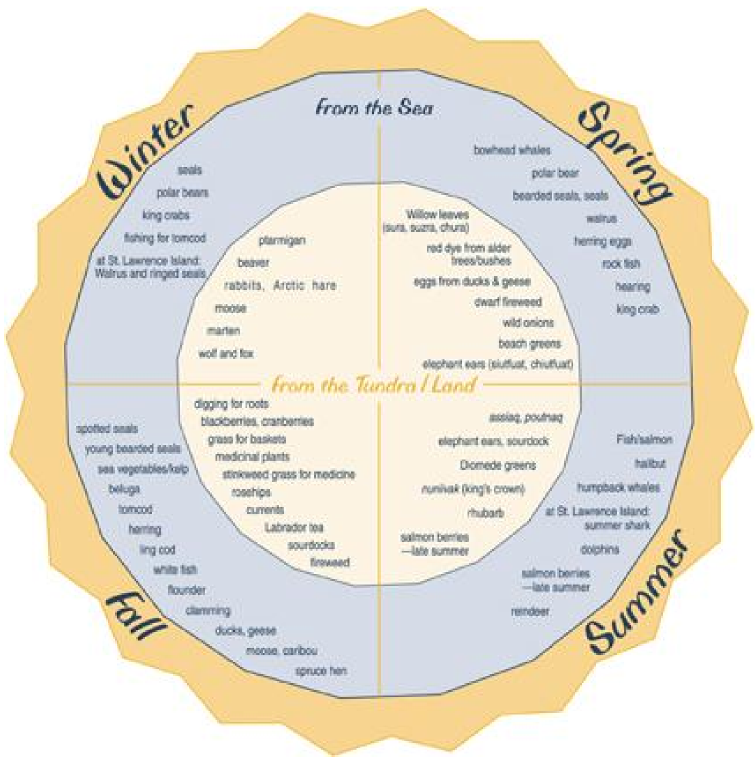


Figure 6.2. Seasonal based calendar of The Inuit (source: The Artic Food Network)

The Arctic food Network (AFN)[13] seeks to enhance the production and the exchange of local food and to create small scale economies. The AFN tries to set a unique integrated architecture, landscape and technology adapting to the harsh dark winter and treeless landcape of the Canadian north. The Inuit have a seasonal calendar which determines their seasonal activities related to their likelihood and livelihood (see Figure 6.2).

4) India's monsoon case

The behavior of the summer monsoon has significant implications for the economy and livelihoods in India, particularly in the rural sectors which are vulnerable and at risk. Over 60% of cropped area in India is rainfed, and over 70% of the population depends upon the rural natural resource base for their livelihoods. Droughts and floods have deep impacts on rural households, and great budgetary implications for the government at district, state and national levels annually. The ability to generate reliable seasonal climate forecasts, tailored to specific policy and institutional contexts, could improve India's ability to manage climate risks and reduce these impacts.

The India’s Ministry of Agriculture developed a project seeks to improve capacity to forecast the Indian summer monsoon, and to demonstrate approaches to using forecasts and other climate information to benefit agriculture and rural livelihoods. It integrates risk management and climate science research, involving leading institutions in India in climate research and agricultural management. The project adopts a demonstration approach, focusing on select districts in nine states that face significant livelihood impacts due to variability in the southwest monsoon, namely: Andhra Pradesh, Gujarat, Maharashtra, Madhya Pradesh, Orissa, Himachal Pradesh, Rajasthan, Tamil Nadu and Uttarakhand.

[13] The AFN network observe Inuit's people and their life, http://lateraloffice.com/ARCTIC-FOOD-NETWORK-2011-12, accessed on 21st march 2013

6.1.2. *Pranata Mangsa* Calendar at a Glance

Java island can be divided into four big cultural regions (see Figure 6.3) accordin to local (dialect) language (GEERTZ, 1963). The interactions between humans and the environment define what and how culture is. The adaptation to environmental challenges characterize the people and also the environment they live on. Central Java is influenced by volcanoes, riverine and coastal activities coupling with climatic influences. Agriculture in its broad meaning and application, characterizes the rural landscape in Central Java. Farmers have a long history in keen observation known as *ilmu titen* of climatic factors and the environment for agriculture and fisheries.

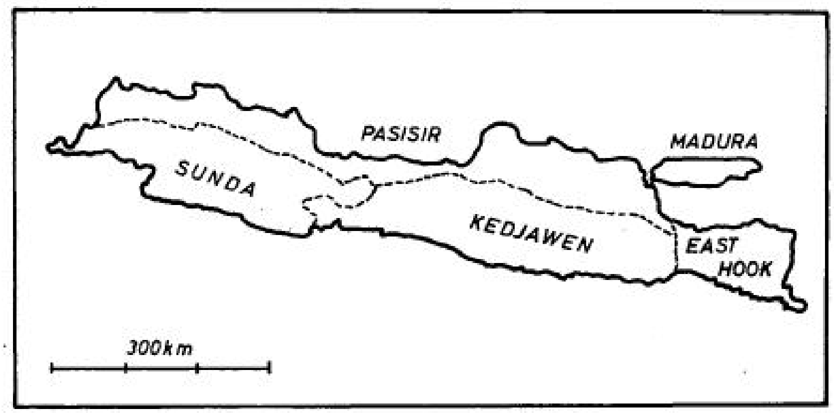


Figure 6.3. The Cultural Regions of Java (GEERTZ, 1963:42)

The seasonal based calendar *Pranata Mangsa* was first designated for the region under Mataram Kingdom (see Figure 6.4), particularly in Surakarta territory, which has the same climate condition. Gunungkidul Regency was once under the Mataram Monarchy and was splitted into two areas by the Dutch government in 1755, namely *Ngayogyakarta* (Yogyakarta Special Province at present) regulated by Sultan and Surakarta regulated by Paku Buwono. By 1757, Gunungkidul had become full part of Yogyakarta. The King of Mataram known as Sultan Agung, and the King of Surakarta known as Paku Buwono, both introduced a calendar to guide their people. *Pranata Mangsa* as a seasonal calendar based on the solar system was introduced in 1855 by Sri Susuhunan Pakubuwono VII, the King of Surakarta in Central Java (DALDJOENI, 1984; WISNUBROTO, 1999). This region was mainly affected by the volcanic activities of Merapi volcano. However, *Pranata Mangsa* then become well known throughout Java. The essence of *Pranata mangsa* is similar, in terms of keen observations to develop knowledge of climatic factors that change seasonally. This applies to weather lore in Vietnam, India, Bangladesh, Aboriginal Australia, and the The Inuit in Alaska.

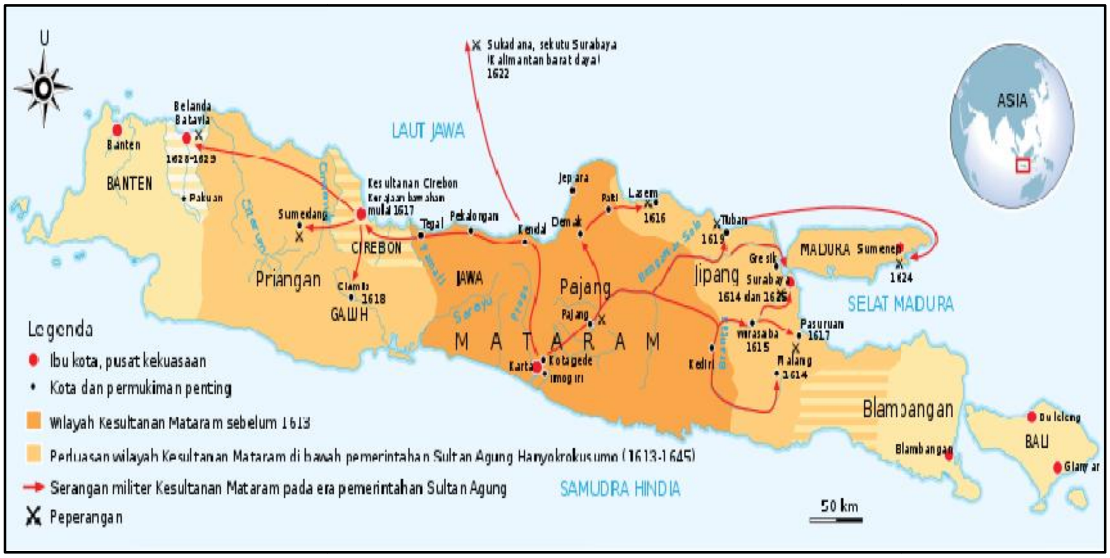


Figure 6.4. The Whole Mataram Kingdom Spatial Dimension when *Pranata Mangsa* first introduced (in dark orange color)[14]

Pranata Mangsa calendar starts on 22 June - 1 August when the sun in the equatorial region is located to the North (see Figure 6.5), and most regions in Java experience a dry season. Phenomenological hermeneutics approach applies due to the keen observation of phenological occurrences of plants and animal which respond to climatic factors in adaptation to the physical environment. *Pranata Mangsa* is an evolving legacy through temporal and spatial changes become the legacy of local knowledge in the keen observation skill known as "*ilmu titen*" of seasonal changes in Central Java. The knowledge is learnt by reflection and imitation of experience. Whilst *Pranata Mangsa* was applied during the middle 1800s in Central Java particularly, the Gregorian calendar then followed nationally in Indonesia.

[14] The whole Mataram Kingdom then divided into Surakarta, Yogyakarta, Mangkunegaran and Pakualaman by The Dutch government. http://id.wikipedia.org/wiki/Kesultanan_Mataram, accessed on 11th January 2014

Gregorian calendar was adopted first in Indonesia during Dutch colonialism in 1910 when *Wet op het Nederlandsch Onderdaanschap*, the constitution was applied to the Dutch East Indies colonies. Nowadays, *Pranata Mangsa* is coupled with the Gregorian calendar and Javanese calendar (introduced by Sultan Agung).

Figure 6.5. Solar Movement on the Equatorial (source: blendedlearning/itb.ac.id.)

Pranata Mangsa as local knowledge on climatic factors and seasonal changes and its application in agriculture is still widely applied and existed until at least the beginning of the 1980s. But since the green revolution and the introduction of modern irrigation systems, the habit of observing seasonal changes broadly and its application has gradually decreased and is about to vanish. New technological applications have replaced and solved the problem of plant diseases and pests by the use of chemical products; while any threat of drought due to lack of water can be solved by providing good irrigation and tapping water sources in order to increase water supply.

There is heterogeneity in farmers' responses to climate change or variability. Farmers do change planting timing in response to shifting rainfall pattern but not crop variety, because farmers found difficulties in changing or converting paddy rice field to other purposes, not to mention the large investment necessary (YAMAUCHI, SUMARYANTO, and DEWINA, 2010). In Karst regions like Gunungkidul, timing and crop variety are consider important to adjust to the given characteristics of the physical setting. The cultivation method called *Tumpangsari*, has proven effective for karst Gunungkidul farmers (SUNKAR, 2008; Indepth interview 2012 and 2013), yet the crop variety which adapted to shifting rainfall or water availability in short time and mitigates exposure to climate change still needs to be considered. The head of Tileng village in Gunungkidul Regency, said that farmers in his area are aware of certain paddy seeds which can survive a lack of water in the dry season.

Such environmental change also induces some adaptive behavior, such as changing planting time with less water sensitive crops, and mitigating the negative impact of climate change. The individual-level variations in the perceived change of the rainy-season onset explain the likelihood of adopting adaptation strategies such as changing planting timing. (YAMAUCHI, SUMARYANTO, and DEWINA, 2010). Empirically, their study shows there is a tendency to shift the beginning of the cultivating season as the rainy season shifts from the end of October – the end of November, to mid November - the end of December. The shifting rainfall pattern affects the irrigation supply for agriculture which depends on the reservoir which collects the rainwater. Limited meteorology equipment in the field sites is resolved by using simple materials that farmers can utilize from their surroundings, such as used can for tipping bucket (record rain water quantity), and they have the chance to get involved in the Climate Field School (*Sekolah Lapang Iklim*/SLI). Use of the *Pranata Mangsa* seasonal based calendar is a challenging discussion during SLI school activities (WINARTO, STIGTER, HESTU, ANANTASARI, and KRISTIYANTO, 2011) and FGDs conducted with representative of villagers (2012, 2013).

6.1.3. Exploring Phenology on Keen Observation of Seasonal Cycle *Pranata Mangsa*

Phenology is the study of periodic plant and animal cycle events and how these are influenced by seasonal and inter-annual variations in climate, as well as habitat factors such as elevation. It indicates the occurrence of biological events in their annual cycle. In ecology literature, the term phenology is used generally to indicate the time frame of any seasonal biological phenomena, including the last appearance dates of seasonal species.

At each different time frame of *Pranata Mangsa*, people can interprete the symbols of climate and weather parameters described in it. The ecologial value of *Pranata Mangsa* can be interpreted using phenological phenomeon in plant and animal behavior, in application of a broader phenomenolgy hermeneutics approach. Phenology takes into consideration a plant's stages of growth as a response to growth requirements from climatic factors (i.e. humidity, solar radiation, etc.) and physical features (i.e. soil properties, etc.). Environmental and ecological indicators in *Pranata Mangsa* represent the bio-indicators attached to it (see Table 6.1). Phenology teaches people to live in harmony with the nature for generations, until some interference such as non-ecological and non-environmental development agendas intervene.

Table 6.1.Symbols of agro-climate factors and personification

Plant and Animal Indicators	Season and biodiversity issues
 ***Gryllotalpa*** is a genus of insects in the family Gryllotalpidae. Gryllotalpa africana normally found in Asia and Africa. In Europe, commonly known as the European mole cricket. Mole crickets are omnivorous, feeding on a range of soil invertebrates and plant roots; often leaving neat circular holes through the roots of tuberous plants. (source: http://www.arkive.org/mole-cricket/gryllotalpa-gryllotalpa/image-A24841.html, accessed on 13 March 2013)	Start of dry season Male of mole crickets occasionally produce a soft, but far-carrying 'churring' song from within a specially constructed chamber in the burrow system, which acts as an amplifier for the song, which is likely to be used for attracting females. The song is typically produced on warm balmy evenings in early spring between dusk and dawn. When they start to "sing", people recognize that its time to be prepared for the dry season. However, their occurrence has declined drastically. Reasons for decline in numbers include changes in agricultural practices and the widespread use of pesticides or chemical product which kill its prey, and land conversion in Indonesia.

<table>
<tr><th>Plant and Animal Indicators</th><th>Season and biodiversity issues</th></tr>
<tr><td>
Macrotermes sp. or Giant ternite, which in Java known as Laron, is the most common mound building termite throughout South East Asia. There are also several subspecies which have slight variation, mostly in terms of size. Their diet is highly varied and they can subsist on dead grass and other plant matter, in the absense of wood sources, although their main preference is of course, wood. Chewed up plant matter is used to construct elaborate fungus gardens in their nests. There are occasional reports of Macrotermes gilvus being a minor pest by consuming wooden structures for nesting.
(source: http://www.termiteweb.com/termite-pictures-macrotermes-gilvus/, accessed on 13th March 2013)</td><td>Shifting season from dry to wet (rainy) season.

When the moths of Giant ternite or Laron emerge early in the morning or evening, it is the indication of the shift from the dry to the wet (rainy) season. Their occurrence has declined, but in the teak forests of Gunungkidul, the moth still can be seen and is considered disturbing to the timber growth.</td></tr>
<tr><td>
Discorea hispidadennst, in the Javanese language is called Gadung. Dioscorea hispida occurs naturally from India and Southern China, and throughout Southeast Asia to New Guinea. Yams are one of the tuber crops in Indonesia, need to be detoxification to be consumed as food, however it has potential function in medicine as well.</td><td>Early wet season

Gadung is the most recognized seasonal bio-indicator and is described in the seasonal calendar Pranata Mangsa.
During indepth interviews and FGDs (2012, 2013), all respondents knew this plant as the indicator of an early start to the rainy season. However, people have no interest in cultivating this crop for economic reason, despite still consuming it occasionally. They know it grows somewhere in the fields without being taken care of. Gadung is one example of food diversification beside rice in term of food security.</td></tr>
</table>

Each plant and animal bio-indicator follow their natural cycles in adaptation to the surrounding environment. Any disturbances or changes from climatic factors, will cause disruption to their growth. In a prolonged rainy season, water availability is so abundant that the leaves grow enormously. As a consequence, the caterpillar population also increases, to consume the leaves. Grashoppers or locusts and teak caterpillars are popular among rural people in Karst Gunungkidul particularly as finger food eaten with staple food (see Figure 6.6). Grasshoppers or locusts occur during the rainy season when the soil humidity is wet enough to lay and support their eggs and when harvest time arrives. Another phenomenon during the wet season is the appearance of caterpillars on teak trees, for example in the rainy season of 2012. Teak caterpillars swarm over teak leaves during periods of high rain intensity in the region, often between November - January and worsen during the ENSO years and with the uncontrolled expansion of monoculture cultivation and the loss of the predators. Such phenomena are climatie sensitive, responding to temperature and rainfall. The phenological record can a play role as proxy for temperature and rainfall in historical climatology to study climate change and global warming. In Japan and China, the time of cherry and peach tree blossom is associated with ancient festivals and some dates can be traced back to the eighth century.

Teak caterpillars

Grasshoppers

Figure 6.6. Teak caterpillar and grasshopper population increases indicating weather anomaly

Phenology is not popular scientific knowledge, including in Indonesia. Phenological recording started in the 17th century when Robert Marsham systematically recorded “indications of spring” on his estate at Stratton Strawless, Norfolk. Richard Fitter and his son Alistair Fitter published the average First Flowering Date (FFD) of 385 British plant species that have advanced by 4.5 days during the past decade compared to four decades before in *Science* 2002. Such phenological events are significantly related to temperature and suggest profound ecosystem and evolutionary consequences as the climate get warmer. Phenological and water-use patterns underlying maximum growing season length at the highest elevations indicate climate change. Knowledge on ecological balance have decreasing, and extreme weather is to blame.

International institutions working in phenology are the UK Phenology Network, USA National Phenology Network, European Phenology Network, Canada (Alberta and Saskatchewan Plant Watch). China and Australia also have phenological programs. *Poor Will's Almanac*, is a phenological almanac traditionally used for information on phenology in agriculture in eastern North America, which take into account the astronomical positions at the time. There is no phenomenological network or institution yet in Indonesia, nor any recording of the stages of crops in time series. However, research related to phenology and crops in Indonesia exist. One example is the research on phenological and maturiy stages of *mengkudu* seeds (*Morinda citrifolia* L.) by NGITUNG and BAHRI (2008).

VAN VLIET (2010) proposed that to adequately respond to phenological change and to improve the adaptation potential, there is a need to (1) continue and improve monitoring of phenological changes; (2) advance the analysis of phenological changes and its socio-economic and environmental impact; (3) improve the projections of phenological changes and their impacts; and (4) improve the communication on observations, knowledge, tools and techniques. Multi stakeholders need to work together to enhance capacity building of human resources, particularly farmers and institutional person in executing local knowledge to foster learning system.

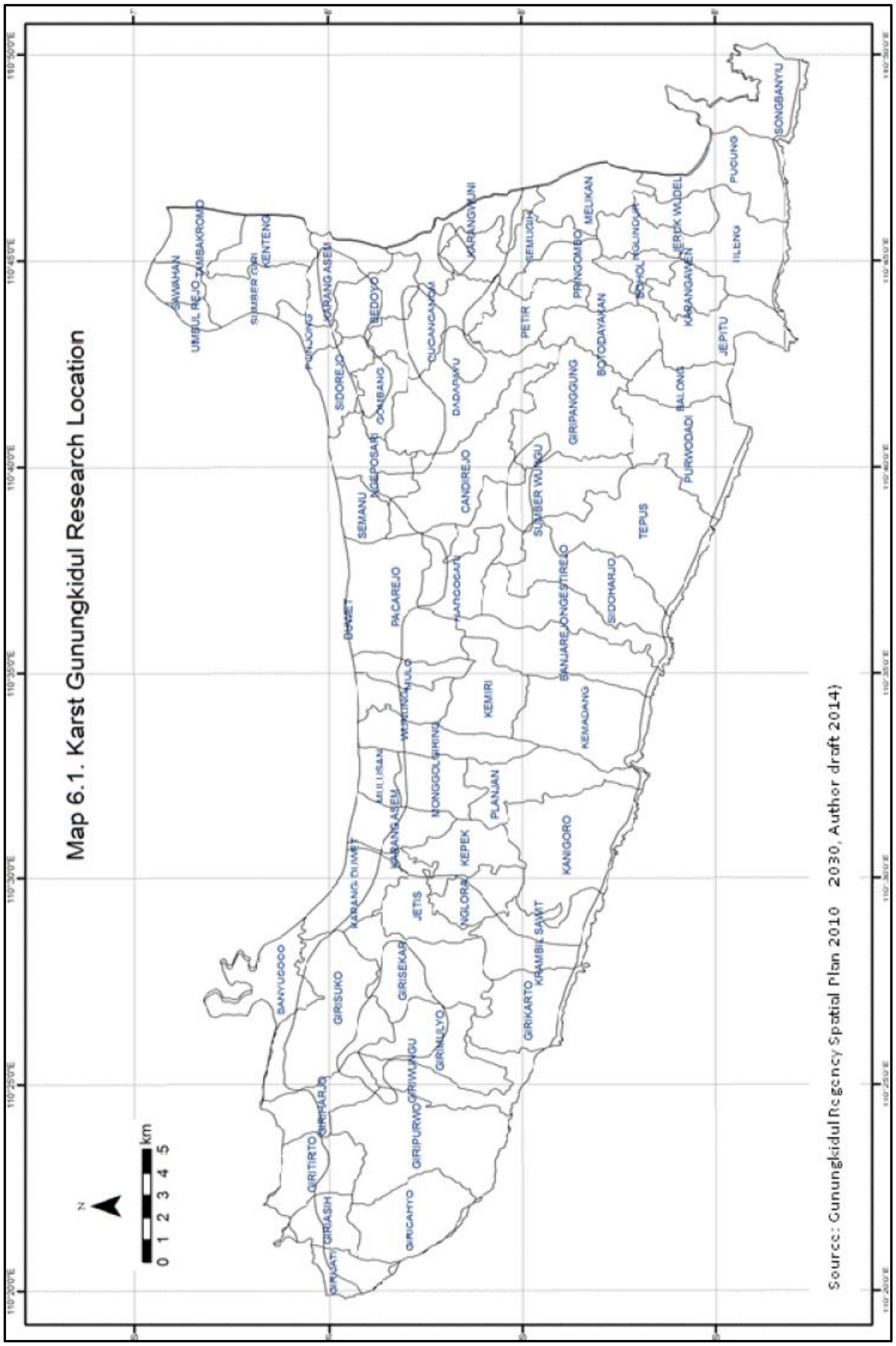
6.2. Collecting *Pranata Mangsa* and Phenology Application for Water and Land Management

If knowledge is power, then understanding is the liberation (Manulani Aluli Meyer, Hawai'i proverb). The limitation of local, traditional, or indigenous knowledge, is that it needs to be seen as something that is nuanced, pragmatic and flexible, even provisional, highly negotiable and dynamic (BRIGGS, 2005). Questions might emerge on how effective the local knowledge of *Pranata Mangsa* and its phenology as part of Javanase culture, in particular for agriculture. How well do rural communities know their environment? Is water and land management understood in a local and wider context? Is seasonal based local knowledge a tool to empower Karst community or liberate them to gain understanding to support their livelihood? Do the farmers or the governance need to understand the essence philosophy of *Pranata Mangsa* and its phenology in the evolving or culture?

Climate variabilitiy has confused farmers about when to cultivate, and this has degraded the farmers belief on the climatic cycles of *Pranata Mangsa* and Phenology. This study tries to foster local knowledge and a learning system using anthropological approach to collect rural Karst people's understanding and interpretation from their inherited and experienced knowledge. Focus group discussion (FGD) and indepth interviews, were conducted in the Karst area of Gunungkidul Regency to collect primary data and assess community behaviour and perception. During FGDs, the expression, behavior, and perception of the respondents are observed and noted (the participant observation).

6.2.1. Focus Group Discussion (FGDs)

The FGDs were conducted in sub-districts which are classified as Karst ecosystems based on Regional Plan and Development Board (Bappeda) Gunungkidul's spatial plan 2010-2030 (see Map 6.1), namely Purwosari, Panggang, Saptosari, Paliyan (southern part of the sub-district), Tanjungsari, Tepus, Semanu (southern part of the sub-district), Girisubo, Rongkop and Ponjong (southern part of the sub-district). The representatives were villagers who were considered knowledgable about their villages' character, particularly regarding local knowledge of water, land, and cultural subjects. The age of the representatives ranged between 25 and 60s years old, to consider the variety or heterogenity of the data and information.



Map 6.1. Karst Gunungkidul Research Location

Source: Gunungkidul Regency Spatial Plan 2010 2030, Author draft 2014)

6.2.1.1. Ponjong sub-district

Geomophologically, Ponjong sub-district is situated on Baturagung range, Panggung Massive, and Karst, which consist eleven villages. Karst villages are located in the Southern part of Ponjong sub-district, namely Sidorejo, Gombang, Bedoyo, Kenteng, Karangasem, and Southern part of Ponjong. Villages in the northern part of the sub-district occur in the locations with no water difficulties during the dry season and irrigation paddy can be grown. There are at least 19 ponds in the whole sub-district. Focus group discussions were conducted by inviting the head of villages and representatives of water, land and culture issues. Due to the sensitive issue of Karst mining, in whichr some mining companies were forced to stop (between 2010 - 2014), the FGD was quite tense and ascertained that Karst mining played significant role in the site (see Figure 6.7). Agriculture and mining are the main activities in Ponjong that significantly influence on regional development.

Figure 6.7. Carbonate Rock Mining in Bedoyo village (Author, 2013)

Application of the seasonal based calendar for agriculture still occur in the Karst area of Ponjong sub-district, but water supply can be managed by optimizing water sources from the northern villages and utilizing doline ponds for short periods of between two to four months in the dry season. Fresh water for households is supplied by the Bribin-Seropan water network and rain harvesting tanks (when needed). The mining activities in Karst areas of Ponjong sub-district is worrying the hydrogeologists due to Karst function in hydrology. Only a few well informed local people understand the hydrological function of Karst and can correlate the environmental disturbance to Karst ecology. There were two officers in Kenteng village who can explain the *Pranata Mangsa* cycle and admitted that their knowledge is an inherited from their parents' knowledge.

6.2.1.2. Semanu sub-disrict

There are at least 40 (doline) ponds in whole Semanu sub-district of which only 80% of the ponds can hold rain water for a maximum of two to three months. There are no specific sinkholes (*luweng*), which is different to the southern part of Guunungkidul around Tanjungsari, Tepus, Girisubo or Rongkop, according to the people. The representatives of villagers said that it has been at least a decade since the ponds discharge began decreasing. This condition also occurs throughout Karst areas in Gunungkidul (field observation and FGDs 2012, 2013). People understand that during the dry season, water discharge is decreasing but are unable to explain in detail seasonally based *Pranata Mangsa* correlations with the water quantity condition. They keep in mind and memory only on certain time frame of *Pranata Mangsa*, particularly the months to start cultivation when the rain supposely starts falling, known as *Mangsa Labuh Kapat* (early October - November). Before *Mangsa Labuh Kapat* comes, even if the rain has already fallen, farmers still wait until *Mangsa Labuh Kapat* to start cultivation.

The water piping network from PDAM is installed in the villages close to the road in acessible topographic locations. This phenomenon is similar to other parts of the region. Before PDAM installed the network in 1990s, people dug wells of between 15 - 30 meters deep to get water from the underground water connected to Telaga Beton in Ponjong sub-district. Main sources water supply for household connections (SR) of PDAM in Semanu comes from Sindon and Seropan. Local people said that Bribin's water network supplied water to villages in the Southern part of Gunungkidul such as Girisubo, Rongkop, Tepus and Tanjungsari. People hope that one day the water supply from Seropan or Bribin can support agriculture activities. In reality, PDAM only distribute water three times per week in rotation with other villages and sub-districts particularly during dry season.

6.2.1.3. Rongkop Sub-district

Rongkop sub-district has 37 (doline) ponds. Semugih village conducted a Karst Conservation theme on several programs that support the development of regional conservation and optimum utilization of water like the Environmental Planning Community-Based Settlement Program (*Program Penataan Lingkungan Permukiman Berbasis Komunitas*/PLPBK). Optimum utilization of water starts from environmental friendly Karst management, including simple waste water treatment systems (e.g. showers, laundry and cooking) for agriculture and fisheries. People's awareness is increasing towards the optimization of water in the village (FGDs, 2012). The increase of awareness is very crucial considering the relatively high price of water during the dry season, when the ponds dry up quickly, whilst treated domestic (household) wastewater can be used for watering plants and cattle. Processed waste water in the Village Semugih has been used for catfish ponds in Semugih hamlet and agriculture in Karangwetan hamlet. The community based organization calculated that wasted water due to people's daily activities using 50% asumption of human water requirements per day can be described as:

1) on average 80 litres per day per person, decreasing to 70% per person during dry season.
2) waste water from domestic use is 28 litres per day per person.

6.2.1.4. Girisubo sub-district

There are at least seven (doline) ponds in Girisubo sub-districts. One of its villagers once received Kalpataru, an acknowledgement of environmentalist subject, from Yogyakarta Province in 2006. Deforestation since 1980s was devastating in some parts of Gunungkidul Regency, such as in Girisubo, Tepus, Rongkop and the Ponjong sub-district. The wisdom of local knowledge on environment and ecological issue faces the economy survival challenges experienced by villagers.

The seasonal based calendar *Pranata Mangsa* is still applied for agriculture as inherited knowledge and considered as good cultural behaviour. Shifting patterns of rainfall have been experienced within at last two decades, but can still be managed by farmers and non-farming villagers who depend on water availability for the livelihood. Traditional agriculture methods known as *Ngawu-awu*, include when the farmers put the seeds on the soil and then cover with ash (*awu*), in accordance with *Pranata Mangsa*. Therefore, when representatives of the villagers were asked about the application of *Pranata Mangsa*, they say it is still applied, but not the practices of *Ngawu-awu*. Only 30% to 40% of farmers in Girisubo practice *Ngawu-awu* for seedlings and nurseries, the rest wait for the rainfall to start cultivation.

The head of Tileng village recognized that within a decade the rain pattern has shifted uncertainly. In 2012 Tileng village was the first to receive rainfall, before any other villages in Gunungkidul Regency and also in nearby Pacitan Regency, another Karst region in East Java. Field observation confirmed that this village's paddy field is older than other villages (November - December 2012). He argued that *ilmu titen* of *Pranata Mangsa* is still applicable. From different perspective, he agreed that bio-indicators or phenology still can be used to indicate the changing season from dry to wet seasons. His own farming system depends more on Meteorological Institution (BMKG) forecasting and agriculture officer's instructions than *Pranata Mangsa*. He added that farmers have developed knowledge to recognize and plant paddy which is resistant to less water conditions with shorter periods of cultivation.

The PDAM water piping network reaches the villages close to main road so that it can be connected as household connection (SR), with shifting water supply three times a week during the dry season. This phenomenon is experienced by all villages who have household connection to PDAM water network. The officer in PDAM said that the shifting distribution is a consequence of decreasing water discharge. Since the renovation of Bribin project in 2008 - 2012, the villagers consider that the water supply has not changed much compared to the 1990s when the water piping was first distibuted. People still apply diverse water sources beside PDAM water, namely water tankers, nearby springs, and ponds with short duration (1- 2 months).

6.2.1.5. Tepus sub-district

Administratively there are five villages in Tepus sub-district, namely Sidoharjo, Tepus, Purwodadi, Giripanggang, and Sumberwungu, and all villages are geomorphology and geologically located on Karst. This sub-district has been widely known to suffer from water scarcity or drought during dry seasons due to limited water source availability compares to other sub-districts in Gunungkidul over many years. However, one of its villagers received a *Kalpataru* from Indonesian government in 2011 for his devotion in greening the region. The result is that three springs in Tepus manage to keep the discharge during the dry season although the amount is less than in the rainy season.

Figure 6.8. Abandoned Communal Rain Water Tank for Agriculture Purposes, in Krakal coast Tepus (Author, 2013)

The farming system in Tepus is entirely rainfed field, with a *Tumpangsari* or inter-cropping system. Calculations based on the seasonal calendar are still applied for agriculture but also face uncertainty over time keeping on its cycle. Agriculture practices near the coast and western part of the sub-district show that there are abandoned water tank for watering the crops (see

Figure 6.8.). The rain water tanks were utilized once, but mismanagement has lost the farmers' trust.

6.2.1.6. Tanjungsari sub-district

Sub-district Tanjungsari covers Hargosari, Banjarejo and Ngestirejo villages which vave considered receiving Bribin II services. Currently, they receive Baron waterpiping services. In Tanjungsari sub-district, there at least 27 (doline) ponds. Water supply demand in the whole Tanjungsari sub-district is provided by PDAM Baron, beside the use of rain water cisterns (tanks) and mobile private water tankers. Some doline ponds have been rehabilitated within the last two decades, but 80% of the ponds have dried up or experience only short periods of rain water collection. Each village stated that they suffer from annual water scarcity during the dry season, but able to cope with the scarcity.

The agricultural system here follows the governmental program, coupled with the inherited knowledge from their ancestors. Most farmers copy their neighbors, demonstrating subtle social control and consensus, although a few develop individual break-throughs and innovations for their own land. People still acknowledge that *ilmu titen* or *Pranata Mangsa* is a good cultural heritage for them, but as agriculture guidance it faces great challenges because of climatic factors and environmental changes.

A governmental program on community empowerment national program called *Program Nasional Pemberdayaan Masyarakat* (PNPM) has helped to boost rural development (HOSSU, 2013), and one of the program is to develop accessibility. The access to mobile private water tankers is easier as the access of transportation developed through governmental program PNPM (FGD, 2012). Water scarcity during the dry season is an acceptable risk for rural Karst people in Gunungkidul, including the risk of agriculture failure. Therefore, people develop their local knowledge of coping with the harsh condition of conical hills in Karst Gunungkidul, by combining the knowledge inherited from their elders with their own experiences. However, the coping mechanism still reflects seasonally based and physical environment interpretation.

6.2.1.7. Paliyan sub-district

Paliyan sub-district has at least ten (doline) ponds. There are rural community based water management programs in three villages of Paliyan sub-district located between the Karst region and Wonosari Plateau. Boreholes are a community based water source, which is managed by the young generation aged between 20 to 35 years old. The funding and management system of the water distribution is supported by PDAM and the PNPM program. To conserve water availability from nearby sources and maintain the environment, villagers conduct greening activities that require continuous actions. The piping network supply connections only those household that are close to the main road access. PDAM water from Baron and Ngrenehan only supports domestic use, whilst people hope to use the water for agriculture. Farmers build rain water tanks to support agriculture during the dry season. They can identify which type of soil is suitable for particular crops, for xample red soil is suitable for groundnuts, soya beans, or corn/maize known as *Palawija*. People have developed the skill to read the landscape from the soil properties which then dictate a suitable farming system.

Agroforestry exists in Paliyan sub-district as part of re-greening and maintaining the livelihood of the people. Application of *Pranata Mangsa* for agriculture is still acknowledged, but the representatives said that only the elder farmers aged between 45 - 60 years old or 30-40% of the farmers apply. Agriculture is not an interesting occupation for the younger generation in Giring and Karangasem village. The elder farmers still use the traditional time frame to plant the seed, to do nursery and to harvest. An example is that seeding in November or December (in the *Pranata Mangsa* calendar is the sixth and seventh month), is considered too late and the harvest will not succeed as expected. Younger farmers usually follow the government instructions, but occasionally imitate or follow others. This behaviour is common to most Gunungkidul people. People in Gunungkidul, including farmers will imitate or follow the example (FGD, 2012 in Figure 6.9). Of individual or communal farmers applying *Pranata Mangsa* when the crops yield higher or increase.

Figure 6.9. Focussed Group Discussion in Paliyan sub-district (Author, 2012)

Paliyan agriculture is mainly rainfed field with T*umpangsari* system. During December to March farmers plant paddy, groundnuts, cassava and soya bean. Between April and August the crops are groundnuts, soya bean and cassava. Within one patch of farm field, we can find at least three different crops, but some farmers do cultivate one or two crops. The decision of what crops to cultivate is an individual decision, but communal behaviour also influences farmers' decision (SUNKAR, 2008; FGD, 2012). During the rainy season, the first rain onset can flood the field, thus farmers usually build up farm-dykes or gullies. People also optimize their home yard to cultivate corn, groundnuts, cassava, fruit trees or timber. Paliyan sub-district experiences disturbance from long tail monkeys which are located in the animal sanctuary nearby. In certain condition, particularly during prolonged dry seasons, the longtail monkeys take the farmers crops.

6.2.1.8. Saptosari sub-district

There are 21 (doline) ponds in Saptosari sub-district, but people have understood the need for rain water tanks (PAH) to support their water needs, especially since the ponds hold rain water for shorter periods than two decades ago. People use PAH during the rainy season to keep the rain water although the households have the household connection (SR) from PDAM. In the dry season, PAH's function is to save water from PDAM and the water that the households buy from mobile private water tankers. PDAM water comes from Baron and Ngrenehan. The water supply from both sources decreases significanty during the dry season. The longest dry season experienced by the people was eight months in the last decade (FGD, 2012).

Application of *ilmu titen* for agriculture is still being practiced by farmers and is initiated from a farmers' group. *Tumpangsari* crops in this sub-district show similar patterns to other parts of Karst Gunungkidul. The first haverst crop is paddy, which is cultivated during October to December/January. This crop is followed by corn/maize, groundnuts, and cassava. The people said that in the Southern part of Saptosari sub-district, close to coastal region around Krambilsawit, Kanigoro, and Planjan village, crops grow better than the other villages in the sub-district. Farmers still keep their haversted crops in the house to secure their daily needs, and paddy is rarely sold. Home yard or home gardening still needs to be ptimized according to representatives of villagers.

6.2.1.9. Panggang sub-district

There are at least 22 (doline) ponds, and 32 hamlets in Panggang sub-dstrict. Panggang sub-district is rich in cultural artefacts and ceremonial activties which are empirically connected to environmental issues. Each hamlet holds ceremonial activities related to natural cycle representing annual changes in the environment, i.e. *ruwat bumi*, *bersih telaga*, or other environmental clearing, one of which is known as *Grumbegan*. The annual activities may not contribute significantly to ecological management. However, it can be used as an indicator to evaluate and monitor the cultural shift or changes in the rural communities.

Agriculture is still dominating people's livelihood in Panggang sub-district with the *Tumpangsari* system, but some farmers have moved to a monoculture system. Seasonal based *Pranata Mangsa* is still applied, but is also adapted to government instruction, BMKG and the agriculture offfice. There has been a landuse shift from agricultural cultivation to monoculture forestry. Demand for teak wood for domestic and non-domestic use has affected the landuse and been made worse by the escalating price of basic daily needs. There is a saying "*tebang butuh*", that describes cutting down timber to be sold for urgents needs like buying water, or to pay for children's school costs. In the meantime, people admit that mixing cultivation or inter-cropping crops is an efficient strategies to optimize limited availability of land and water (FGD, 2012).

Panggang sub-district's annual rainfall ranges between 1870 - 2120 mm/year, but much of this can not be kept as surface water due to the porosity of the Karst region. People have developed rain harvesting techniques which started in the 1980s when the National Government gave aid to build rain water tanks (PAH). The current rainwater tanks with 3 m^3 to 9 m^3 capacity, can only save water for a maximum of three months during the three to six months of the dry season. Community based water management exists in this sub-district to support domestic water needs which are supplied by PDAM.

KUSUMAYUDHA (2005), classified Panggang sub-district into a Hydrogeological Sub-system (*Sub Sistem Hidrogeologi*/SSH) of Panggang with an underground water network leading to River Opak and Oyo. The people are aware that their surroundings provide sufficient water for their needs, but the depth of some groundwater remains outside some local people's capital capacity to access or explore with sophisticated technologies. Local people's water consumption is adjusting to annual availability, following the cycle from dry season to wet season. During the cycle, anomalous phenomenon might occur in accordance with global climatic conditions, particularly the ones common in equatorial zones. Water and land management are necessary in the region where the rain and physical setting affect one another.

6.2.1.10. Purwosari sub-district

Purwosari sub-district is located in the western part of Karst Gunungkidul and influenced by River Oyo and Opak microclimate. It has different Karst morphology compared to other sub-districts. Sub district Purwosari has 31 (doline) ponds, of which two or three still can be used in every villages even during the dry season. People have an annual ceremony to clean the area surrounding the ponds on certain dates acccording to the Javanese calendar after harvesting. The ceremonial event has become a cultural behavior, but for some people with "strong" religion beliefs consider it irrational or lacking scientific background to the younger generations. For elderly people in Purwosari, the annual events express gratitude to nature, which is an environmental ethic. The annual ceremony is also utilized to introduce environmental issues to the children by some of the elderly.

Pranata Mangsa is still applied for agriculture along with government instructions on farming activities. *Tumpangsari* is also applied in this sub-district, but the soil properties and water availability are different to other villages in other sub-districts in Karst Gunungkidul. According to Kusumayudha (2005), Purwosari sub-district is classified as a Hydrogeological Sub-system (*Sub Sistem Hidrogeologi*/SSH) of Panggang, the same zone with Panggang sub-district. Only well informed village representatives, who seek knowledge from many sources, can correlate the seasonal based *Pranata Mangsa* with environmental issues like climatic factors variability, global changes and the loss of biodiversity and forest.

Water supply in Purwosari is from PDAM, but people access water from boreholes, springs, rain water tanks and mobile private water tankers. Water pumping using solar panels once were developed in Giricahyo village, but no longer operated. However, people still can get the water from Giricahyo's underground water cave. The maintanance of water pumping system need to be adjusted to local culture in term of introduction and know-how fpr its upkeep.

6.2.1.11. Summary of the FGDs

Pranata Mangsa is still applied for farming throughout the sub-districts and villages in the Karst Gunungkidul, but is being questioned for its shifting time frame per *Mangsa* (clustered month). Farmers households reliant on rain-fed fields throughout all subdistricts in Karst region range between 80% to 90% according to the *Population Census* 2000 and the percentage was still in that range during the author's field observations in 2012 and 2013. Only the elder farmers aged between 40 and 65 years old apply the "traditional" forecasting system of the calendar. Meanwhile, the younger farmers follow the government institution's instructions, namely BMKG and the agriculture office, regarding the seasonal calendar. However, when the seasonal forecasting seems to fail in the field, for instance when the rain stops falling for longer than a month between October and November, then in the next planting season, the farmers use *Pranata Mangsa* guidance. When first being asked directly whether they still apply *Pranata Mangsa*, representatives of the villagers say it is used to calculate the time frame called "*itung-itungan*" for cultivation, also known as "*ilmu titen*" or keen observation.

Respondents correlate the application of *Pranata Mangsa* with the practices that they call "*Ngawu-awu*", a preparation of the land when seeding starts during *Mangsa Labuh*, even when the rain has not commenced. Farmers spread ashes on the soil to cover the paddy seed they have sown. Figure 6.10. shows a field that applied this method and with the paddy having grown for at least four to six weeks old. This method is the one considered "old fashioned". The "sceintific" background of the ash use has not been analyzed further and farmers are unable to interpret the method they inherited through generations. From a landscape gardening view, ash from the fireplace is useful for discouraging insects, adds lime and potassium to the soil. This helps control odors and neutralizes the pH of fertilizer compost. The wood type determines the nutrients of the ash, and the use of wood correlates with kitchen activities. The use of wood for fire in the kitchen was a tradition and adaptation to the environment of Gunungkidul which once had a high dense forest, but this has shifted to the use of liquefied petroleum gas (LPG) instructed by government less than a decade.

Figure 6.10. Ashes residual (see red circle), an evidence of "*Ngawu-awu*" tradition (Author, 2013)

The uncertainty of shifting weather has been recognized for two decades, but within the last decade it has become more "uncertain". Due to weather's importance in agriculture guidance, people have some understanding of the direct correlation of *Pranata Mangsa* to water availability and its management. However, at the field agriculture level, they understand that crops need certain amounts of water to grow and result in a good harvest. The inherited cultural behavior to store the harvest at home is still applied, and benefits from innovative harvest yields that last longer because of good quality.

Phenology or bio-indicators of annual season change from dry to rainy season are easier for people to follow and understand. For instance people understand when the leaves of tamarind tree bud and blossom and when the yam shoots blossom, the rainy season is starting. The blossoming leaves indicate enough humidity and temperature for plants to grow and this reasoning makes sense to younger farmers. However, representatives of all villages are unable to correlate environmental or ecological disturbances to the loss of biodiversity which are used as phenology proxies. They point out that the big old trees used to be the shifting annual season indicators, but these have been cut down due to economic reasons, or were considered useless.

Water scarcity is not considered as a hazard or a risk, rather it is just an annual cycle. However, it is a risk when correlated to economic reason, lack of water forces people to sell their livestock, timber, or other belongings. In the research locations, water pricing was not considered by the community to be an issue as long as the water runs as intended and those who use a lot water pay the amount based on the standard price. The piping water project was established between 1991 and 1993, but has had no significant influence on the water supply. People still need to buy mobile private water tankers during the dry season. People buy seven to eight water tankers worth of per household, which consist of 5 litres per tank and cost 130.000 IDR per tank or equal to $ US 13. The water can last between 3-5 months during dry season in a household with three to five members. During observation conducted by the KIT team between 2000-2009, showed only a slight difference discharge from Bribin cave caused by temporary changes in the precipitation characteristics in the region (BRUNSCH, ADJI, STOFFEL, IKHWAN, OBERLE, and NESTMANN, 2011 and NETSMAN, OBERLE, IKHWAN, STOFFEL, SOLICHIN, 2013).

The water demand and use are determined by the household size and the number of catlle they own. The representatives of all villages during discussion agreed that the combination of water sources, from rain harvesting tanks (PAH), doline ponds or *Telaga*, springs, boreholes, mobile private water tankers, and PDAM are the most suitable strategy to manage their water needs for domestic use. Water for agriculture on Karst Gunungkidul depends on rainfall and the most suitable crops farming system is *Tumpangsari* and Agroforestry to support people's livelihood. Water efficiency starts at household level. Grey water from domestic use is re-used; rice cleansing waste water can be added to the cattle fodder and dishes or cloth washing waste water can be used for watering the homegarden or homeyard plants and to flush the toilet.

6.2.2. In-depth Interviews

In-depth interviews were conducted with key informants who are considered knowledgeable on culture, inherited traditions and local behavior based on their experiences and observation as an individual and community member. The key informants were identified during Focused Group Discussion in the villages and sub-districts, showing prominent or different understanding of local knowledge compared to other villages representatives. Their age ranged from 40 to 60 years old, which indicates that the inherited seasonal based and the phenology or bio-indicators attached to such knowledge is considered "old fashioned" to younger farmers or people. However, all respondents understand the use of phenology or bio-indicators as proxies to annual seasonal changes. Seasonal based knowledge and the physical features of adaptation in Karst Gunungkidul are gained by imitating and experiencing, whilst minimizing the risk due to limited sources of availability.

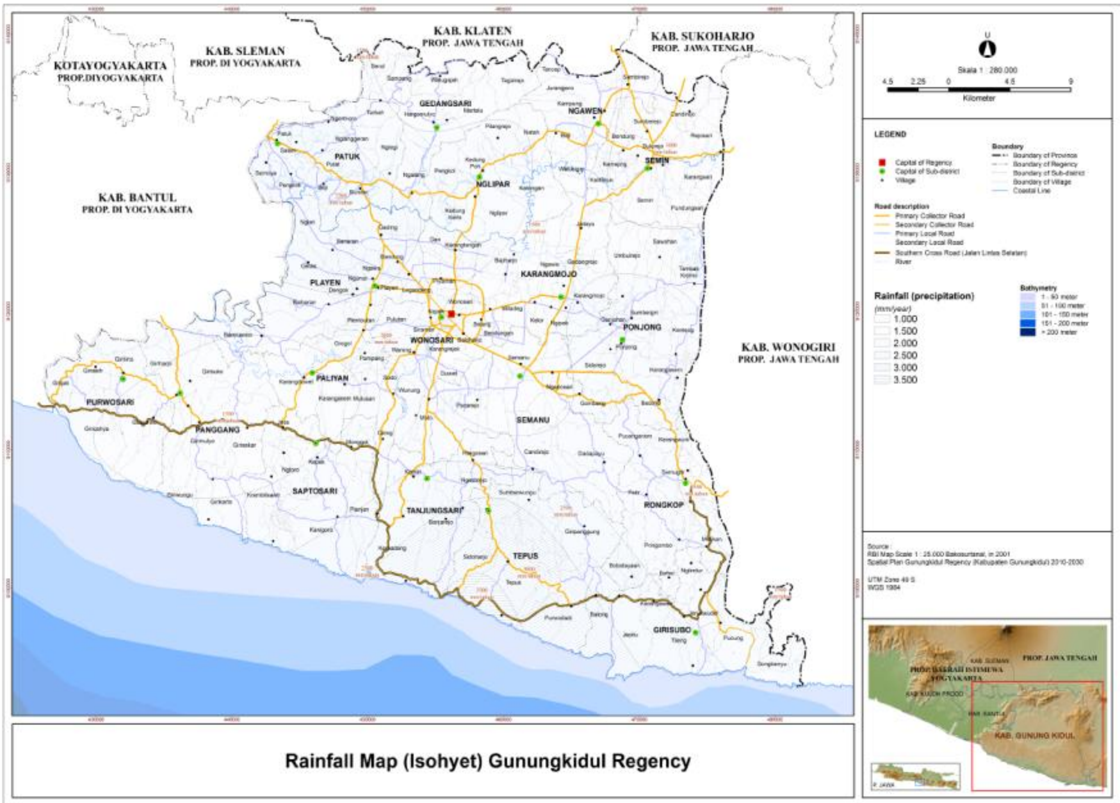
6.2.2.1. Walikangin, Ngestirejo, Tanjungsari

The key informants from Ngestirejo village, Tanjungsari were male, 45 and 50 years old, farmers and had also served the village administration (see Figure 6.11). Both respondents stated that *Pranata Mangsa* is still used and applied by 30% of all farmers, and the remaining 70% of farmers follows government instructions (forecasting system). *Pranata Mangsa* is considered as a tradition in agriculture. People have lost their trust against its forecasting accuracy due to the shifting time frame each month. However, forecasting from the Meteorological agency (BMKG) also sometimes miscalculates. Hence, the 30% of farmers apply *Pranata Mangsa* calculation, whilst the others are actually waiting to start seeding just when the rain starts falling.

Figure 6.11. In-depth interview in Ngestirejo, Tanjungsari (Author, 2013)

The keen observation of annual environmental changes, known as "*ilmu titen*" by the repondents is following the natural cycle changes. They understand that human behavior influences nature's cycle and its timing. Personally, one of the respondents said that he starts to spread seeds only when the rain start to fall, not necessarily following the calculation of *Pranata Mangsa*. However, he develop his own keen observation from his surrounding based on phenological approach. He recognizes when the season is about to shift by observing the mango tree on his home yard, when the leaves start to blosom then it is time to start seedings.

Knowledge of weather between villages and sub-districts is represented by rainfall onset differences, related to land and water management afterwards. Respondents said that when the rain starts from coastal region in the Southern part of Karst Gunungkidul, the crops yields would be good. When the rain onset is from the Nothern part, the crops yield would not be good and pest disease could occur. There is no scientific analysis of this observation, but microclimate factors, geographical differences and land cover (vegetation) might be involved. In correlation with people's keen observation, the Isohyet Map shows that the southern part annual rainfall is between 2500-3000 mm. In some parts of Saptosari, Tanjungsari, Tepus, and Girisubo, rainfall is higher than in other parts (see Map 6.2). Local micro-climate knowledge and recorded data from government institutions can be managed and shared between farmers. Most people remember extreme weather events talked about by their elderly relatives and experienced in their own such those *Pegaber* era (*jaman pegaber*) in 1963/1964 and extreme weather in 1997/1998. These events were years of extreme weather for the Southern part of Java according to BMKG in correlation with ENSO.



Map 6.2. Rainfal Map (Isohyet) Gunungkidul Regency (source: Gunungkidul Regency Spatial Plan 2010-2030 and Author draft 2014)

6.2.2.2. Sumuran, Kemadang, Tanjungsari

Sumuran hamlet is located in Kamadang village, Tanjungsari sub-district, close to a water source and the infrastcture of PDAM in Baron. The key respondents are Mbah Pujo who is nearly 70 years old and Pak Mendot who is 45 years old. Mbah Pujo is a person who is considered to be the respected elder in the village, with inherited local knowledge from the previous elder before him. Whilst Pak Mendot is a puppeteer, who plays *Wayang* puppets considered as knowledgeable on cultural aspects. The age difference of both respondents reflects the degree of inherited knowledge on water, land and cultural behavior in their region.

Mbah Pujo said that the village used to hold a ceremonial event in response to extreme weather occurences once every eight years. The ceremonial event time frame correlates to the osciliation type of ENSO occurrence in the zone where Southern Indonesia is located (RASMUSSON, 1987). Other ceremonial activities are usually conducted annually, before and after havesting time and these have become tradition. The traditional ceremonies are related to environmental issues and climatic factors, but are considered irrational to others, in particular when related to religion. For example, there is a water source which can support the village's water needs and is considered sacred. Thus on certain dates Mbah Pujo cleans the area surrounding the water source. The water source is actually a perched aquifer which was discovered using an electric sounding system in the 1980s by a missionary. However, the water source had already been dried up for the last decade. At the time this research was conducted, fresh water for domestic used is supplied from PDAM's Baron piping network system, but residents still use rain water tank and private water tanks when needed during the dry season.

Doline ponds used to exist until the 1980s, but all these have dried up or keep rain water for only a short time (one or two months) after the rain stops falling. The shifting rainfall time frame according to Mbah Pujo's observation started in the 1940s in correlation with *Pranata Mangsa* annual forecasting. *Tumpangsari* is applied on rain-fed fields in Tanjungsari, coupling with *Tajarwo* method (see Figure 6.12) *Tajarwo*, shorts for *Tata Jajar Kiwo*, a paddy cultivation method optimizing space and water consumption, introduced and taught by the agriculture departement. *Tajarwo* uses column and row calculation in considering that each group of paddy require an amount of space and water to grow.

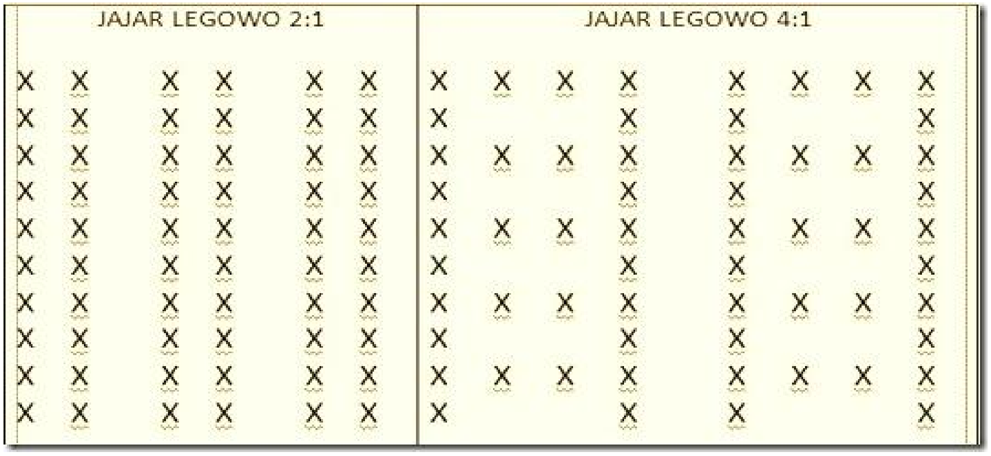


Figure 6.12 *TAJARWO* (*Tata Jajar Kiwo*) method for Paddy Fields (source: Agriculture office, 2013)

People cultivate different crops on different topography, a spatial consideration of risk applied. Lowland is cultivated witth paddy, higher fields cultivate cassava and the highest hilly fields are used for timber. Farmers have developed keenness observation or "*ilmu titen*" on soil properties from the texture and color. Farmers recognize that paddy growth is optimum when staged on black soil, while on the red soil yield less (harvest) unless more fertilizer and water is used.

Keen observation surrounding changes and the reasoning knowledge of annual ceremony as a response to climatic factors is not drawing the attention of younger generations or those people who consider the inherited local knowledge to be against their religion. Knowledge transfer from the elders like Mbah Pujo is conducted by story telling and Pak Mendot uses the puppet (*Wayang*) performances. Mbah Pujo has begun recording all his knowledge into documents, a transfer and transformation of tacit knowledge to explicit knowledge. This knowledge management at an individual level with the possibility of sharing with othersthat develops communal knowledge management.

6.2.2.3. Singkil, Giring, Paliyan

They key informant from Singkil hamlet is Mbah Darmo, a 60 year old, farmer who used to serve the village administration (see Figure 6.13.). He experienced the process and application of Agrarian Law in Indonesia during the 1960s, in the shift from Colonial law. The shifting landscape from his observation is due to cultivation system. Hills used to be planted for food crops, but it has been changed within two decades. Agrofrestry and the *Tumpangsari* farming system support people's livelihood in Paliyan.

Figure 6.13. In-depth interview in Paliyan sub-district (author, 2013)

The application of *Pranata Mangsa* and "*Ngawu-awu*" to those who wait for rainfall is 50% : 50% among farmers. The application of inherited knowledge *Pranata Mangsa* is also correlated to the more land a farmer owns and cultivates. Mbah Darmo suggests that farmers who own land 0.5Ha or bigger, apply *Pranata Mangsa Mangsa Labuh Kapat* in early October before the rain onset, to reduce the cost of labour compared to starting land preparation and seeding after the rain starts falling in November. Another individual invention and adaptation is to add fungicide during the seeding period to prevent fungus during the vegetative stage. Mbah Darmo adapted and modified *Tajarwo* from early 2012 on his field and then imitated by other farmers when his crops yields increased. Transfer of knowledge is important using example and personal approach according to his experiences.

Paliyan sub-district is one of the areas where the Southern road network (*Jalur Jalan Selatan*/JJS) connects the Southern part of Java island. The opening of the main road slightly changed the accesibility of people and influenced the piping network from PDAM. Before the JJS was built, the PDAM network was limited. However, the distribution of water is still only a maximum three time per week, and during the dry season this amount decreases. The use of rain water tanks, and mobile private water tankers provide optional water supply. Water is indeed a crucial element for living creatures. There is a local saying and advisory related to water management and livelihood: "*Boros air, boros rejeki*" which means "in-efficient use of water or lavish water use, would decrease livelihood or prosperity". This saying is characterized the people of Gunungkidul who use water wisely, but it might change when the access to water imrpoves and cultural values shift. Before the 1980s, farmers still used water buffalo to plow the farm, and their steps left footprint tracks filled with rain water during the rainy season, and the water in the footprint used to be consumed.

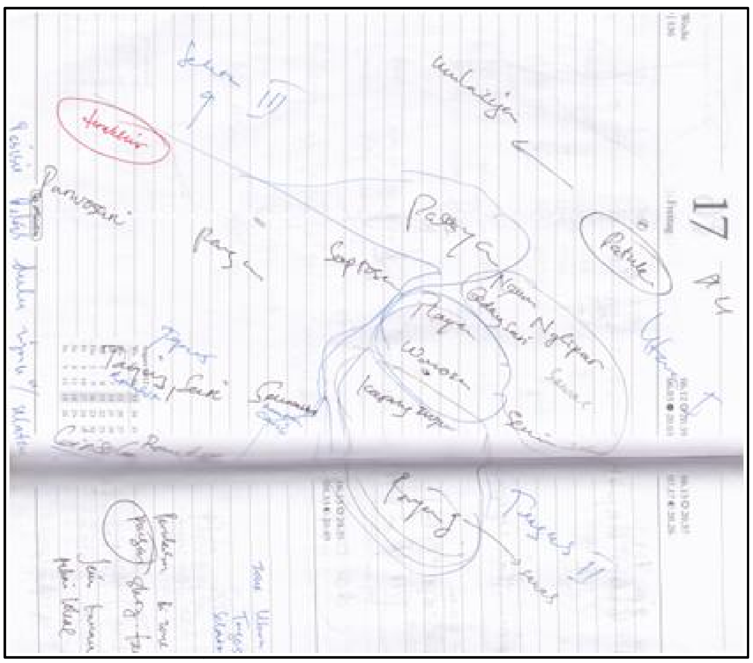


Figure 6.14. Local Spatial Knowledge of Rain Onset Observation (key informant's knowledge)

The key informant revealed his cognitive spatial knowledge regarding the rain onset based on his experiences and understanding (see Figure 6.14). As revealed by other key informants in this research, when the rain onset starts from North, the crop growth is not optimum. When the rain onset commences from the Southern part on the coastal area Gunungkidul, the crop yields reach optimum growth. However, the respondent was unable to describe the reasoning of the phenomenon, but stated that it must be a correlation of Karst landscape, climate, and coastal influences.

6.2.2.4. Jeruk Wudel, Girisubo

The key informant from Jeruk Wudel village was Pak Wasiman, 47 years old, a farmer and work for village administration. He stated that 95% of the village population are farmers growing the same type of crops annually. Seasonal based knowledge *Pranata Mangsa* is still applied as guidance in agriculture, adapting to changes and innovations introduced by the government's agriculture and climatology institution. He argued that the forecasting from governmental institution is 100% reliable, based on his observation and experience. He would rather read natural signs, following the phenology or bio-indicators to start cultivation. Land preparation is conducted during July and finishes in August. The seeds are spread in September, whether or not the rain falls. This system follows *Pranata Mangsa*, using "*Ngawu-awu*". Meanwhile, some farmers wait for the rain onset before starting seeding. The distinct difference between those who apply *Pranata Mangsa* and those who wait for the rain onset is the timing of starting cultivation. The remaining agriculture actitivities until harvesting time are similar, such as nursery, adding fertilizer or harvesting. Due to the difference in the beginning cultivation, the harvesting time is also different.

The agriculture departement have introduced *Tajarwo* to managing space and optimize the available water for crops. In Pak Wasiman's experience, the method is high cost in operational activities, but the crop yields increase compared to those who farm their fields using the *Tumpangsari* system on paddy fields. He admits that *Tajarwo* is most appropriate for paddy cultivation, but farmers sometimes adapted and modified it to the crops they plant in accordance their needs (see Figure 6.15). The popular cultivated paddy type are IR 64 or Ciherang with short cultivation time which were introduced during Indonesia's green revolution program in the 1970s. In Gunungkidul, the main type of local paddy has a red color with good quality, but requires extra time, nursery or operational works. The government institution suggests farmers should cultivate other types. Farmers can identify which soil type is suitable for paddy, ground nuts, corn, cassava, or even timber from local knowledge. The red soil is suitable for crops like groundnuts, corn, soya bean. The black soil is for paddy mainly, and the combination soil type is mix.

corn	paddy	corn	paddy	corn	paddy
corn	paddy	corn	paddy	corn	paddy
corn	paddy	corn	paddy	corn	paddy
corn	paddy	corn	paddy	corn	paddy

Figure 6.15. Tajarwo Adaptation on a Field
(20x20 cm or 20x40cm per crops distance)

The rain onset starting direction is also observed by Pak Wasiman. When rain onset starts from the Southern part or coastal area, the whole part of Karst Gunungkidul will have a good harvest. When rain onset starts from the Northern part, then there will be harvest failure and possible pest outbreaks. For example when rain starts from Rongkop sub-district, it indicates the crops will fail in the Southern parts like Girisubo and Tanjungsari sub-districts. Pest outbreaks occur in certain weather conditions on certain physical features. For example certain worms or maggots, called *Menthul* in local name, which consume crops' roots occur during a moderate rainy season on red soil (clay soil).

Ndompol doline ponds in Jerukwudel were still used until 1969, and then gradually dried up. But, another doline pond emerged in 1976 called Wotawati, which had been an open field. Before the 1980s, water from ponds was still utilized for fresh water. Economically poor households use water from ponds as their main water source during the dry season, supplementing with rain water tanks, in combination with PDAM and mobile private water tankers, which cost them some money. The vegetation near the ponds used to be green, but the landscape has changed since 1966. Since 2000, agroforestry has been introduced to Girisubo people and now gradually supports people's livelihood.

6.2.2.5. Gabug, Giricahyo, Purwosari

The key informant from Giricahyo village is Pak Paridja, 43 years old, the head of Gabug hamlet. Pak Paridja revealed that 60% of farmers still follow *Pranata Mangsa* and 40% of farmers wait for the rain onset to start seeding and cultivation. Both groups actually take the same risk due to the shifting rain pattern uncertainty in the field. *Tumpangsari* inter-croping system meant two decades ago all seed was spread on the field without calculating the space, but gradually this has changed following government institution instructions. All seed was spread in accordance with local biodiversities and food stock. Phenology indicators using yam tube plants is still applied, but the plants grow wild on the hilly and non-productive land, and are not intentionally growth. The application of *Ngawu-awu* is adapted to the topography of the field, which is hilly and steep with additional fertilizer applied to manage the crop growth. On the low or flat land, farmers wait for the rain onset amd apply *TAJARWO* method. There is a spatial consideration in the application of seasonal based calendar *Pranata Mangsa*. The stonewalls of field terraces need to be re-newed annually according to Pak Paridja experience and observation, by adding stone 10 cm higher due to erosion process. Therefore, we can predict the age of a farm judging from the stonewall terrace height, because the terrace is also inherited.

Domestic water needs are supplied from PDAM, rain water tanks, private water tanks, ponds, and cave water. Cave water Plawan was first pumped using solar cell power but then shifted to diesel power due to maintenance problems. The management is run by local people who, in consideration of the cave location on private land, distribute 60% of the water to the community and leave the remaining 40% belongs to the land owner.

Pak Paridja has observed that the Southern zone of Gunungkidul is the last region to get the rainfall, where Ponjong and Paliyan sub-district is the region of first rainfall. The southern part receives less rain water compared to the others. In 2013, the rain started to fall in early November but then stopped for more than a week. The impact was the occurence of worm or maggot that ate crops' roots. Ceremonial events related to extreme weather used to be held, but nowadays it is only an inherited traditions.

6.2.2.6. Giriharjo, Panggang

The key informants from Giriharjo were the head of the village, and two administrative officers of the village, whose age ranged between 30 and 45. There are three amlets in the Southern part and three in the Northern part of the village. The village depends on the rainfall to start cultivation. The northern part can cultivate crops using nursery seedling method in certain patches, whilst in the Southern part they spread the seed on the land. When the first rainfall starts, the villagers initiate the seeding period. The comparison between farmers who depend merely on rain onset and those who start seedling using "*Ngawu-awu*" following *Mangsa Labuh Kapat* in *Pranata Mangsa* is 70% : 30%. *Ngawu-awu* method starts the seedlings in the middle of September, whilst the other depends on rainfall starting in November.

The awareness of climatic factors has been initiated by farmer groups (*Kelompok Tani*) in coordination with Meteorology and Climatology Board (BMKG) and agriculture office representative in the sub-district. Thus, understanding of climatic factors shifting from seasonal based *Pranata Mangsa* has been gradual due to the shifting pattern climate. Loss of phenology or bio-idicators to identify the annual shifting of seasons has also gradually left, although some people still know certain plant stages indicating annual seasonal change. Agriculture following *Pranata Mangsa* knowledge is considered old fashioned, not modern. Innovation in agriculture and agroforestry is introduced and socialized through farmer groups and a mentor from the agriculture office. *Tajarwo* cultivation system has been applied and the most suitable land is the flat farm field. On sloping fields, cash crops or *Palawija* are most suitable, with some mixing cultivated timber. In 2004, farmers experienced crop failures due to less precipitation, and pest outbreaks.

Water supply in Giriharjo village comes from the PDAM Baron network for domestic needs. Additional supply comes from Banyumeng solar energy water pumping, rain water tanks and mobile private water tankers during the dry season. Three ponds in the village are utilized for cattle needs and surrounding fields. Rain water tanks can hold rain water for up to five months, but the utilization depends on the households needs. Water sources in Panggang sub-district contain less carbonate sediment compared to other Karst Gunungkidul sub-districts, unless the water comes from PDAM Baron piping netwotk.

The key respondents said that the rain onset pattern in Panggang sub-district usually starts from the Eastern part of Gunungkidul, such as Girisubo sub-district, then spreads to the West and turns to the coastal area (the Southern part Karst Gunungkidul). When the rain starts from the Eastern part, there will be a "break" in Paliyan sub-district, locally called *Betatan* for more than two to three weeks which influences the crops' growth. When the rain onset start from Panggang, it will rain continuously with the possibility of breaks of less than a weeks duration.

6.2.2.7. Semanu

They key informant from Semanu is Pak Supoyo, who is 50 years old and a farmer and who also serves the village administration. In his observation, the Southern part of Semanu is rain-fed field, whilst the northern part resides partly on the border of Wonosari Plateau and Karst Gunung Sewu. *Pranata Mangsa* is still applied in agriculture. The green revolution was introduced in 1980s and farmers started to cultivate non-local paddy types, such as IR 36, IR 64 and Ciherang from 1983. People's food shifted from consuming cassava (starch) to rice, and those who still consume dried cassava are considered "poor" economically. Rice has become the symbol of wealth and prosperity in Gunungkidul.

Pranata Mangsa is adapted to recent changes in rain onset time, depending on the month when rain starts in the fields. When the rain starts from September, there will a break or stop within several days. When the rain starts on October, it will continously rain. Pak Supoyo observes and recognizes that when the rain falls in the Southern part, the crop's yield will be good. On the contrary, when the rain direction is Northerly, there will be a failure or less crops yield. The shifting time of *Pranata Mangsa*,with the first rain is anticipated by practicing good land management, such as adding fertilizer in his experience.

6.2.2.8. Summary of In-depth Interviews

Seasonal based calendar *Pranata Mangsa* application is being gradually abandoned, in terms of time frame stages for cultivation. The essence of keen observation of annual season change still depends on the climatic factors. Knowledge of seasonal based phenomenon is adapted to recent conditions, with the main climatic factor used as an indicator being rainfall onset. Key informants represent the cognitive local knowledge of rural Karst communities in Gunungkidul which testify that scientific research in the field and a knowledge management between rural people and experts is validating a conceptual framework and theory. Key respondents test the scientific theory by experiencing it themselves and end up deciding on their hypothesis. Phenology or bio-indicators knowledge of shifting annual season change parameters is still used, but is also gradually being abandoned since people are unable to correlate the environmental issues with the ethics from the knowledge.

The older the respondents or key informants, the more tacit knowledge can be collected in the temporal dimension. This knowledge needs to be validated by available recorded knowledge or explicit knowledge, transforming tacit knowledge to explicit knowledge. Elderly people still recall some old sayings related to conserving natural resources to sustain livelihood. For example, "*Boros air boros rejeki*", means that water is so crucial to their livelihood. The values of such old sayings is challenged by social and economic changes followed by cultural change, for instance households who can afford to buy water during the dry season from mobile private water tankers utilize much more water compare to those who are considered less fortunate (if not poor economically). Beside the use of water from doline ponds, farmers in the field consume water from water buffalo mudhole footprints as an optional in three decades ago, a strategy similar to pastoral tribes in Africa and their mobility herding system in dryland. The use of buffalo for ploughing (see Figure 6.16.) in Karst Gunungkidul had vanished before the 1980s.

Figure 6.16. An Illustration of Water Buffalo for Ploughing[15]

Household water and land management shows similarities and differences. it is correlated with social and economic condition, family members, and communal behavior or social values. Main water sources for domestic needs are rain water tanks (PAH), PDAM, springs or cave water, mobile private water tankers and doline ponds. During the rainy season, water from PDAM contains high sediment loads of carbonates and mud mixed, whilst during the dry season the water contains less sediment but also less discharge. Hence, mixing or combining water sources is still most suitable as an adaptatation strategies for rural Karst Gunungkidul people to cope with water supply and its availability. People in Karst Gunungkidul have developed water saving on domestic use, i.e cooking, washing clothes, or taking a bath. If scientists urge people to re-use grey water, rural people in Gunungkidul are already aware of their water due to its limited availability and economic cost. Awareness increases when they experience it.

People have inherited the knowledge to read Karst landscape through water condition and soil properties, which transform into water management at household and community level and the cultivation (farming) system using inter-cropping *Tumpangsari*. Knowledge of soil properties (see Figure 6.17), inherited through generations and tested by individual and communal experiences, is important and needs to be developed further. Local

[15] http://commons.wikimedia.org/wiki/File:KerbauJawa.jpg, accessed on 17th January 2014.

knowledge of physical features, particularly soil properties, can be developed as Pedology Cognitive Map, in collaboration with "non-local scientists" with scale consideration.

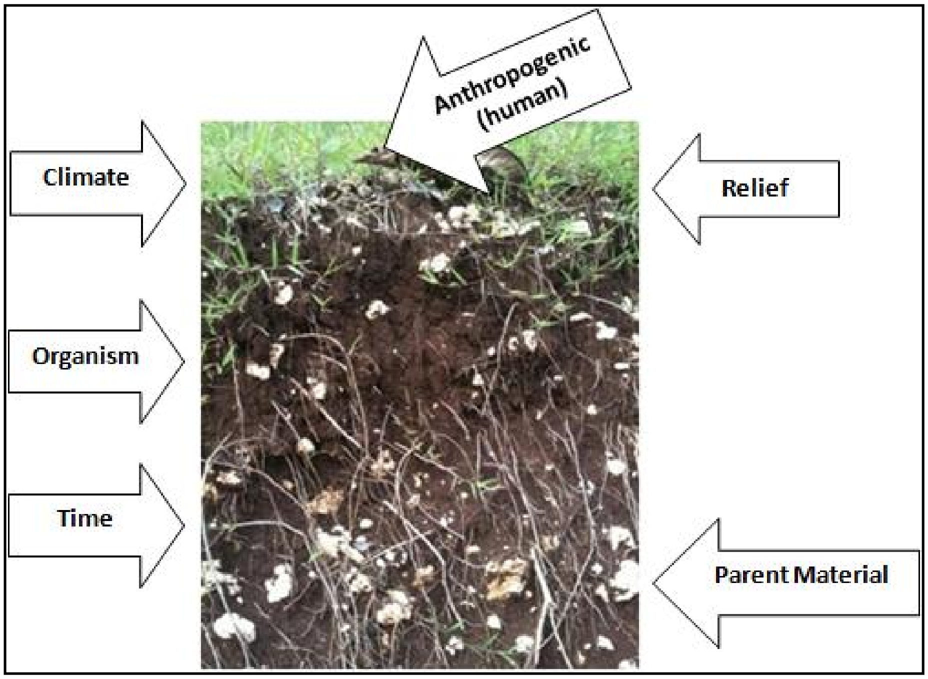


Figure 6.17. Local Knowledge on Soil Properties to Pedology Cognitive Map (Author, 2013)

Knowledge management from tacit knowledge to explicit knowledge has been initiated through farmers groups, in cooperation with Government institutions, namely meterology and climatology board (BMKG) and agriculture and forestry office. Knowledge of rain onset due to microclimatic factors is important to sharpen individual and communal knowldege, skill and capacity. By sharing, discussing and transfering knowledge, people's capacity to cope with uncertainty environment changes can increase. By understanding where rainfall first starts for instance, farmers develop adaptation and mitigation strategies to cope with crop growth or failure.

Soil is an important factor in Karst ecological system. Knowledge of soil properties based on local charateristics leads to adaptation, founded on the experiences and learning from inherited knowledge which is communally applied. Local taxonomy has not been developed in Karst Gunungkidul, yet farmers have applied their local knowledge. Local indicators for allocation of land for agroforestry, cropland and grassland are steepness of land (slope), soil color and texture (fertility), and relative location of land from village (topographic position of land and location). A community in Damote-Sore have also used knowledge of indigenous soil classifications and indicators of soil fertility to distinguish soils of different quality (HERWEG, 2002:679). Local or indigenous knowledge can be used in allocation of land for various purposes. Local people's insights, perceptions and management strategies are often attuned to local soil conditions and can offer guidance for realistic land management.

Local understanding of the seasonal calendar and the bio-indicators can be assessed from household level and community level in a collective way and represents heterogenity among homogeneity (interview with agriculture lecturer, 2012). The application of the seasonal calendar depends on observations, experiences and evidence. Each patch or matrix of land, represents household or the communities knowledge.

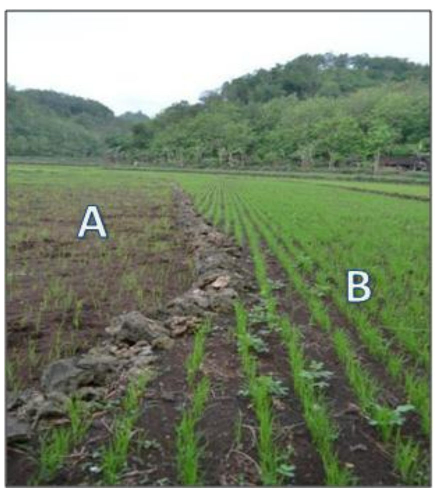


Figure 6.18. Different understanding of cropping system (A) old way practiced *Ngawu-awu*, (B) adaptation of *Tajarwo*; at Tepus sub-district on the coastal area (Author, 2013)

Figure 6.18 shows different applications of cultivation systems. Both farmers still consider of seasonal based local knowledge, but field (B) has adopted and adapted recent farming system *Tajarwo*, whilst field (A) applies the traditional farming system *Ngawu-awu* derived from understanding of the *Pranata Mangsa* cycle. Morphological, topographic and landcover/landuse differences, and the micro-climates on Karst Gunungkidul landscape might seem similar, but in the field level it shows differences in each application of understanding and interpretation of inherited local knowledge.

6.3. Knowledge Discovery and Knowledge Management of Local Knowledge in Karst Gunungkidul

6.3.1. Knowledge Discovery

Knowledge of historical landscape conditions and the changes over time is significantly important for documentation in correlation with planning and managing human footprint on Earth as heritage, but challenges arise due to scale and the link to social and ecological data (TURNER, CROW, LIU, RABE, RABENI, SORANNO, TAYLOR, VOGT, and WIENS, 2002; BENDER 2009:131). Ecological and socio-economic aspects of cultural landscape change have been the object of many studies of the landuse change and landscape's cultural historic value.

Knowledge discovery from keen observation or *ilmu titen* characterized by cognitive knowledge of people in Karst Gunungkidul. *Ilmu titen* is an embedded knowledge which is locked in processes, products, culture, routines or structures (HORVATH 2000, GAMBLE and BLACKWELL 2001). It is also embodied knowledge which bond in human. That is how the seasonal based calendar *Pranata Mangsa* was discovered through long term observation processing that became embodied within the people. Keen observation plays a role in discovering knowledge through time with trial and error, leading to the success of individual and communal.

6.3.2. Knowledge Management

Knowledge management is community enabling – policies and processes promote and support knowledge based community working across and between departments. People, processes, and technology are the main subjects in knowledge management that are necessary for implementing the tools and techniques. Knowledge management is the systematic management of information to develop strategy and guide practice. Capture and management of knowledge as an asset is the concern of mainstream knowledge management. It is about facilitating knowledge work practices rather than the management of information assets or knowledge (URIARTE, 2008) According to LINGER, AARONS, McSHANE, and BURSTEIN (2013), knowledge management may be viewed in terms of:

a) People – how you increase the ability of an individual in the organisation to influence others with their knowledge. The social network distributes information between and inter groups.
b) Processes – The approach varies from organization to organization, depending on local global interests or the issues for the different actors involved.
c) Technology – It needs to be chosen only after all the requirements of a knowledge management initiative have been established. Technology and innovation adaptat to actors or information providers, enabling rather than being the solution.
d) Culture –The biggest enabler of successful knowledge-driven organizations is the establishment of a knowledge-focused culture. Culture may vary in definitions, but in this case it is what people have already known and applied, yet possible to be changed, adjusted or adapted in the process.
e) Structure – the business processes and organisational structures that facilitate knowledge sharing.

Social networking among younger farmers, through social media which is popular recently, can be used to do some kind of storytelling to transfer such knowledge among them in a community or when in discussion with outsiders. It should be noted that knowledge holders in each new generation adopt and adapt and then added to the body of knowledge in a constant adjustment to the changing environment. In present times, the creation of knowledge is complex; its sharing requires diverse tools for translation, conversion, filtering and a two-way communication and interaction. The indigenous, local, or traditional knowledge system needs to be approached in a holistic manner, while still considering the aims of research.

6.3.3. Introducing *Pranata Mangsa* to Knowledge Management

The keen observation system of seasonal based knowledge *Pranata Mangsa*, is tested through time and generations. Acessibility to data and information, documentation difficulties and unorganized and overlapping tasks in water and land management in the institutional organization from regional to local level, all impact on applying knowledge management in Karst Gunungkidul landscape management. The triangular supporting system between scientists, practitioners, and communities circulate their knowledge sharing. *Pranata Mangsa* is tacit knowledge (see Figure 6.19), therefore understanding and interpreting the essence of it requires skill from multiple sources, validated or correlated with scientific knowledge.

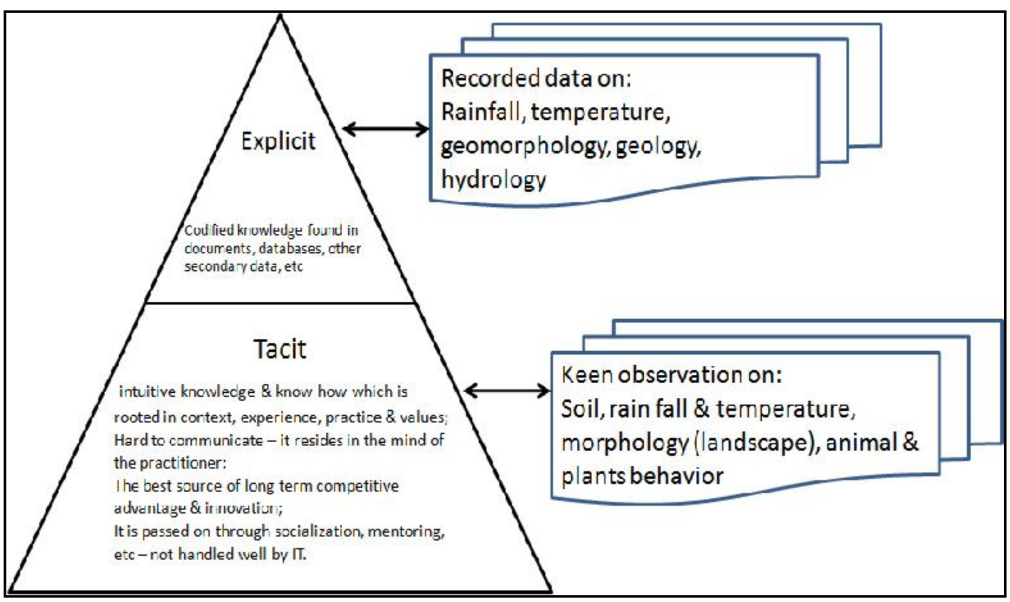


Figure 6.19. Knowledge derived from *ilmu titen* or keen observation (modified from FROST, 2013)

Pranata Mangsa consists of information about human and nature relationships, particularly data and information on climatic factors and the stages of vegetation support with animal behavior. Together with social economic changes, *Pranata Mangsa* needs to be developed as an evolving knowledge in adapting to the dynamic changes of human community. This, in line with idea that knowledge managment is to arrange, organize an environment where people are invited and facilitated to apply, develop, share, combine and consolidate knowledge based on their and others experiences, observations, perceptions, understanding and values.

Figure 6.20 shows how the taxonomy of knowledge management is adapted to build a framework of local knowledge system from seasonal based model to address risk reduction efforts following uncertainties changes due to climatic factors. The culture of keen observation on seasonal changes coupling with physical features adapation knowledge become embodied and embedded identity for rural Karst people Gunungkidul. Ethnometeorologists and Phenology approach are included into embodied and embedded knowledge management.

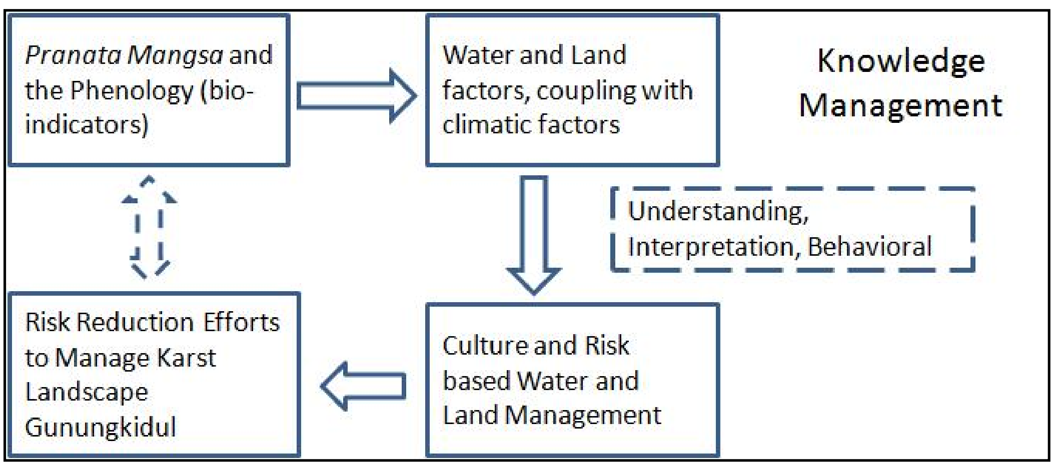


Figure 6.20. Knowledge Management Model on seasonal based local knowledge for Karst Gunungkidul Landscape Management (Author, 2014)

6.3.4. Embodied and Embedded Local Knowledge

Local knowledge is preservable, transferrable, and adaptable in different locations, but physical and socio-cultural settings will determine the application of the knowledge. Local practices vanish or are adapted when they are inappropriate, or in the face of new challenges. However, many practices disappear because of the intrusion of foreign technologies or development concepts that promise short term gains or solutions to problems. Local knowledge is a part of people's lives. The economically poor groups depend, almost entirely, for their livelihoods on specific skills and such knowledge is essential to their survival.

Proper planning is required to "educate" farmers to cope with the shifting or changing climate, and uncertaintes changes, to encourage related institution to think archivally to bridge the knowlege gap among generations through social, economic, and cultural changes. Farmers are most vulnerable in response to climate variability, yet they have the capabilities to cope with, adapt to and develop mitigation strategies in changing conditions. They are able to notice which climate factors are shifting by the length of rainfall months. Adapting, coping and inventing such behavior to limited availability of water and land correlate to food security and reducing the exposure of livelihood risk to farmers in Karst Gunungkidul region, who are adressing rapid natural environment changes. Inherited knowledge from previous generation is evolving as a result of intellectual capital (see Figure 6.21).

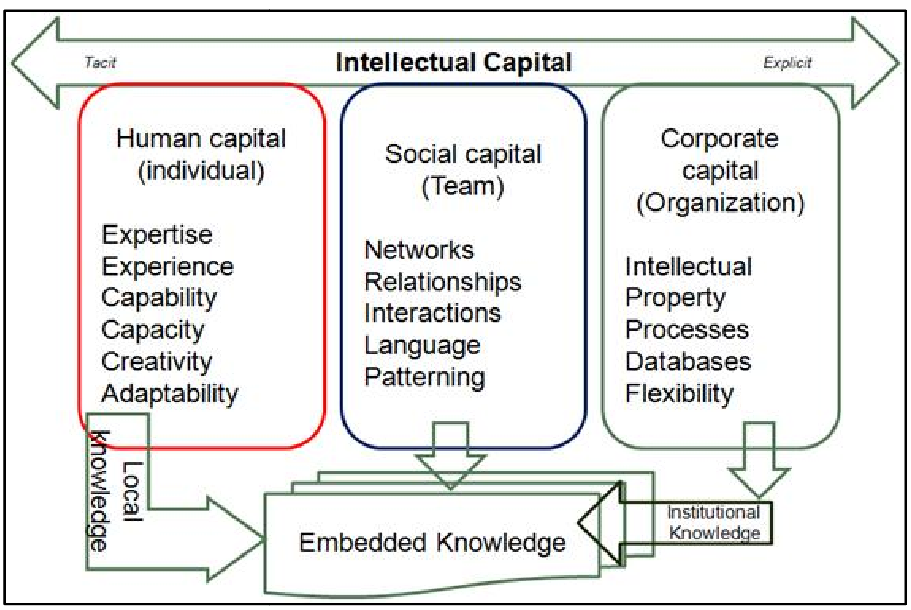


Figure 6.21. Embedding Knowledge using triangulation Intellectual Capital Model (adapted from WIIG, 1997)

Local farmers and their institution are a part of knowledge management in agriculture and related fields. Some farmers and other beneficiaries have an understanding and wisdom of seasonal based knowledge that is inherited and then applied depending on their perception and evolving experiences. *Ilmu titen* or keen observation of the surrounding environment is the basic skill to develop seasonal based knowledge and physical features adaptation. "*Ilmu titen*" or keen observation is validated within long life experiences as cultural identity.

Pranata Mangsa is the product of long, historical keen observation based on dynamic changes of climatic factors (variability) and validated using plant and animal behavioural changes. Thus, the knowledge is actually dynamic, and not static. Identifying changes as embodied knowledge of rural Karst Gunungkidul, evolves through time during life experinces in such a way that it becomes an embedded knowledge. The knowledge attaches to people during life in response to phenomenon changes that lead them into certain behavioral patterns as individuals or community in their management of available resources; tailoring environmental management strategies for specific location or region such as Karst ecosystem Gunungkidul.

6.4. Incorporating Local Knowledge into Integrated Water Resources Management and Risk Management (early warning signs, preparedness, adaptation and mitigation)

The illustration of water consumption over time in Gunungkidul, for example Dadapayu village, is shown in Figure 6.22 (Lux, 2004:34). MacDonald and Partners (1984) had proposed Gunungkidul Rural Water Supply System. In the era of uncertainty or shifting climatic pattern, an alternative of water exploration from varied water resources sounds more promising for the people in Gunungkidul Karst region. However, the support from other factors like better accessibility of transportation and promising agricultural trade for peasant farmers need to be improved. The improvement of water infrastructure in Gunungkidul by. IWRM's Bribin project, seems promising to meet future adequate clean water needs.

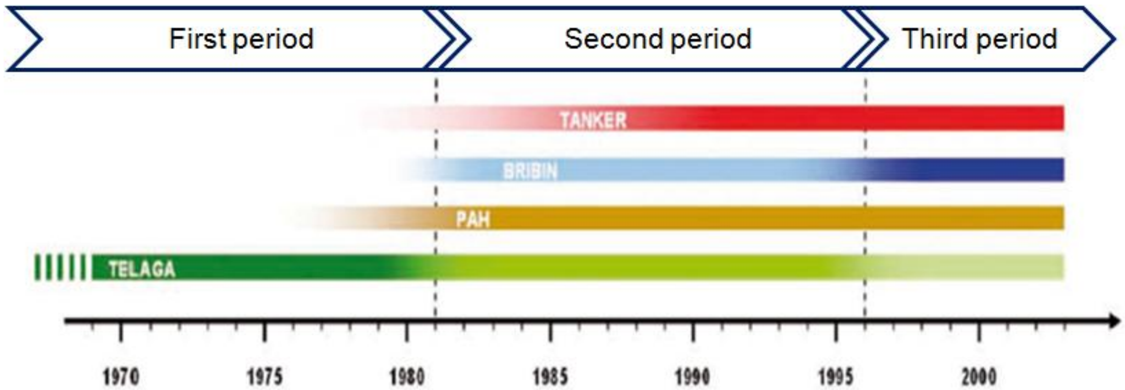


Figure 6.22. Development of Fresh water supplies in Dadapayu village representing Gunungkidul Regency (Lux, 2004:34)

Seasonal based local knowledge is an embedded and embodied knowledge in Karst Gunungkidul, reflected in the cultural behavior as an identity. Community knowledge of water resources availabilty can be assessed from the community's knowledge of water discharge rates in their region and the application of *Pranata Mangsa* to agriculture with its phenology or bio-indicators (SUDARMADJI, SUPRAYOGI, and SETIADI, 2012). The respondents of that study, from three different geomorphology characters on Gunungkidul regency, namely Baturagung Ridge, Wonosari Plateau and part of Karst Gunung Sewu, were unable to correlate the seasonal calendar *Pranata Mangsa* with water discharge amounts. Indeed, there is no explicit explanation of water calculation in the seasonal cycle *Pranata Mangsa*. Therefore, this study propose to use the term 'early warning sign or system' regarding water issues and put the process of observation and knowing into embedded knowledge. Then, spatial knowledge of water sources needs to be recorded as an input in developing knowledge management on water and land subjects.

In comparison and verifiying Sudarmadji's (2012) study, this study revealed that 95% of the respondents during FGD (2012, 2013) receive and understand the knowledge of seasonal based calendar for agriculture but find it hard to explain the correlation between it and water availability in a quantified way. Respondents agreed that there is a decrease of water discharge during the dry season. The most memorable cycle in the *Pranata Mangsa* for farmers are *Mangsa Kapat Labuh* and *Mangsa Mareng* which signed the time to start cultivate with available water and appropriate humidity. However the amount of available water is another issue to be calculated numerically in scientific terms and some younger famers have recognized this to be "modernized' famers.

Water availability is crucial for livelihood; in this study correlates with the application of seasonal cycle of *Pranata Mangsa* and its phenology (bio-indicators). The seasonal cycle teaches people to observe the changes of climatic factors through bio-indicators, both from plants and animal behavior in the ecological cycle. Application of the knowledge is adjusted to physical features differences, considering and affected by local institutional divergences of understading and perception. The same *Pranata Mangsa* can be interpreted differently, yet most agree that a change or shift have occurred related to agroclimate factors (FGD and indepth interview, 2012 and 2013), but micro-climatic factors need further research.

Pranata Mangsa with its phenology indicators leads to biodiversity proxies within a rotation life cycle of particular animal and plants described in the seasonal calendar. The dissappearance or extinction, of some animals and plants in Karst Gunungkidul is proposed as proxies for changes of climate factors. Phenology encompasses all the critical events in the lives of plants, animals, and ecosystems that are linked to Earth’s climate, including when leaves fall, when flowers bloom and when animals mate. The shifting time frame of the seasonal calendar *Pranata Mangsa* should be inseparable from these natural events and complementary to one another. The dissappearance of certain plants humidity indicators and seasonal change require plant substitution from amongt those species that have adapted to the changing environment. Differences or changes of temperature and the rainfall pattern affect the growth of certain plants and need to be observed due to food security and livelihood.

Local people in Gunungkidul respond to the "unpredicted" climate behavior through a ceremonial offering agenda. The water cycle in the *Pranata*

Mangsa calendar has been described using symbol and parable, thus it takes keen understanding to interpret (see Figure 6.23). The cycle put elements of earth (*Bantala*), wind (*Maruta)*, fire (*Agni*), and water (*Tirta*) on certain months (according to Gregorian calendar). During the *Tirta* time frame, water availability is symbolized. When the *Bantala* cycle starts, the dry season approaches.

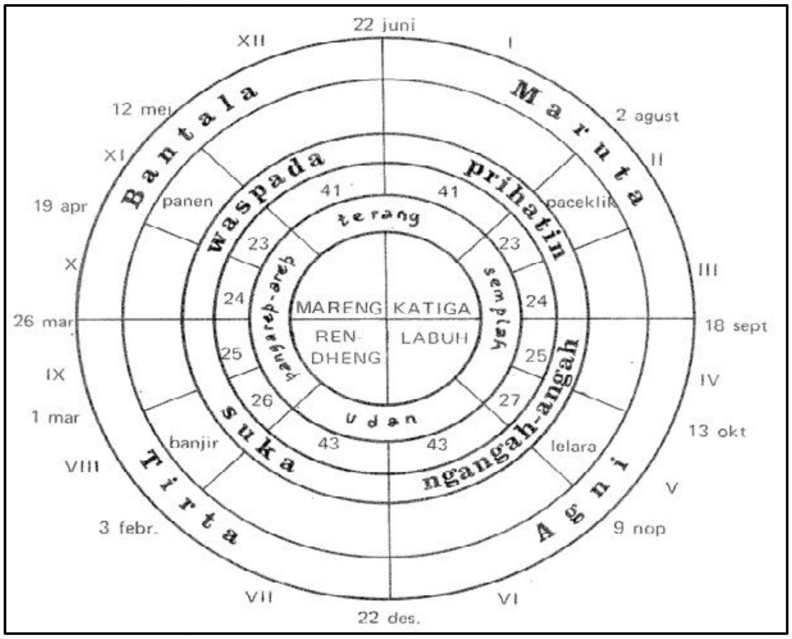


Figure 6.23. *Pranata Mangsa* calendar cycle with "early warning" time frame (Source: DALDJOENI, 1978, 1984)

Symbols are also attached with parables and phenology phenomenon (see Table 6.2). Sharing and transfering this knowledge is important. Water management in this study starts at individual or household level and builds up to the community, region and institutional level; innovation from tacit knowledge is transformed into explicit knowledge in practice and decision making or policies. Phenology of certain plants like yam tubes, tamarind, or mango trees needs to be observed and recorded to analyze the shifting leaf and blossom time as indicators of annual climatic factors.

Table 6.2. *Pranata Mangsa* calendar with symbolic and parable

Starting day	Name	Length of days	Description
Jun 23	*Mangsa Kasa*	41	The dry season; leaves are falling from the trees; the ground is withered and arid, bereft of water "like a jewel that has come free of its setting."
Aug 3	*Mangsa Karo*	23	The dry season; parched earth lies in hard clumps; the mango and cotton trees begin to bloom.
Aug 26	*Mangsa Katelu*	24	still dry season; spice roots are harvested; *the gadung* or yam tube begins to bear fruit.
Sep 19	*Mangsa Kapat*	25	Rain starts to fall, as "tears pooled up in the soul", marking the end of the dry season; birds are singing and busily constructing nests. The Labuh Season is at hand.
Oct 14	*Mangsa Kalima*	27	The beginning of rainy season, sometimes with fierce winds and flooding; mangoes are ripe; snakes are driven from their nests; "a fountain of gold falls across the earth".
Nov 11	*Mangsa Kanem*	43	The rainy season; lightning strikes and there are landslides; but it is also the season of many fruit.
Dec 23	*Mangsa Kapitu*	43	The rainy season is at its peak; birds are hard pressed to find food and in many areas there is severe flooding.
Feb 4	*Mangsa Kawolu*	27	The rainy season; rice fields are growing and the cat is looking for his mate; grubs and larvae abound.
Mar 2	*Mangsa Kasanga*	25	The rainy season; rice fields are turning yellow; "happy news is spreading"; water is stored within the earth, the wind blows in one direction, and many fruits are ripe.
Mar 27	*Mangsa Kasadasa*	24	Rain still falls, but is diminishing; the wind rustles and blows hard; the air is still chilly. The Mareng Season is at hand.
Apr 20	*Mangsa Desta*	23	The dry season has begun; farmers are harvesting the rice fields; birds tend their young with affection, as if they were "jewels of the heart".
May 13	*Mangsa Saddha*	41	The dry season; water begins to recede, "vanishing from its many places".

Source: DALDJOENI (1978, 1984) and WISNUBROTO (1999)

The indicator of cracking soil is most obvious to observe as soil humidity decreases. To integrate water management, have early warning and prepare against the risk of water scarcity, it takes keen interpretation coupled with experiences, which might be varied among individuals or the community. Interpretation and understanding of local specific features plays an important role in deriving which hazard and risk characterizes a region. A PDAM officer said that there is no correlation between seasonal calendar *Pranata Mangsa* with water management, due to his interpretation that *Pranata Mangsa* is only applied for agriculture. However, he admitted that during

Mangsa Katiga/Katelu (see the calendar cycle on Figure 6.23 and Table 6.2.), water discharge is decreasing. People need to develop keen observation to read the landscape changes through this guide. The incorporation of local knowledge and integrated water and land resources management in consideration of cultural ecosystem services and disaster risk reduction and management, within knowledge management framework, is ilustrated on Figure 6.24.

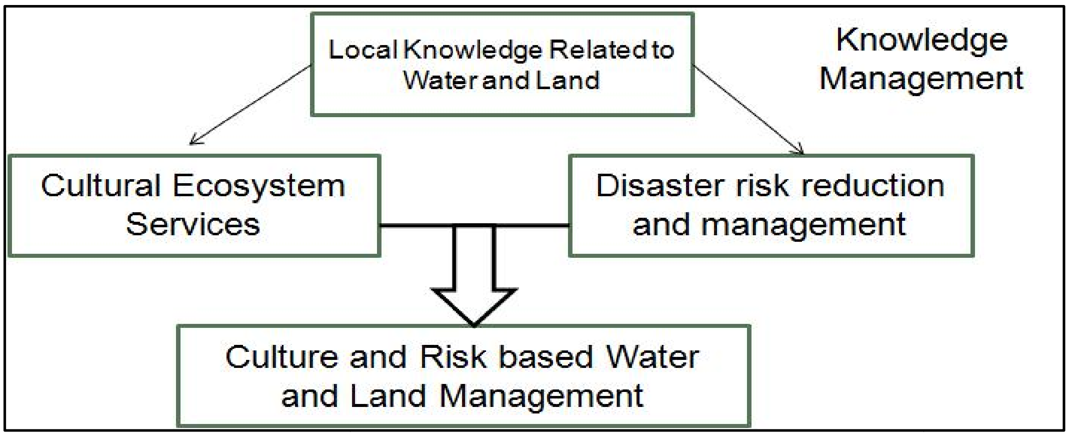


Figure 6.24. Culture and Risk Based Water and Land Management within Knowledge Management Framework (Author, 2014)

6.5. Institutional Challenges in Climatic Data Recording

Initiation of climatic data recording was started when the Netherland Indies Company occupied Indonesia. BOEREMA (1925) published mean rainfall figures for 2,715 rainfall stations in the Netherlands Indies. Figure 6.25 shows the graph from rain station observations in Nglipar and Wonosari, Gunungkidul using data during the period 1879 - 1922. Between the end of May and the end of September, rain water significantly decreases. This historic characteristic still correlates with recent conditions, accounting for the fluctuations due to the ENSO oscilliation period.

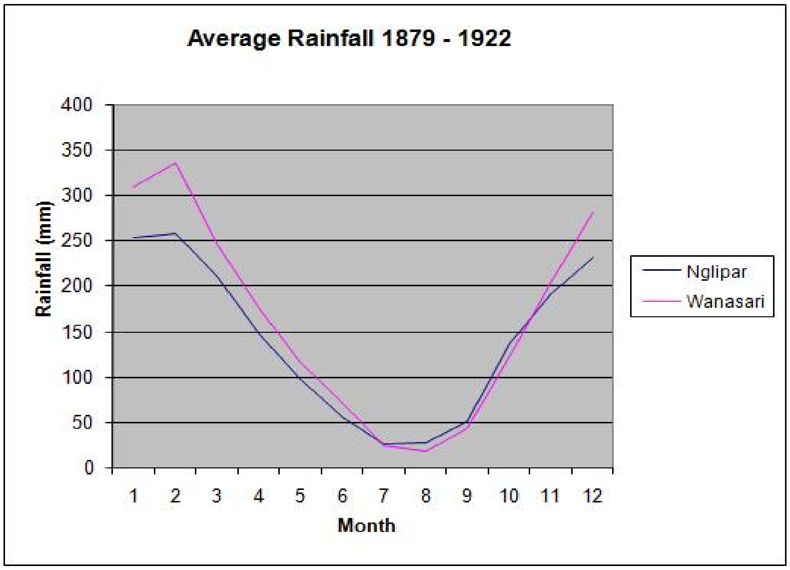
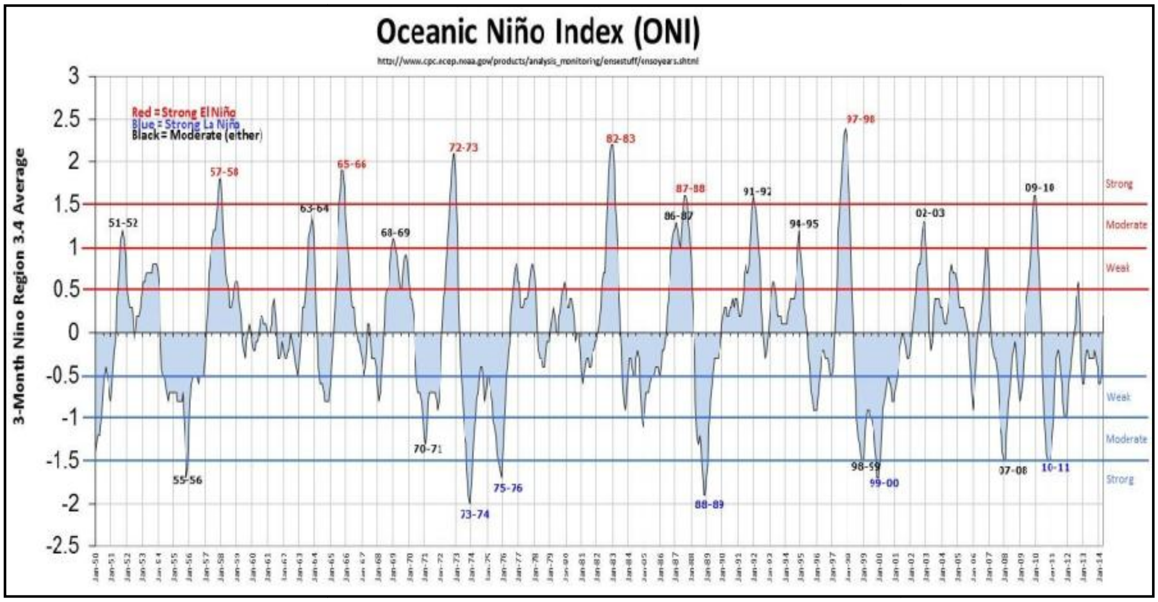


Figure 6.25. Monthly Average Rainfall Gunungkidul 1879 - 1922 (BOEREMA, 1925)

Nowadays, people who receive information from BMKG also validate this at field level. BMKG issues dry season forecasting every February and rainy season forecasting every August each year. They usually analyze 30 years of record data. Gunungkidul is in cluster number 42 Season Zone (*Zona Musim*/ZOM) based on BMKG classification from 342 ZOM throughout Indonesia. A season Zone (ZOM) is a clustered region where a distinct different between the rainy season and the dry season exists. It is not based on administrative boundaries.

The challenge of climatic factors to *Pranata Mangsa* should be tested against the calculation of BMKG to re-new the seasonal calendar. It required a long process of recording, thus local knowledge contained in *Pranata Mangsa* is actually dynamic, it has ecological adaptation using human interpretation following phenomenology hermeneutics and anthropology approaches. BMKG Yogyakarta recorded and calculated that within the last five decades, several extreme weather events related to global ENSO phenomenon have occurred. The *Pegaber* era (*jaman Pegaber*) in 1963 did correlate with the extreme weather (see Figure 6.26 and Figure 6.27), and was worsened by lack of accessibility to additional recources at that time. The possibility of extreme weather occurrence is not decribed in seasonal calendar *Pranata Mangsa*, thus memory of the elderly people about certain phenomenon occurrence is important.



Graphic 6.26. Oceanic Nino Index (ONI)

(source: http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml, accessed 17th August 2014)

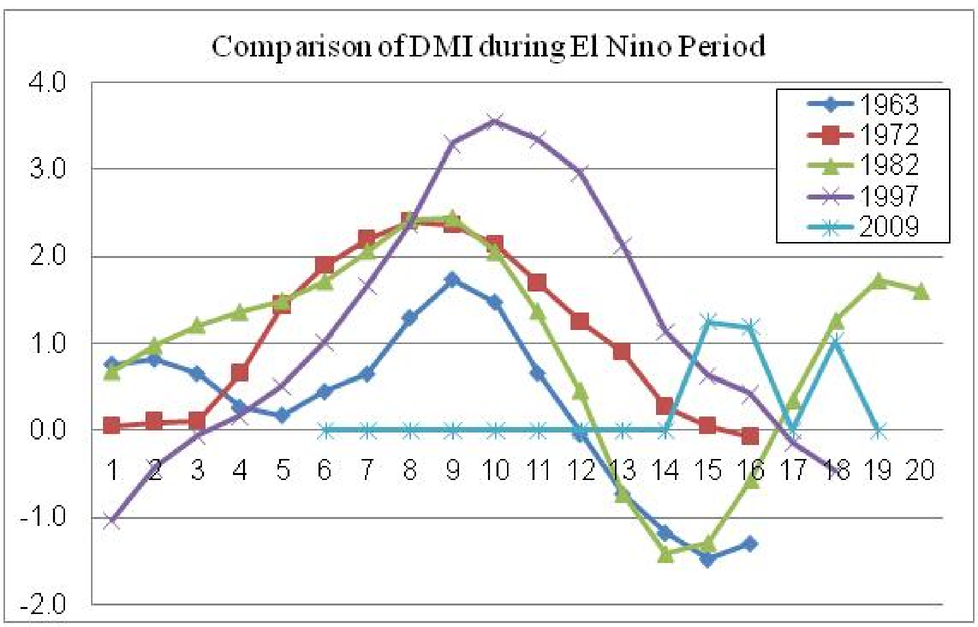


Figure 6.27. Comparison of DMI during El Nino Period

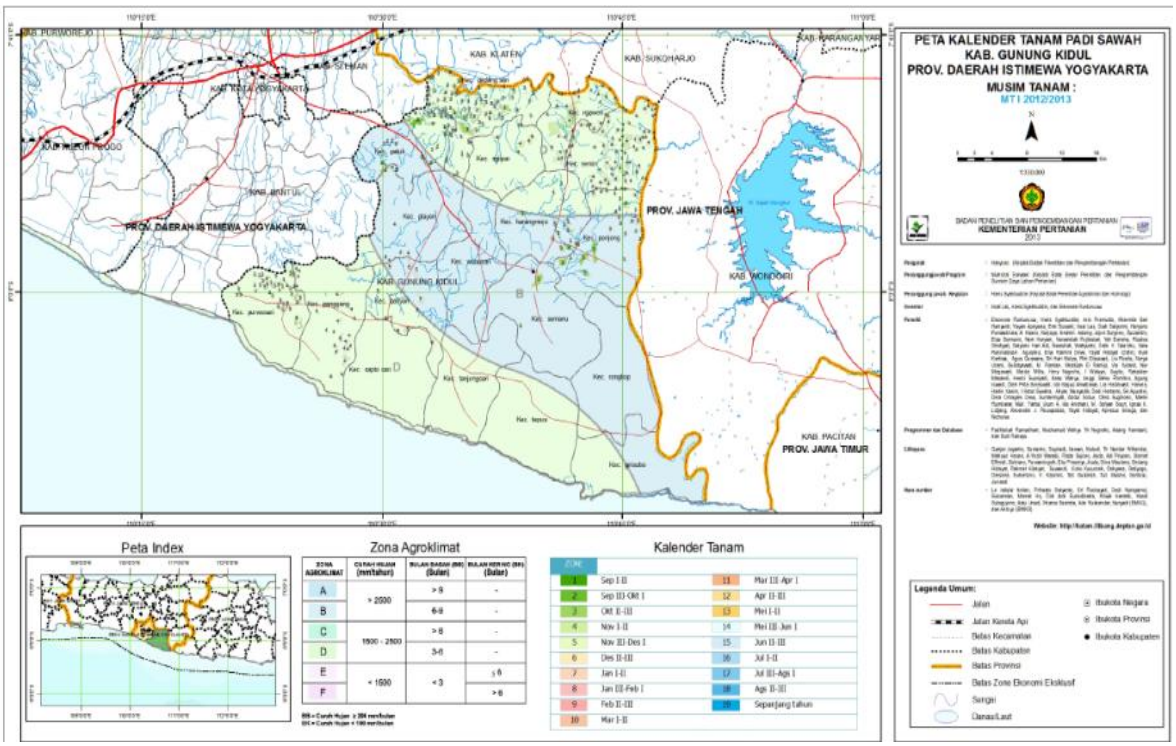
(Source: BMKG Yogyakarta, 2013)

Recording data at local community level is rarely conducted due to the assumption that in tropical region like Indonesia there are only two seasons, either dry or wet (rainy) season. However, in regional institution the awareness is increasing since the occurrence of flood and drought have been significant in some region of Indonesia within the last decade. During the rainy season regions receive high intensity rain water, but on the contrary, when the dry season comes water discharge decreases significantly. BMKG through its climate field schools (SLI), in cooperation with agricultural institutions and climate experts, have initited a data and information recording culture. This transform environmental phenomenon into coded knowledge and can be transferred and shared.

The Agriculture Ministry (*Departemen Pertanian*) through its representatives in each regional zone of sub-district (*Balai Penyuluh Pertanian*) have developed weather stations which record at least rainfall and temperature data. The recorded data is also transferred to BMKG to be analyzed further. However, the agroclimate zone issued by agricultural institution show different regional climate zoning to those issued by BMKG due to different purpose of use and the parameters analyzed. The agriculture institution merely developed agroclimate zoning for irrigated fields. Rongkop, Girisubo, Tanjungsari, Saptosari and Tepus sub-district are located in the zone of rain-fed fields. Meanwhile, Purwosari, Panggang, the Northern part of Paliyan, Semanu, and the Northern part of Ponjong are located in the irrigated paddy field.

Agroclimate classification, issued by the Agriculture department, classify Karst Gunungkidul into ZOM 142. In 2012, the region experience a delay of one *dasarian* (ten consecutive days within one month in climatic calculation BMKG) with the rain fall below average for the region. The last extreme El Niño was in 1997-1998, Indonesia and Australia experienced devastating droughts and wildfires. In 1997, Indonesia experienced economic collapse due to the extreme El Nino. All respondents during FGDs and indepth interview confirmed that people suffered economic changes and climate effects in 1997/1998.

Mapping of the agroclimate zone by the agriculture department is aimed to guide farmers. Map 6.3. shows a cultivation calendar within one season time frame (2012) for Gunungkidul Regency. Southern part of Karst Gunungkidul is rainfed field which is not suggested to cultivate the irrigated paddy (*padi sawah*) type by agriculture departement. However, farmers in Karst region also cultivate the same paddy type, such as Ciherang, and IR by adapting to water availability and soil type.



Map 6.3. An Example of Irrigated Paddy Cultivation Calendar Map for Gunungkidul Regency, issued by Agricuture Board of Research and Developement (*Badan Penelitian dan Pengembangan Pertanian*) 2012/2013

6.6. Re-invent or Re-create Seasonal based Local Knowledge

Water cycles globally and locally have reached to the consequences for human and ecosystems (CHIFFLARD and KARTHE, 2014:1). Changes related to climatic factors and increasing population followed by increasing water use affect global water resources (ARNELL, 1999:S47), and affect or are affected by, landscape changes in response to the rise or shift of human needs. Groundwater resources study in Gunungkidul (MACDONALD and

PARTNERS, 1984, vol 2, pp. 4) revealed the hydrology condition which were affected by rainfall distribution. BOEREMA (1925) showed Westerly monsoon (December - February from the Java sea) resulting rainy seasonal, Easterly monsoon (June - September from Australia) resulting the dry seasons. There were also effects from the active Merapi volcano activities. Rainfall distribution is affected by monsoons, the annual passage of the sun and local influences (mainly the mountains, hills effect). The rainfall distribution on Karst landscape Gunungkidul is observed by local people based primarily on the direction.

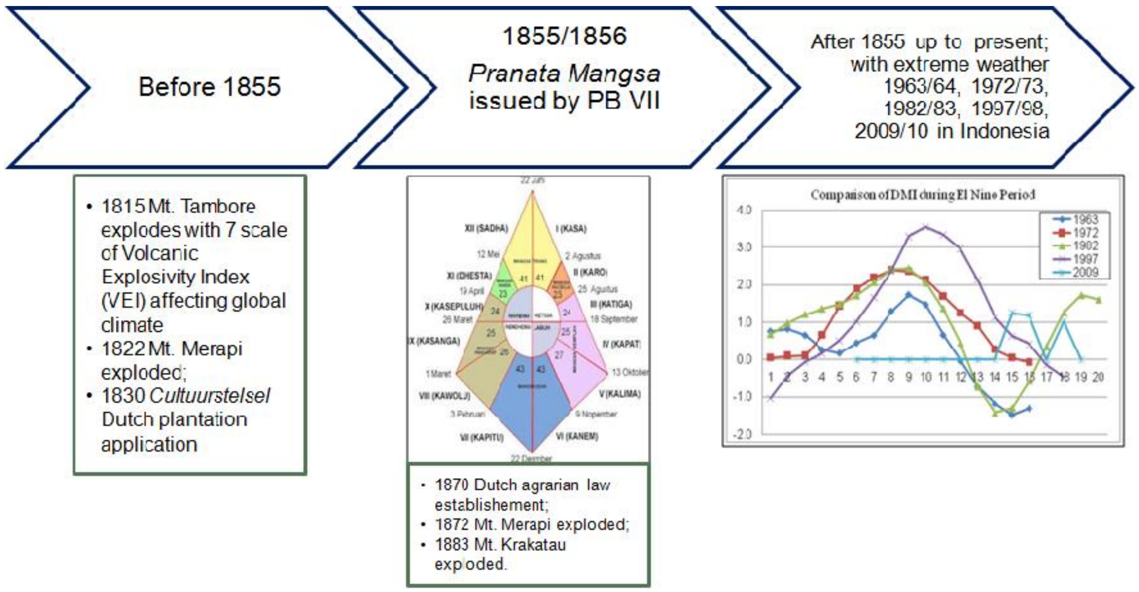


Figure 6.28. Time frame before, during *Pranata Mangsa*, and present epoch time with Volcanoes eruption events (Author, 2014)

The challenge to the seasonal calendar *Pranata Mangsa* is the shifting climatic factors, highlighted by rainfall. The seasonal calendar cycle was issued before 1855/1856 based on recorded data from previous epoch of climate conditions on long periods observation of locality characteristics (see Figure 6.28). Changes have occurred since the introduction *Pranata Mangsa*, including dynamic changes of landscape due to human activities. Hence, local knowledge *Pranata Mangsa* needs to be re-invented to get new concepts following the changes of recent years and decades. In the site study, the shifting of ten-day (*dasarian*)[16] meteorological factors, particularly temperature and rainfall, have been studied by KRISTOKO, EKO, SRI, and BISTOK (2012) using a fuzzy logic model. That study tries to evolve the system of *Pranata Mangsa* using climatic data (between 1969-1989 and 2000-2010) and the planting pattern for Boyolali region where *Pranata Mangsa* was first intoduced in 1855/1856. The study collates the previous climate condition with the experience of the 20th century. Any anomalous events like volcanic eruptions or extreme weather compromises the climatic models developed by scholars for global and the Southeast Asian conditions (HULME, MITCHELL, INGRAM, LOWE, JOHNS, NEW, and VINER, 1999; LASCO and BOER, 2006). *Pranata Mangsa* as a guideline or baseline for determining environmental conditions in this different climate epoch may take the IPCC's (1997) instigation as its start date. Or in the field, Karst Gunungkidul might take its start date from 1963/1964 when Pegaber era (jaman Pegaber) occurred due to extreme weather.

6.7. Understanding of Risk from The Community Knowledge

Scientists are not landscape managers, but an"Early Warning System..." (VOLK, LAUTENBACH, and SEPPELT, 2011). Local people are also expert at reading their surrounding landscape, but they are also risk takers. People modify and adjust landscape based on the needs of life. *Pranata Mangsa* as seasonal based local knowledge is a result of keen observations of with certain climate condition at the time it was inititiated. It shows and teaches people how to use the knowledge to adjust to natural cycles. In correlation with the Hyogo Framework on Disaster risk Reduction priorities and ACCRA Adaptive Capacity Framework criteria[17], this study tries to correlate seasonal based local knowledge to gain an understading of efforts to minimize the risk of water and land scarcity on Karst Gunungkidul, Java (see Figure 6.29). This study proposes people to re-sharpen their keen observation and develop recording cultural behavior.

[16] BMKG terms of ten consecutives days of rain fall, there are three dasarian within a month (30 days)

[17] http://community.eldis.org/.59d669a8/research.html, accessed on 7th October 2014

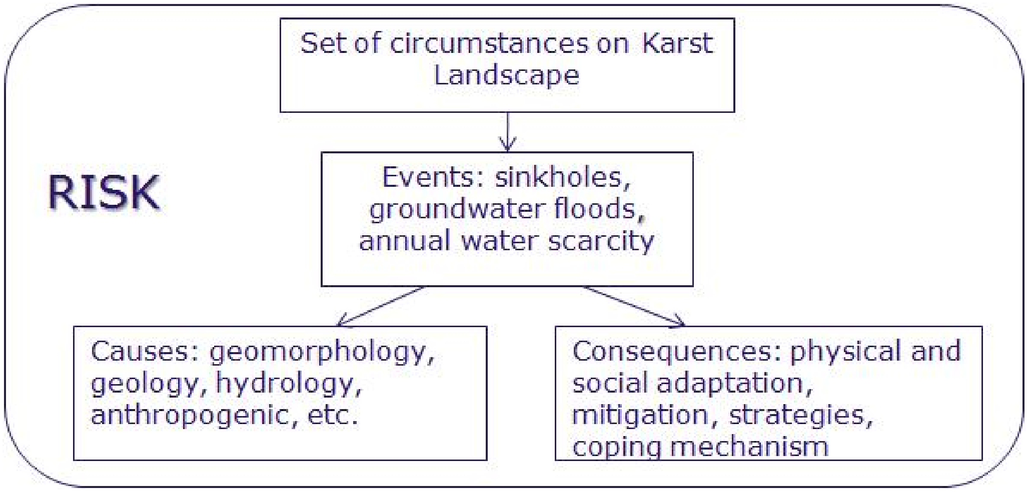


Figure 6.29. Risk Concept on Karst Landscape in Gunungkidul (Author, 2014)

Rural Karst Gunungkidul communities, in particular farmers, still apply seasonal based local knowledge for their agriculture activities and also ther daily activities. The Hyogo framework priorities are to identify and monitor risk and enhance early warning; use knowledge, innovation and education to build a culture of safety and resilience (United Nations International Strategy for Disaster Reduction/UN-ISDR, 2007). Seasonal based local knowledge inherited through generations and still applied, at least by older farmers (40 to 65 years old), is considered the stepping stepstone to derive knowledge on early warning, hazards and reduce the risk, in order to build safe and resilience culture.

Annual temperature and precipitation in Gunungkidul Regency has been gradually increasing over the last three decades (SUDARMADJI, SUPRAYOGI and SETIADI, 2012). Through these decades people have experienced uncertainties in correlation with climate variability. The way people respond to changes of climatic factors reflects not only on physical adaptation, but also in symbolism and (art) perfomances. Ancient Javanese people have already put Osciliation and Dipole into *Pranata Mangsa* calculation or forecasting explicitly. They used to make offerings to God, in response to extreme changes of climatic factors with negative impacts on their lives. Indepth interview with elderly people during field study revealed that in

Kemadang village, they used to have a ceremonial offering once every eight years (*sewindu*) in response to severe climate challenges. Another key informant in Giriharjo village, Panggang sub-district, added that their region experience distinct changing climate factors every five to eight year. The timing of ceremonial events and abnormal climatic occurrence correlate to RASMUSSON (1987:176). Seasonal based knowledge *Pranata Mangsa* was formulated as a response to phenomenological aspects of climate variability.

This study applies the second risk concept by RENN and KLINKE (2013:11), taking into consideration the natural characteristics of site location to gain hazard and risk understanding. Interdisciplinary risk estimation has two stages :

1) risk assessment: experts from natural and technical sciences produce the best estimate of the physical harm that a risk source may cause.
2) concern assessment: experts from social science, including economics, identify and analyse the issues that individuals or society as whole associate with certain risk. Hence, the repertoire of the social sciences, such as survey methods, focus groups,economic analysis, macro-economic modelling or structured hearings with stakeholders may be used.

It is important to see the relation between shifting weather patterns observed and experience by local people to support and exchange "scientific" knowledge. Self-assessment on how community evaluate their coping capacity starts from proactive communities engaging with their seasonal based knowledge within acceptable and tolerated risk on management parameters. Seasonal based calendar *Pranata Mangsa* expresses knowledge dimensions in the way of spatial differentiation and the limitation of certain information, such as morphology of the area. Morphology of an area is identified through living experiences in human's life. People's understanding and interpretation of seasonal based knowledge will liberate them from hazard impacts within community based sense, in accordance with the concept of human security pillar (BRAUCH, 2005).

Resilience is applied not only to humans but also to landscape where community livelihood are imprinted on it. Criteria in ACCRA Adaptive Capacity framework also put knowledge and information as necessary for innovation of adaptation strategies. People in Gunungkidul Regency, particularly the southern part occupying the Karst region, have developed time tested coping mechanism for erratic climatic factors, yet their livelihood improvement is still inadequate. The resources they possess, mostly in the case of economically poor households, are prepared to be sold when the dry season comes to fulfill the need of water. Livestock such as cattle and timber are among other of their resources most at risk during dry season (see Figure 6.30).

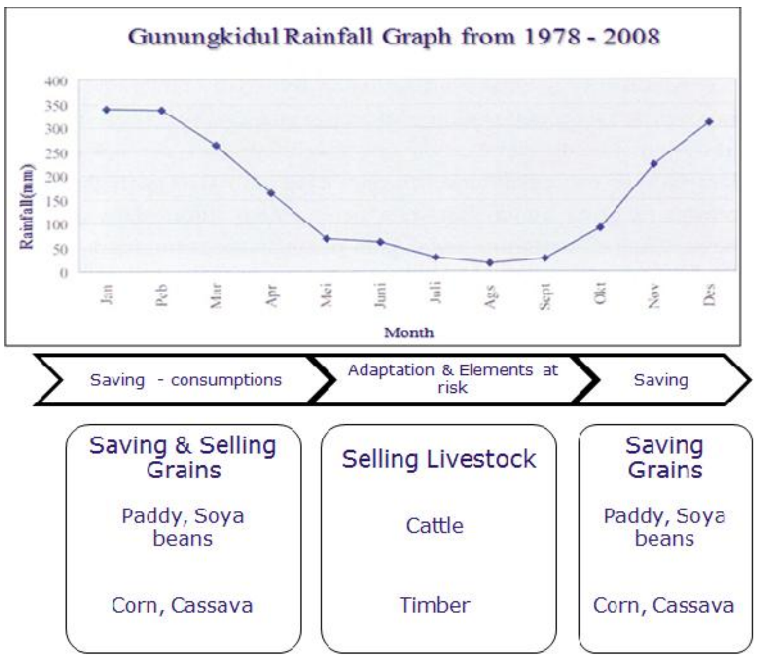


Figure 6.30. Cycle of Element at Risk in Gunungkidul (Author, 2014)

6.7.1. Read and Interpret the Hazards

Sinkholes are the most studied hazard in Karst system. Identification of sinkholes that threat infrastructures, utilities, and settlements can be done by using remote sensing tools, and field observation. The occurrence of these features might increase exposure to human activities and artefacts. Another threat is erosion which being coped with teraccing stone wall on agriculture and agroforesty field (see Figure 6.31.).

Figure 6.31. Stone Wall Terraces to Prevent or Reduce Soil Erosion (Author, 2012)

Karst landscape is affected by water flows. Water velocities in Karsts system are determined by the network of cave systems and the degree of network organization. High velocity determines its vulnerability. Caves systems (Figure 6.32) transfer contaminants since the pollutants cannot be treated by chemical reaction or attenuation mechanisms.

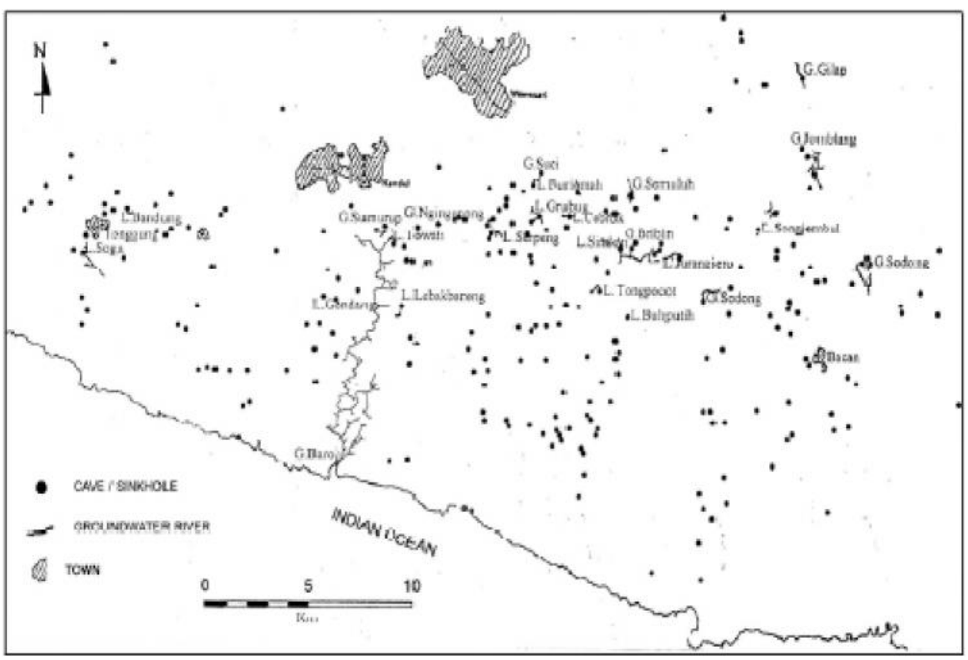


Figure 6.32. Cave/Sinkhole Distribution in Gunung Sewu
(source: FAKULTAS KEHUTANAN, 1993)

Physical features which expose people to hazards not explicitly described in seasonal calendar *Pranata Mangsa*. The phenomenology hermeneutics approach is applied to interprete the hazards from natural cycle in *Pranata Mangsa*. The seasonal calendar is considered as a "text", that needs to be read to understand the meaning. However, the knowledge transfer since 1855/1856 is a closed system, where only certain people have the capacity to interpret it and there is only limited discussion of *Pranata Mangsa* in "scientific essence". Table 6.3 describes the seasonal calendar with climatic paramaters from Surakarta (Solo), region where *Pranata Mangsa* was initiated first. The micro-climate in Surakarta is affected by Merapi Volcano and the riverine system Bengawan Solo, with diverse land use land cover.

Table 6.3. Comparison of *Mangsa*'s (months) Characteristics with Meteorology Data of Surakarta (Solo)

Name of *Mangsa*		Nature signs and the effect on human	Meteorology indicator			
			Sun light (%)	Humidity (%)	Precipitation (mm)	Temperature (°C)
Katiga	1	fallen leaves, shifting stars	72	60.10%	67.2	27.4
	2	Hot weather			32.2	
	3	dried up well, dusty wind			47.2	
Labuh	4	end of dry season	70	75.50%	83.3	26.7
	5	First rain fall			151.9	
	6	greening nature, comforting and peaceful mind			402.2	
Rendheng	7	diseases and flood occurs	67	80%	501.4	26.2
	8	cats mating; lightning occurs			371.8	
	9	*Garengpung* sings; epidermis diseases occur			252.5	
Mareng	10	Birds lay eggs; dizziness strikes human	60	74%	181.6	27.8
	11				129.1	
	12				149.2	

Source : DALDJOENI, 1978

Reading and interpreting hazard exposure from the seasonal calendar cycle needs to be compromised with the dynamic changes of nature and human behavioral. Farmers who still applied *Pranata Mangsa* admitted that the seasonal calendar helped them to identify early sign of potential hazard on water scarcity during annual cycle (RETNOWATI, ANANTASARI, and SURYANTI, 2014). However, farmers and non-farmers who do not apply *Pranata Mangsa* are also aware of the annual water scarcity and ready to sell their belongings when it is needed.

6.7.2. Integrating Local Knowledge Systems into Risk Management Strategies

Local knowledge can be used in monitoring early warning systems that involves the users in feedback and follow-up systems. Ecosystem understanding plays important role in disaster risk reduction (RENAUD, SUDMEIER-RIEUX, and ESTRELLA, 2013). Therefore, understanding the ecosystems characteristics from *Pranata Mangsa* perspective is a steping-stone to building seasonal based risk management (see Figure 6.33) in consideration of dynamic changes. Situational awareness comes from observing and validating phenomenon against long time frame of experiences to reach awareness on certain emerging phenomenon related to climatic factors which may possibly affect physical features.

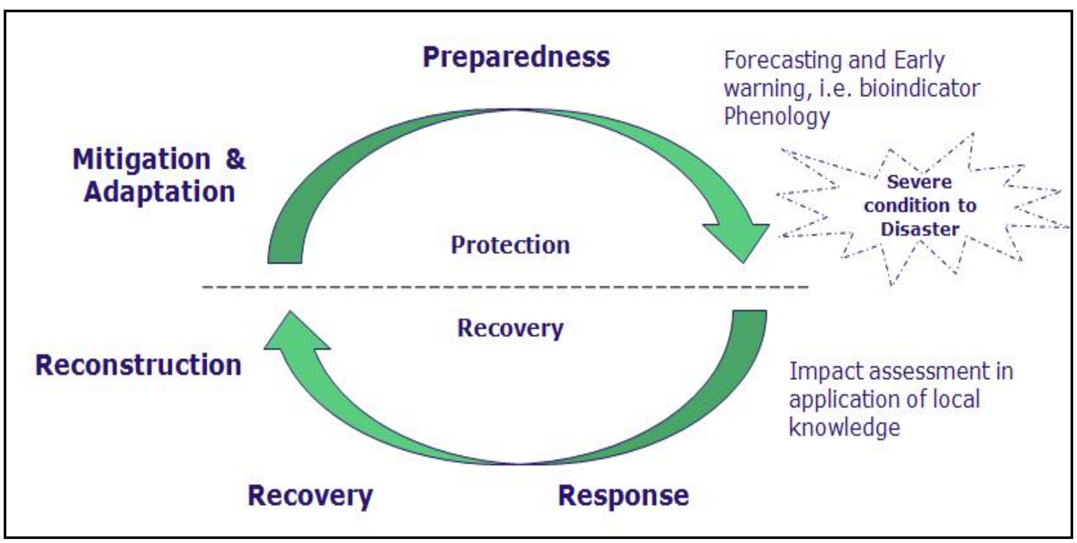


Figure 6.33. Seasonal based Disaster Risk Management
(adapted from WILHITE, HAYES, KNUTSON, and SMITH, 2000:698)

NIBBERING (1991:126) questioned the sustainability of the livelihood of farmers without harming the environment they rely on and concluded that they will conserve the resources. SUNKAR (2008) revealed that farmers do take into consideration whether their actions jeopardize their resources. However the question remains how farmers can manage the risks to their livelihood. Uncertainty about the degree of exposure to climatic factors change in Karst areas, can lead to a threatening cultural landscape conical hills of Gunung Sewu.

Elements at risk in the coming the dry season are cattle (livestock) and timber (logging) from individual fields or homeyards. However, no official record so far made to approve this fact, but people acknowedge this issue and the phenomenon is particularly observable between August and September (peak dry season). Another phenomenon is that people sell their livestock or timber prior to certain occasions, for example to pay for the children to go to school, or having a marriage reception. Understanding the seasonal cycle will guide individuals, the community and institutions to develop planning, management, and action plan (see Figure 6.34), regarding responses to certain types and degree of hazard and risk.

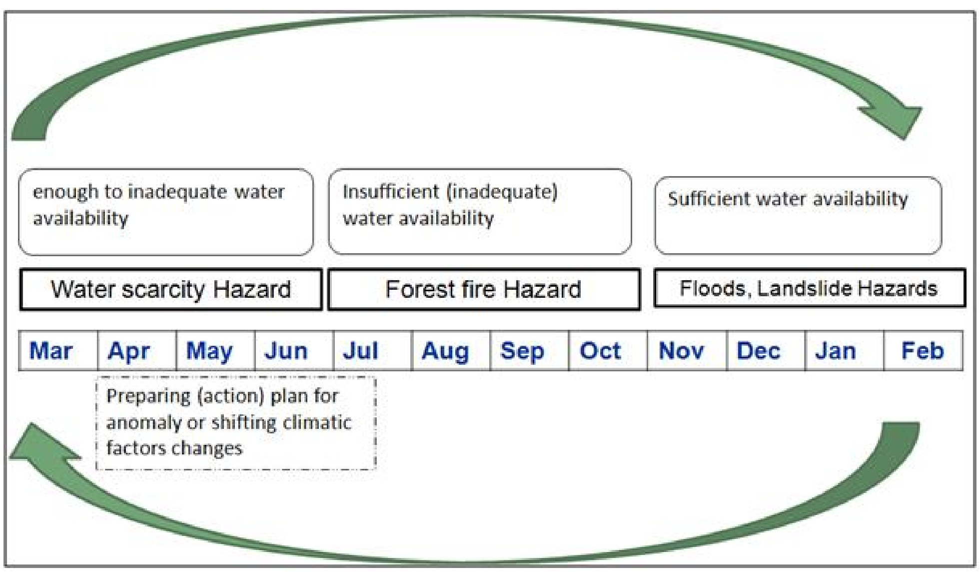


Figure 6.34. Identifying Hazard and Risk through Cycles for Planning, Management and Action Plan (Author, 2014)

Gunungkidul government have understood that their region is indeed prone to annual water scarcity and prepare a financial budget to provide their inhabitants with water in the peak months of the dry season. However, responsive action puts people inside the cycle of economic water demand, although it is inevitable. Inspite of the knowledge that the community lives in a hazard prone area, people still continue to live their lives. The explanation of this situation is multi-faceted and complex and should play a role in future disaster prevention. In order to prevent and reduce the impact of drought in Karstic areas of Gunungkidul, spatial planning plays an important role in mitigation and prevention. However, the efficiency of spatial planning and other planning documents to reduce risk needs to be considered and understood best (ETKIN, 2009).

International Centre for the Study of the Preservation and Restoration of Cultural Property (ICCROM) and the World Heritage Centre for the International Disaster Reduction Conference (IDRC) promoted an approach in Disaster Risk Reduction effort by integrating Traditional Knowledge Systems into Risk Management Strategies (KING, WIJESURIYA, and COPITHORNE, 2006). World heritage properties, including the traditional knowledge and sustainable practices which possibly ensured a certain degree of protection from the worst impacts of natural or man-made hazards, as early warning systems in the philosophical essence, are being abandoned.

Recent national and regional or local disaster risk reduction mechanisms, including early warning system, preparedness and mitigation, do not take into consideration traditional or local knowledge systems and cultural heritage. The process of exchanging information on seasonal based climate related risk among various information holders, providers and policy decision makers, needs to include local people, governmental institutions and other related and interested stakeholders. Using seasonal based local knowledge to communicate the risk from certain climatic factors, can be initiated through local institutions like famers groups, the Integrated School of Plants and Pest Management (*Sekolah Pengelolaan Tanaman dan Hama Terpadu*/SL-PTT, SL-PHT) or Climate Field Schools *(Sekolah Lapang Iklim*/SLI). The 'school' is a medium to "educate" and train farmers to become agent of risk knowledge management. The farmers field schools can initiate the culture of recording data of Karst Gunungkidul environment changes.

VII. The Landscape Story, Potency of Disturbances and The Landscape Modeling of Karst Gunungkidul

"*Landscapes are heterogeneous geographic areas characterized by diverse ecosystems like natural terrestrial and aquatic systems such as forests, grasslands and lakes. It also includes human-dominated environments like agricultural and urban settings*" (WYLIE, 2007)

Within the discipline of geography, the notion of landscape is one of the key ideas and the description and explanation of landscapes has an extensive tradition. The two main fields of research can be identified broadly as landscape ecology, also known as the ecological branch of landscape geography, and culturally oriented landscape studies practiced within human geography. Conical hills in the Karst Gunungkidul landscape are the work of its inhabitants, implementing human activities that significantly alter and add due to the geographic location. These activities shape the concept of a cultural landscape in the Karst Gunungkidul.

Potential disturbances or worse destructions in the Karst landscape are due to human activities. Therefore, a multi-level and multi-scale understanding of landscape function in monitoring Karst disturbances on conical hills Gunungkidul is important. Understanding landscape is essential to manage limited natural resources on Karst Gunungkidul Regency, and Gunung Sewu's wider area. PENNY and SINGARIMBUN (1973:2) mentioned how during first era of Suharto's New Order (*Orde Baru*) in the 1960s people were unable to read the story of their land, ignoring land and water ethics by destroying forest to meet their hunger for land to produce rice, only to produce floods.

SUNKAR (2008:89) revealed the cultural landscape of Gunung Sewu from quite a different perspective, yet demonstrating similarity on how landscape in Karst Gunungkidul Regency was shaped by the inhabitants' activities as adaptation strategies and coping mechanism to meet sustainability management of livelihood. This study aims to view the landscape of Karst Gunungkidul Regency as part of Karst Gunung Sewu. Remote Sensing, Geographic Information Systems and Models are tools to be utilized to assess landscape phenomenon derived from spatial cognitive knowledge of rural people in Karst Gunungkidul. This study tries to model water resources, ecosystems and landscape to cope and live with uncertainty based on local seasonal knowledge. The ecological footprint known through landscape phenomenology on Karst Gunungkidul has been embodied and embedded by the people. Integrating Karst Landscape management for managing water and land, in particular using local knowledge, namely "*ilmu titen*" of the seasonal calendar, physical features and phenology or bio-indicators. People's behavioral pattern are imprinted on the landscape.

7.1. Landscape of Karst Gunungkidul

Landscape is observable from different dimensions which reflect interactions between humans and place in the variety of physical features where social issues compromising intangible values (TURNER and DAILY, 2008; GRAUMANN, 2002). Karst landscape is subject to contrasting human pressures and land uses to varied degrees by water exploitation. Human pressures show an overwhelming role in driving landscape patterns.

Many references describe Gunung Sewu Karst characteristic in different epochss and time-scales with the appearance specific landscapes (JUNGHUHN, 1856 and 1857; DAMES, 1955; VAN BEMMELEN, 1970; UHLIG, 1980; HARYONO, 2008b). Rural landscape reflects a narrative on how humankind relate their life to the natural environment. Any system of interaction between man and the natural environment is considered cultural landscape (DIMITRIADI, 2000). People live in adaptation to their environment.

Karst Gunung Sewu, where the Southern part of Gunungkidul Regency is the biggest region in the system, represents both a tangible and intangible geo-heritage in this study. Karst landscape provides underground water resources as part of its ecosystem services. People in the Southern part of Gunungkidul rely their water sources 80% of their needs from underground river water and springs during dry season. The cultural landscape can be considered as a narrative landscape based on seasonal changes Karst Gunungkidul, a derivation and understanding of local knowledge.

Landscape changes dynamically, reflecting changes in natural and human activity and also the interaction between them. Water is the agent of cultural landscape in the Karst region, which in this research on Karst Gunung Sewu which administratively includes Gunungkidul Regency. Water's role in the evolution of Karst landscape is very specific and requires integrated approaches to generate Karst landscape management that integrates water and land issues for rural livelihoods. The idea is to find solutions for achieving water, food and climate security in a productive landscape by building up community capacity through a climate-smart Karst landscape. The vision is of a community capable of coping with climate variability and the uncertainties in Karst landscape, that is both climate and landscape sensitive while remaining a productive one.

In "Anthroposcape" (KAPUR, ESWARAN, BLUM, 2011) settlement patterns, residents' houses and land use are the kernels of a rural cultural landscape (FANG and LIU, 2008: 314). The main subjects of rural cultural landscape study are rural settlement and land use. Ancient inhabitants of Karst Gunung Sewu in the Gunungkidul Regency developed their culture along Karst valley (YUWONO, 2009). SUNKAR (2008:94-95) has described the historical events which related to the settlement and development in Gunung Sewu from the 8th century up to 1970s. Whilst, LIES (2012:82) described the historical human culture from early pre-neolithic to post modern (present).

Table 7.1. Historical Human Culture (Periodic Time) on Karst Gunung Sewu

Time	Periodic	Culture
12,000 - 4,000 BP	Keplek	Pre-Neolithic and Early Neolithic
4,000 - 1,000 BP	Ngrijangan	End of Neolithic
1,000 - 600 BP	Klepu	Paleomethalic
600 - 450 BP	Hindhu and Budha	Neomethalic
450 - 0 BP (1500 - 1950)	Moslem and Colonialism	Modern
1950 - present	Indonesia today	Post Modern

Source: LIES, 2012:82

Landscapes by the European Landscape Convention (ELC) are described as areas, perceived by people, whose character is the result of the action and interaction of natural and human factors. Landscapes dynamically transformed by inhabitants, in line with Sauer's work "landscape modified by human activity, where natural landscape is fashioned by cultural group" (1925) are considered as living space or *lebensraum* in German (RATZEL, 1902). However Sauer's approach to culture de-emphasizes its non-material elements of culture such as values, social structure, religion and economic organization. COSGROVE (1985) redefined landscapes as a 'way of seeing' and in doing so opened up a whole field of investigations into the processes of visualizing the landscape. Reading landscape and correlating with human ethics was proposed by DRENTHEN (2011). HAGGET (1983:263) described cultural landscape in the field from aerial photos, which showed how the patterns of field and farms reflects the manner and timing of agricultural settlement.

Phenomenological hermeneutics applies to read and interpret Karst Gunungkidul landscape sensitivity from an inhabitants's view, understanding and experiences. Landscape embraces more than agriculture. It includes forests (agrogorestry, silviculture, community forest), soil (pedology), water and atmosphere where people build homes and other structural buildings.

Pranata Mangsa as an annual seasonal based calendar applied by different communities, is highly affected by philosophy and culture rooted in and characterized by rural people of Karst Gunungkidul. The conical hills of the Karst Gunungkidul landscape are a text of human, cultural, and behavioral geography, as well as philosophy, archaeology, anthropology, and geo-bio-diversity study. Thus, this research combine the ideas of those subjects.

7.1.1. Source of Cultural Landscape throughout Time of Gunungkidul, South Java Landscape

Vernacular Landscape is a landscape that evolved through use by people whose activities or occupancy shaped that landscape. Through the social or cultural attitude of individual, family or a community, the landscape reflects the physical, biological and cultural character of everyday lives. Photos present visualization of vernacular landscapes of certain people on particular location with specific characteristics. Houses and their surrounding environment represent human culture adaptation (see Figure 7.1). From the pictures, the material of housing and surrounding environment can be analyzed. Big trees, including coconut trees were still part of home gardening at the time this photo was taken. It means the local people still considered it important for daily life and was a commercial commodity at that time. Houses built using teak timber due to its abundant availability at least until the 1950s, still exist nowadays and reflect heritage or social status.

Figure 7.1. Traditional House in Wonosari during Dutch Colonialism in the 1900s[18]

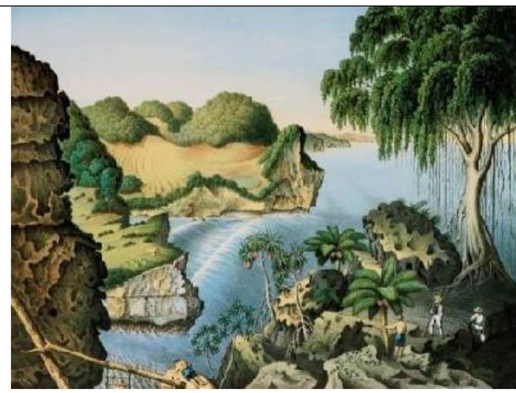
Figure 7.2 shows a cotton tree which is one of the indicators of annual season change in the *Pranata Mangsa* calendar. Other trees are still full of leaves, indicating the weather still permitted to travel, which would not be possible in the peak dry season.

Figure 7.2. Carriage Ride through Gunung Sewu, Southeast of Yogyakarta[18]

[18] pictures are depicted from photo's collection KITLV Digital Image Library, University of Leiden, Netherland

JUNGHUHN, a German-Dutch botanist and geologist, conducted field observations in Java from 1835. In his expedition, he travelled to the Southern part of Java known as Gunung Sewu. He described hillsides and coastal landscapes (see Figure 7.3), which representing seasons now considered as coming from a different period of climate to present studies. The pictures of the Rongkop coast, exemplify and reflect the stories of the Southern part Gunungkidul as swallow's nesting and the legacy inherited by each next generations. The expedition also captured the climatic condition at that time during the 1800s, where Gunung Sewu (Gunungkidul) was still forested and had preferable climatic factors.

Gunung Sewu conical hills



Rongkop coast as part of Karst area in Gunung Sewu systems

Figure 7.3. Natural (Historic) Landscape from JUNGHUHN's drawing 1856 (Landscape as symbol of inhabitants)

RAFLLES (1817) described teak trees growing habitat at a moderate elevation above ocean (sea level) with preferable limestone parental rock Karst Gunung Sewu. His works had already described landscape in that era, with particular reference to climate conditions. Teak demand was to supply the Colonial Government, i.e. Dutch, Japanese; and the Javanese Kingdom (monarchy). Figure 7.4. shows teak forest on Southern part of Gunungkidul in Yogyakarta Province up to Wonogiri in Central Java Province. Nowadays, teak is still in high demand, but needs a long period of time to grow to be good timber. The present landscape of agroforestry include Teak, Acacia, Mahogany, Falcata and Eucalyptus.

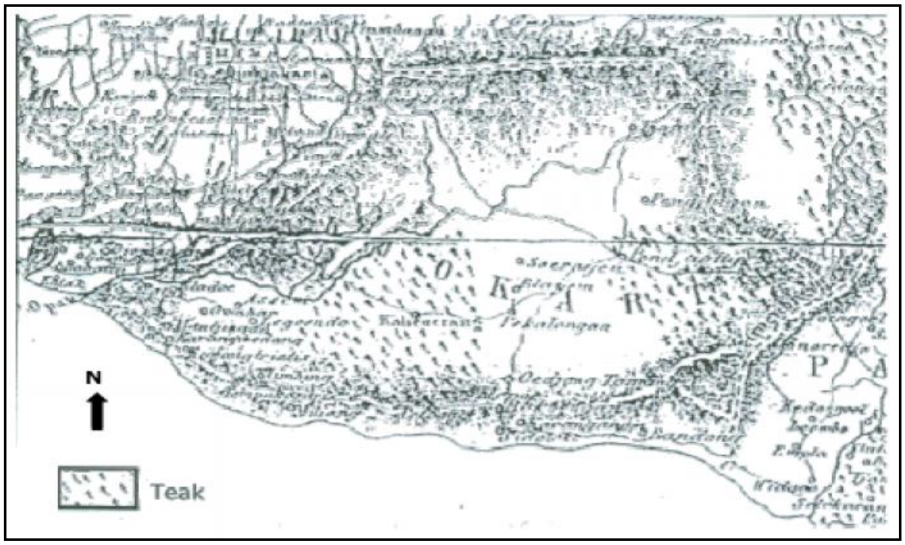


Figure 7.4. Teak Forest as natural landscape represented in the Southern part of Gunungkidul Map during the Java War
(DE STUERS 1847, cited in NIBBERING, 1991:57)

Maps and pictures presented in this study are "text" to be read in a landscape ecological approach, with limited scope (spatial and temporal scale limitation). Uncertainty in landscape modelling correlates with spatial and temporal scaling; landscape attributes such as geomorphology, soils, etc. The Normalised Difference Vegetation Index (NDVI) Map is an effective map for land use management aspects, applying remotely sensed phenology. Using bio-indicators of growth from the *Pranata Mangsa* calendar as knowledge of landscape phenomenon. A landscape approach to ecosystem management and ecosystem services requires a comprehensive approach.

7.1.2. Cultural Landscape to be Proposed as an Approach for Cultural based Water and Land Management : Human Imprint on Landscape

This sections is inspired by the works several scholars, particularly SAUER's idea on cultural landscape, HUMBOLDT's ideas on "the typical character of an area" as landscape and also HAGGET's works. Landscape comes from the German language *Landschaft*, which is a collective term for land that belongs together because of qualities (MÜELLER and VOLK, 2001). Cultural landscape is legacy for everyone. This includes conical hill Karst Gunungkidul which reveals aspects of local origins and historically evolving development of different policies in landscape management from water and land planning and management. The conical hills of Karst Gunungkidul demonstrate scenic, economic, ecological, social, recreational and educational opportunities, helping communities to better understand themselves as a cultural identity.

Landscape also reflects ethical values in human-environmental relationships, which in this study correlate with water and land management derived from seasonal based local knowledge. The philosophy work of MAGNIS-SUSENO (1981, 1984) and socio-cultural work of GEERTZ (1984) revealed the characteristics of Javanese values and beliefs which evolve and affect human behavior in their relationship with nature. The risk of water and land resources exploitation correlate with the necessity of livelihood: that is where a landscape approach is executed (KISSINGER, BRASSER, and GROSS, 2013).

Groups of people among Karst community who utilize water show different use of water, depending on their needs, availability and accessibility. Rural Karst community in the whole Gunung Sewu system use available water resources for their daily needs and can be considered traditional water users, who depend for their life and food sources mostly on water provided by nature. Their life relies on and is related to the environmental processes. Different daily water culture practices in different villages of the Gunungkidul region show varied individual application of the same idea in general community. This can be interesting to reflect cultural landscape in terms of space utilization. The model that SUNKAR (2008) applied to analyze the importance of culture in land use and income strategies proved that cultural sub-systems are the determining factor, the most influential, but the least influenced in the Gunung Sewu resource management system.

Archaeological findings found that dense populations existed not only in the Wonosari Plateau area, but also in the central and northern parts of the Karst Gunung Sewu region. The archaeological excavation team believed that the southern part of the Gunung Sewu range - which is dry and barren, extending up to the East Javanese town of Pacitan - was also a dense settlement area in the pre-historic age but living in a nomadic communities, mostly hunters (YUWONO, 2000). The communities must have developed interaction with the environment at that time.

Modern farmers have been introduced to *Tajarwo*, which in the future might be an "artefact" of agricultural civilization, a method similar to landscaping water conservation in term of grouping or clustering plants or crops with similar water needs together. *Tumpangsari* or inter-cropping with three crops in a patch using *Tajarwo* system could prevent high water consumption, which result in the crops gaining optimum growth. Figure 7.5 shows the *Tajarwo* method adaptated on *Tumpasari* between paddy and corn. Tajarwo (with its local specific adaptation) will be an inherited cultural behaviour similar to the *Ngawu-awu* method in the future. Both are adaptations phenomenon in the field that characterize the landscape and the imprint of the cultural behavior of the people. Adaptation of *Tajarwo* and *Ngawu-awu*, coupling with climatic observation, become the steping-stone to build water landscape and perennial agriculture, including agroforestry in the Karst region in adaptation of HOLZER's (2012) permaculture concept.

Tajarwo adaptation on corn field

Tajarwo adaptation on paddy and corn field

Figure 7.5. *Tajarwo* adaptation on *Tumpangsari* cropping system (Author, 2013)

Landscape as the imprint of human history, shows evidence of human values from the past, present, and offer future generations the possibilities of change (TAYLOR, 2003). Any differences between regions represent varied ecology and culture, while similarities show convergent ideas and culture (LEWIS, 1979 and 1993). If the recent rural landscape of Karst communities in Gunungkidul represents their way of life, then social life needs to seek to comprehensively understand the changing evolution of the Karst environment.

Social or cultural attitudes of individual, family or a community, shape the landscape by reflecting the physical, biological and cultural character of everyday lives. Seasonally different landscapes in Karst Gunungkidul represent landuse evolution with different perceptions and experiences of people in application of keen observation (*ilmu titen*) on physical features and social economic changes through time.

Reading the Landscape by LEWIS (1979), stated that

> "*the attempt to derive the meaning from landscape possesses overwhelming virtue. It keeps us constantly alert to the world around us, demanding that we pay attention not just to some of the things around us but to all of them - the whole visible world in all of its rich, glorious, messy, confusing, ugly, and beautiful complexity*"

Landscape can be read on many levels or scales, as nature, as habitat, artifact, system, problem, wealth, ideology, history, place and as aesthetic. The context of place and time is apreciated by combining a broad overview from ground observations to a bird's eye perspective using images from aerial photo and satellite images. This is important on reading landscape. The landscape can be understood as an artifact, possessing an evolving natural system and evidence of human interventions over time by classifying character, defining features and the visual and spatial relationship. For instance, the terraces on the conical hills of Karst Gunungkidul which imprint human adaptation through knowledge experiences. Water and land adaptation on Karst Gunungkidul landscape has character defining features, located in situ, in relationship to each other and the greater cultural geographic context.

7.1.3. Inventory Process for Cultural Landscape

Understanding the geographic context of Karst Gunung Sewu, in particular Karst region in Gunungkidul Regency is the first step to build spatial landscape knowledge. Development considers historic representations of the conical hills and the present day's view to affect future Karst management (treatment) visually and spatially. Landscape views of Karst Gunungkidul, influenced by human activities may be considered as ethnographic landscape, with some historic site showing how (ancient) Karst inhabitants developed their culture from a riverside community to cave settlers, before Hindu culture entered on 4^{th} century. For this reason, some caves fall into historic sites and ethnographic significance. *Tumpang sari* explains how following the seasonal calendar relates to people's activities and occupancy which shaped the Karst Gunungkidul conical hills characteritics.

Gunungkidul Karst landscape encourages inhabitants to take action to 'modify' their environment. Landcape (ecological) behavior shows homogeneity and heterogeneity based on locality, and cognitive knowledge inherited or developed by experiences and observations. A premise underlying culture and landscape ecology interaction is that cultural concepts of nature differ from scientific concepts of ecological function. The appearance of landscape communicates cultural values (NASSAUER, 1995). Landscape ecology is too focussed on biophysical matters neglects the cultural aspects of landscape (WU, 2010:1149). This study assess local knowledge which is considered an inherited cultural identity which then transforms into landscape spatial knowledge. FORMAN and GORDON (1986) state that understanding the way a landscape involves understanding human influences and their culture, how both human and nature's roles are entangled. DAMES (1955) described conical hills of Karst Gunung Sewu, in several location were suffering the erosion on the terraces and were being abandoned, even at time *Pranata Mangsa* was still applied. Technology in agriculture and soil conservation were inadequate in the early 1900s. On the landscape where reforestation once seemed impossible, pioneer vegetation should now be considered (HOLZER, 2012).

Figure 7.6 and Figure 7.7 expose different dimension of agriculture practices applied during the survival era. Figure 7.6 shows a doline pond which were still full of water which means the rainy season has left at that time. The agricultural landscape shown in Figure 7.7, based on DAMES (1955:98), was used by PENNY and SINGARIMBUN (1973) during the situation of land hunger to support cultivating irrigated rice to support the population. PENNY and SINGARIMBUN picked a word that correlate to reading landscape, they said that "planners should have read the story of the land by seeing how the hungers of the land changed the landscape particularly on the steep hillsides" (1973:2). The peasant who should love their land have ended up destroying their resources due to their life necessity and not in line with land ethics and wisdom from seasonal based local knowledge, in particular the *Pranata Mangsa*. Terracing using stone walls was widespread in the 1940s (DAMES, 1955:131) to cultivating and manage the land's capability to respond to soil erosion (DAMES, 1955:98).

Figure 7.6 Landscape in Gunung Sewu with typical Karst hillocks and small doline pond (source: DAMES, 1955:96)

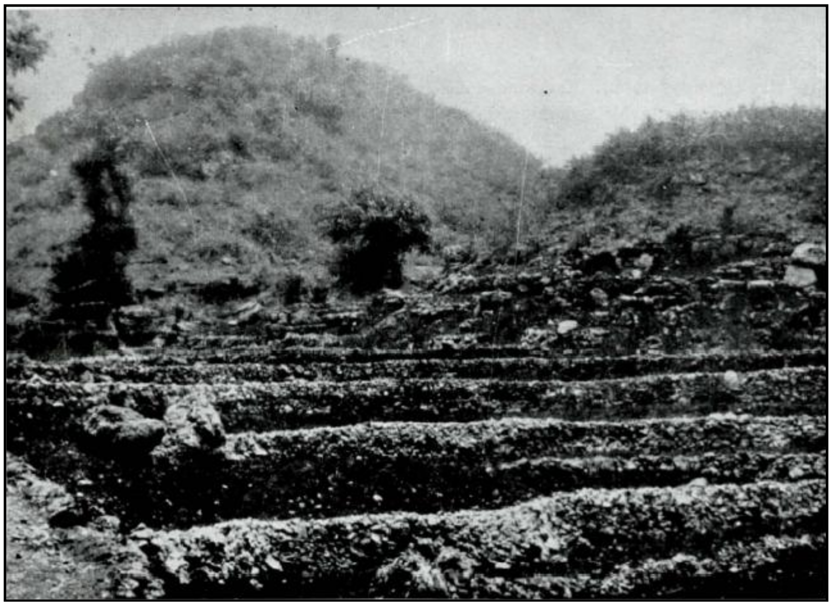


Figure 7.7. Agricultural Landscape (several meters soil depth) with terraces on the slope (source: DAMES, 1955:98)

Cultural landscapes (HAGGETT, 1983: 263) from a bird's eye perspective, shows patterns of fields and farms (see Figure 7.8). Landscapes are where people's livelihoods, identities and belief systems, shaped the environment. Nature's bounty is managed and harvested on a sustainable basis to satisfy people's material and spiritual needs. Therefore, cultural landscapes define the provisioning of ecosystem services. However, cultural landscapes inevitably change within economic development, where areas are opened up through road construction and communications advances, and traditional belief systems give way to new ideas. The spatial impact of the agricultural revolution has shown the human impact on the environment (HAGGET, 1983:279).

Figure 7.8. Cultural Landscape of Gunungkidul on bird's eye[19]

Human and environmental interconnection is part of cultural geography. Cultural geography interconnects the themes of culture, culture area, cultural landscape, culture history and cultural ecology in the research field. Rural Karst landscape are heritage and show the collective identity that built the sustainability of rural communities in Karst Gunungkidul. Figure 7.9 reflects collective activities and the relation to the land, interpreted as a collective behavior within ecology and the economy. Rural landscape exploitation proceeds for food production, water harvesting, timber (logging), and mining minerals.

Figure 7.9. Human (social interaction) and the land as cultural identity (Author, 2012)

[19] landscape view in the border of Karst and Wonosari Plateu

Bio-indicator plants embedded in the phenology knowledge of the *Pranata Mangsa* that disappear need to be recorded. New plant indicators based on existing and evolving conditions need to be substituted. Local knowledge is an intellectual knowledge. Although local intellectual property rights in a global knowledge culture have been considered, the global institutions are critized for creating a new culture of regulation that act as powerful vectors for the transmission of specific, culturally determined systems for codifying knowledge and self-appointed arbiters of the "normative" bases of global regulatory regimes.

7.2. Potential Disturbances Approach on Karst Gunungkidul

Potential disturbances can be observed using a frog perspective and bird's perspective when applying phenomenological methods (KARRO, MAEGI, and PALANG, 2014) to potential detriment to Karst landscapes from human interpretation of water and land management from seasonal based knowledge. Disturbances in karst areas are considered as parameters of how people address their environmental resources. Potential disturbances on Gunungkidul's Karst landscape highlight the role of humans in crafting the land. Changing landscapes facing annual water scarcity on Karst Gunungkidul, correlate with and are affected by the anthropogenic disturbances, relating to water and land ethics. Landuse/land cover changes jeopardize livelihood, including the change of the water retention area in Karst Gunungkidul, and the shortened period of *Telaga*'s water holding capacity because of erosion sedimentation.

Landuse history or legacy is visible in the present landscape which represents previous human value application. Scientists emphasizing the problem of water scarcity in the Karst region consider people's behavior upon the landscape as the main problem related to landscape changes in addition to the shifting climate behavior (KUNDZEWICZ, KANAE, SENEVIRATNE, HANDMER, NICHOLLS, PEDUZZI, MECHLER, BOUWER, ARNELL, MACH, WOOD, BRAKENRIDGE, KRON, BENITO, HONDA, TAKAHASHI, and SHERSTYUKOV, 2013). In the next sub-chapter discussion, this study addresses the landscape approach with an ecological view. Application of local water management and space utlization as an adaptation and coping mechanism which ensures the cultural landscape reduces the risk of water stress or scarcity. This study applies Karst disturbances approach from two different methods as comparison. Both methods emphasize data availability, but differ in the detail of the parameters.

7.2.1. Identification of Karst Disturbance Index parameters based on VAN BEYNEN and TOWNSEND (2005)

Van Beynen and Townsend proposed a Karst Disturbance Index to assess disturbances in Karst environment using geomorphology, hydrology, biota, atmosphere, and cultural factors. Each parameter uses indicators to break down the disturbance condition. Physical features combine with man-made culture to define the degree of disturbance. This study applies available data based on field observation and secondary data. However, some of the indicators proposed by Van Beynen and Townsend are dismissed due to lack of data or unavailable data. Each parameter includes discussion of:

(1) Geomorphology

Geomorphology indicators used in the assessment are quarrying/mining, flooding, stormwater drainage, infilling, dumping, erosion, compaction, decoration removal, sediment/mineral removal, and floor sediment compaction. Several factors that are discussed in this study adapt these indicators, for example sinkholes as infilling or dumping site, mining, and denudation (adapted as decoration removal).

Sinkhole occurrence or location in Karst Gunungkidul cannot be forecast precisely. Research on this natural event has not been conducted nor correlated with water withdrawal activities from several water sources of underground river and caves, i.e. Bribin, Seropan, Ngobaran, Wilayu and Banyumeneng. On the 2nd of January 2011, a sinkhole occurred in a doline pond located at *Telaga Motoendro* in the Panggang sub-district (see Figure 7.10). The sinkhole occurrence affected water source for 300 households from 2 hamlets which lost their daily needs water storage. The pond was once able to hold rain water during rainy season and kept it until the dry season, never drying up. People utilized the pond water for washing and cattle needs, and during the dry season they used it for domestic needs.

Figure 7.10. Sinkhole Occurrence at *Telaga Motoendro* Panggang sub-district Gunungkidul Regency[20]

People are still unaware and lack appropriate knowledge of Karst system while being those most affected by it. Sinkhole occurrence is not well recognized yet, but in the future, due to water and land pressure on the Karst system in Gunungkidul, this might increase people's exposure to the disaster. Sinkhole, in the local people's language is known as *luweng*, is used for garbage and other waste disposal. Sinkhole become a dumping site and threaten underground river water. Figure 7.11 shows that sinkhole plays a role in the underground river network of Gunung Sewu, and the possibility occurrence need to be observed from water flows during rainy season particularly near settlement or human related activities. Denudation rate from previous works suggesting that denudation rate of Gunung Sewu Karst is 50.91 m3/year/km^2. Gunung Sewu Karst area is about 1300 km^2, therefore total calcium carbonate removed from this area is 165.464 ton/year (HARYONO, ADJI, WIDYASTUTI, and TRIJUNI, 2009).

[20] Sinkhole occurrence in the ponds left the water source dried up within a day after one day or several days of raining

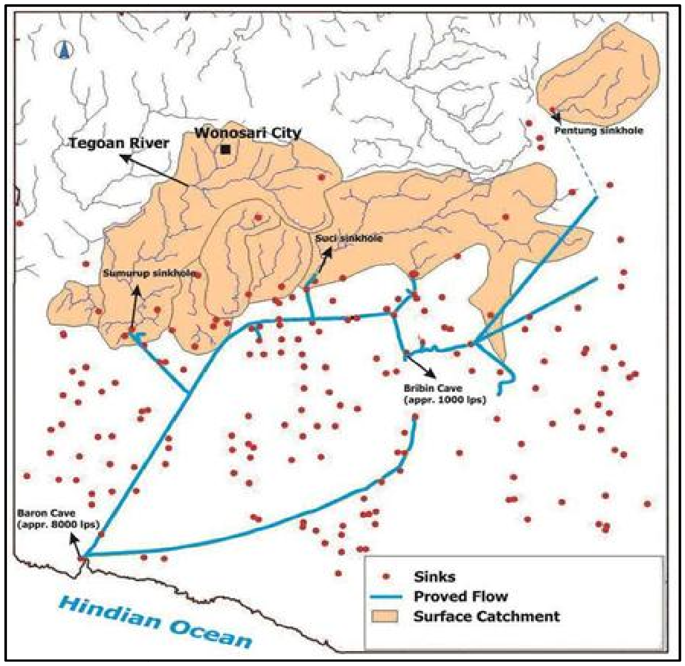


Figure 7.11. Possible recharge of Bribin-Baron Underground Water System with some sinkholes (source: ADJI and SUDARMADJI, 2008:3)

Carbonate rock mining in Karst Gunungkidul (see Figure 7.12) has been a consideration within the last decade due to illegal mining on private land (hills). Land owners give permission to private mining companies to mine the hills without government permission. Bedoyo village in Ponjong sub-district is the most famous mining location in Karst Gunung Sewu system due to its carbonate rock characteristics.

Figure 7.12. Carbonate Rocks Mining in Bedoyo Village (source: Author, 2013)

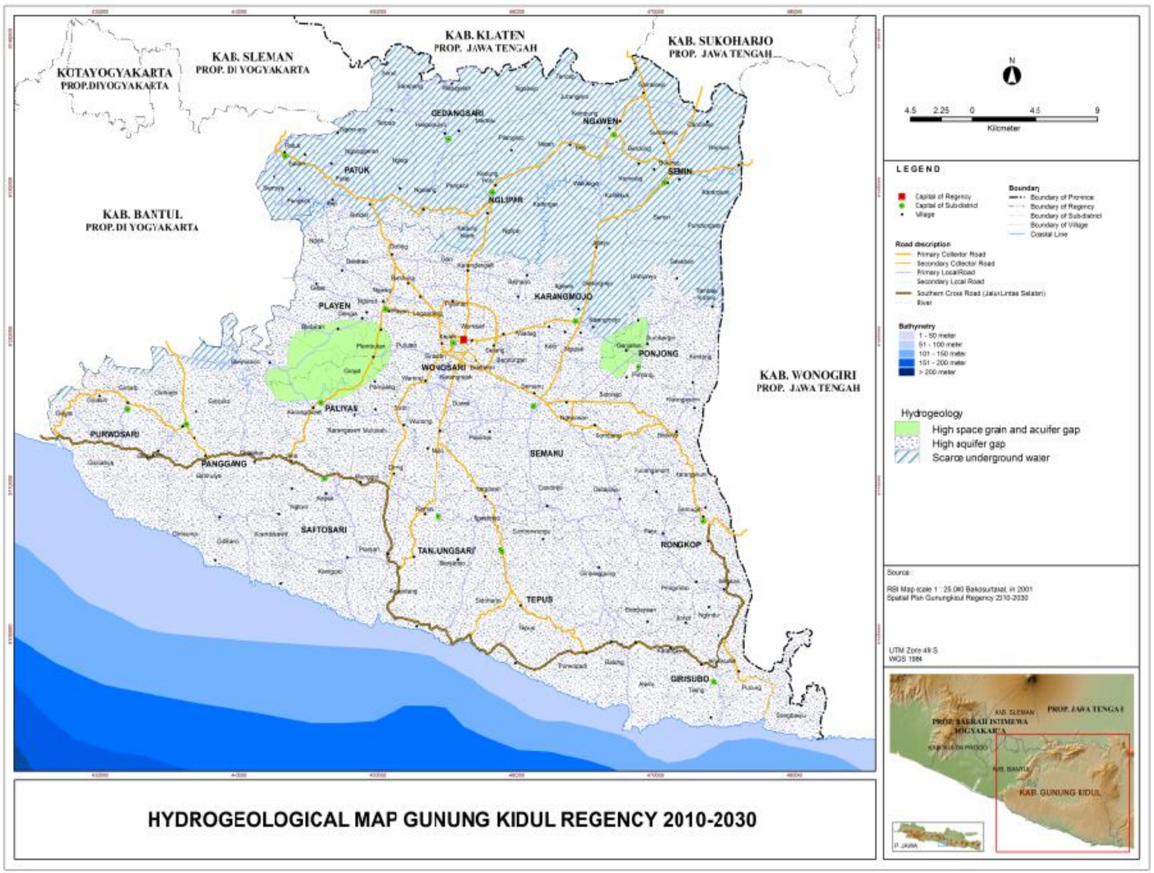
Soil erosion in Karst Gunungkidul has accelerated due to deforestation and agricultural land intensification or extension. This process brings about rapid sedimentation in doline ponds. Almost 90% of doline ponds now have shorter period as rain water pools and quickly dry-up, particularly during prolonged dry seasons (FGDs, 2012, 2013).

(2) Hydrology

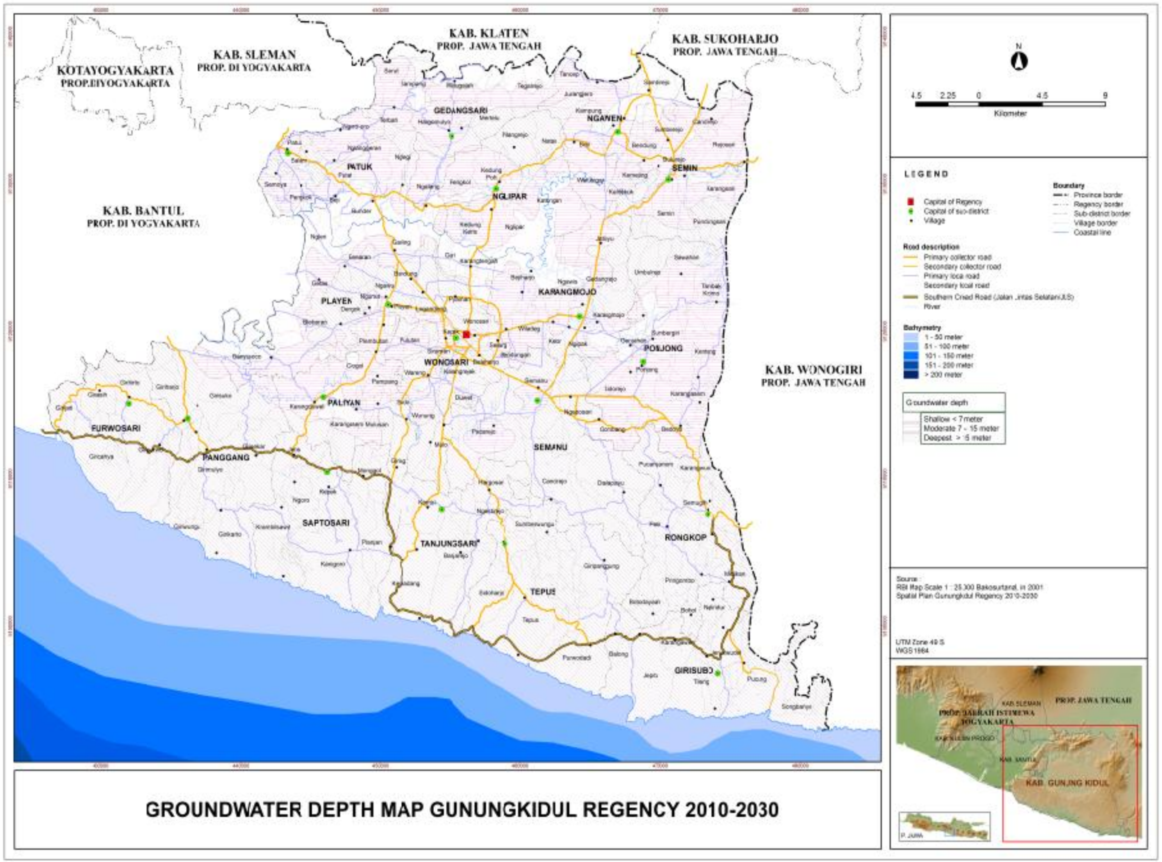
Hydrology indicators are pesticides/herbicides, industrial and petroleum spills, algal blooms, changes in water table, and changes in cave drip water. None of those indicators are recorded and available. Pesticide/herbicides or fertilizer utilization has not shown a negative impact yet, because farmers have combined the chemical products with organic ones. Changes in water table are affected by annual seasonal changes, but detailed observation has not been conducted yet, and that include observation of cave drip waters.

The hydrology system in the Karst area is controlled by geomorphologic and geological characteristics. The conical hills characteristic of the Gunungkidul Karst region determines the hydrogeology of the system and represents the inhabitants' adaptation to the available water. The Gunungkidul Regional government has considered the hydrological system in their spatial plan (see Map 7.1). The Southern part of the Regency suffers higher level of water scarcity annually during the dry season compared to the middle and northern parts.

Karst characteristic in the Southern part of Gunungkidul affect the depth of groundwater. Map 7.2 shows the spatial distribution of groundwater depth in the regency. It is important to analyze in the watershed regionally because the upper or northern and middle region act as a catchment or retention area for the southern or lower part of the Gununngkidul Regency. Landuse changes in any part are likely to affect water storage, underground river water and other water sources. Further survey need to conducted. Water quality from underground river networks or springs is still tolerable for people, although they need to wait for the carbonate solution dregs to settle before use. However, people prefer to use water from their rain water tank (FGDs and in-depth interview, 2012, 2013), particularly during the rainy season because the tap water from PDAM contains (sludge) sediment.



Map 7.1Hydrological System Gunungkidul Regency
(source: Gunungkidul Regency Spatial Plan 2010-2030)



Map 7.2. Depth of Groundwater in Gunungkidul Regency
(source: Gunungkidul Regency Spatial Plan 2010-2030 and Author draft 2014)

(3) Atmosphere disturbance

Atmosphericdisturbances factors are air quality, desiccation and human-induced condensation corrosion. Karst Gunungkidul is a rural landscape with scattered population density. Potential air pollution is mainly due to mining activities that burn limestone. This is not showing serious problem yet, but there is no data from related institutions published.

Figure 7.13. Site of Carbonate Rocks Quarrying with smoke in Bedoyo Village (source: Author, 2013)

(4) Biota (biodiversity) disturbance

Biota disturbances should assess vegetation removal, the state of vegetation, species richness in caves and groundwater, and population density in caves and groundwater. JUNGHUHN (1857:247- 254) described the biodiversity of the forest in Gunung Sewu and how suitable climate was at that time for the vegetation, i.e. acacia and teak, and other plants and fauna to proliferate. In the script, it is mentioned how green Gunung Sewu as if the inhabitants lived in a paradise-like picture duringt that exploring period. JUNGHUHN (1857: 252) also described the same onset of the dry season conditions then that apply today. During March and April the leaves still green and then in July dryness began.

Disturbances of the forest for timber logging and land conversion started when the Dutch colonial government needed resources. Then exploitation continued during the Kingdom (Monarchy) era, and continued with the Japanese colonial government (1942-1945). Then came the enforcement of the green revolution in the 1970s and exploitation continued during the post economic crisis in 1998. Some scholars have analyzed the changes of landscape Karst Gunung Sewu following different time with climatic and environmental changes. NIBBERING (1991) described that escalating land use in Gunungkidul triggered the decrease of vegetation or landcover (see Figure 7.14).

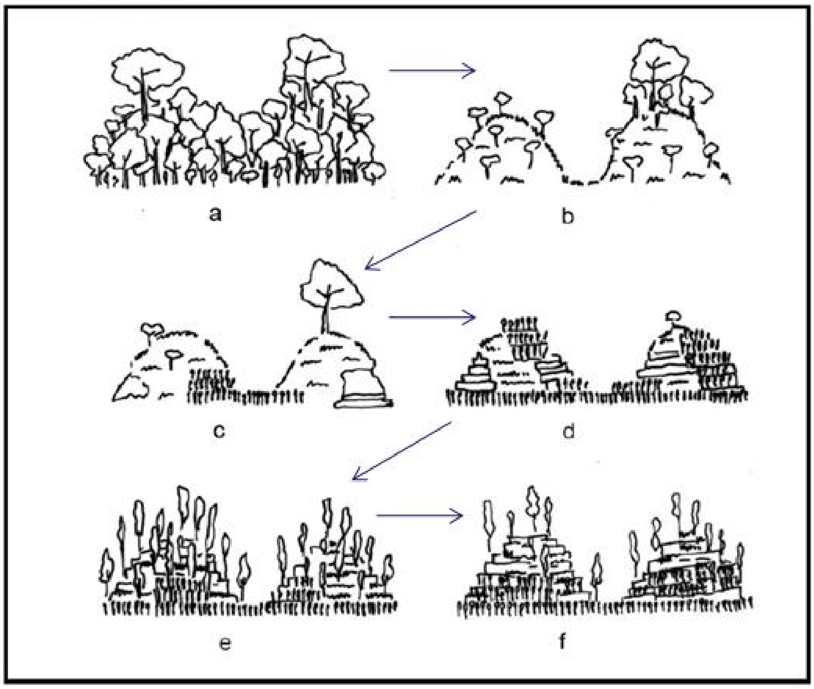


Figure 7.14. (a) Original vegetation: mixed evergreen-moonsoon forest (ca. 1500?); (b) Woodland-savannah vegetation (ca. 1835); (c) Intensifying agriculture; (d) Deforested and degraded land (ca. 1960); (e) Fields planted with regularly pruned trees (ca. 1990); (f) Fewer trees on hillside (1998). (Source : SUNKAR 2008 cited (a – d) DAMES, JUNGHUHN, VETH, DAMES, (e) NIBBERING 1991, SUNKAR 2008)

Environmental pressure have already started for at least 200 years prior to this study. Noting that *Pranata Mangsa* for agriculture was established in 1855, the landscape changes were determined by non-natural factors. A favorable physical setting was changed by humans. External information or knowledge lead to both increasing or enrichment and decreasing or poisoning environmental quality in Karst Gunungkidul.

Before the late 19th century, biodiversity in Karst Gunungkidul was still quite abundant when the area still a primary forest (SUNKAR, 2008; LIES, 2012). Karst Gunungkidul contained high level of biodiversity. Vegetation variation surrounding water sources supported water availability when the dry season came, particularly vegetation with strong roots that retain water such as *Ficus benjamina*. Figure 7.15 shows the present landuse/landcover based on spatial topographic dimension in the early raining season (November 2013 - Feburary 2014).

Figure 7.15. Landuse/landcover based on spatial topographic dimension (Author, 2013)

Time series data on bio-diversity show no comprehensive data compilation yet, but a study by MATALABIOGAMA[21] (1999) revealed 66 species of plants, 32 species of birds, 18 species of mammal and 23 species of reptile and amphibian, in the the 20% area of the centre part Gunung Sewu Karst. Among the flora listed, almost all of the flora in the whole Gunung Sewu Karst are cultivated crops. Cave flora and fauna of Gunung Sewu Karst have not been explored, but ROHMADI (2004) found 11 species of *triglobits* and *stigobits* in a cave in the Gunung Sewu Karst area. Landscape changes connect to the amount of biodiversity and human culture. Agriculture or farming practices in several hills of Karst Gunungkidul shows the *Karren* phenomenon (bands of bare limestone forming a surface) which potentially lead to decreasing biodiversity, not to mention monoculture farming practices.

(5) Cultural based disturbances

[21] student club who explore nature, home based in Faculty of Biology Univiersitas Gadjah Mada Yogyakarta, Indonesia

Parameters for cultural assessment of disturbance are mainly influenced by human products (anthropogenic factors). Human culture and civilization first appear along open river courses. Then, cave habitation developed at the openings of caves along the dry valleys or near doline ponds. The present time shows human habitation is determined by geomorphologic processes which are also being modified by humans. Karst Gunungkidul has witnessed a dynamic inter-relationship between landuse/landcover changes and human habitation. Human habitation stages unveiled by previous archaeological works are likely governed by uplift history and landform development stages of the the area (SIMANJUNTAK, 2002 and YUWONO, 2011). Removal of artifacts have not been recorded in detail, because cave site exploration is still limited. However, over exploitation through mining activities will destroy the cave network.

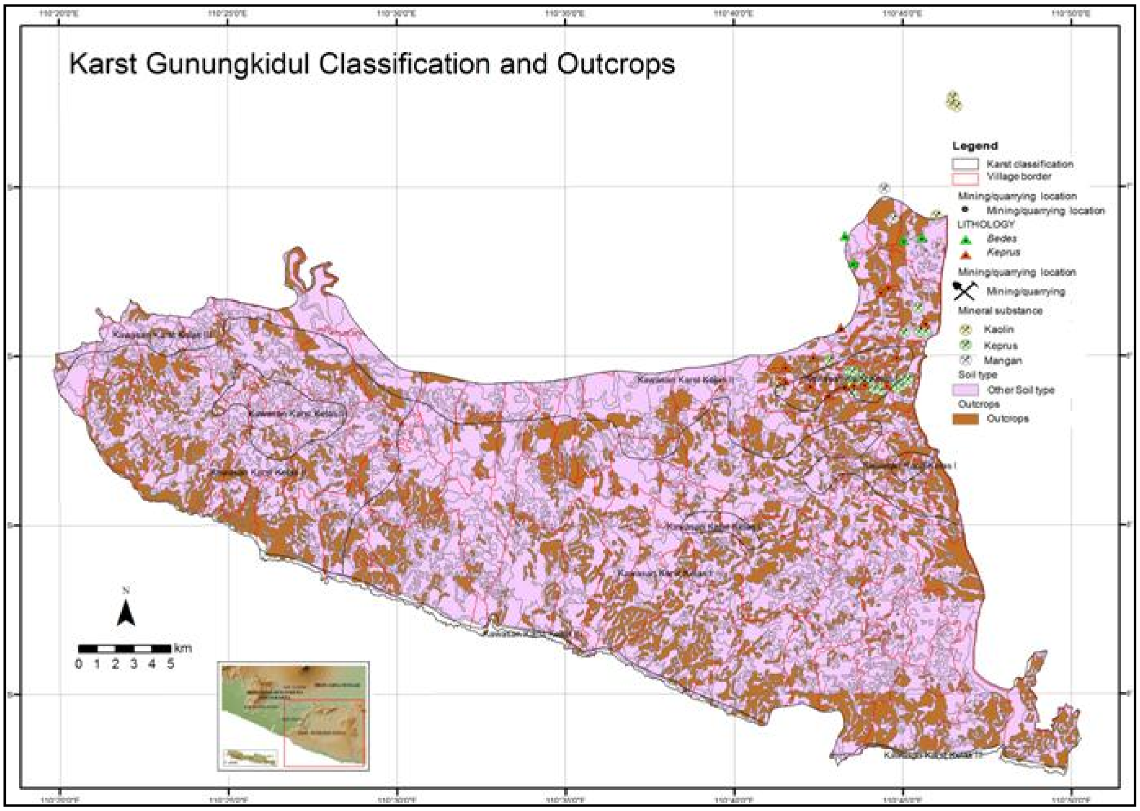
Regulation and enforcement in Karst environments have been established, but in some locations destruction still occurs. National and regional government have issued some regulations and laws, i.e. Spatial Plan (RTRW), Karst delineation Ministerial Regulation (*Permen* ESDM. 17/2012) and regional regulation on mining activities (*Perda* Gunungkidul 11/2003). Public education in Karst environmental knowledge is possible through formal schooling, the farmers "school" (i.e. integrated land and pest managementschool, climate field school), or community gathering. Inherited local knowledge based on the seasonal cycle, physical features identification and adaptations needed are part of the cultural identity of rural Karst Gunungkidul people. Cultural disturbance factors are part of cultural ecosystem services. Thus, assessing cultural ecosystem services is considered a complimentary comprehensive analysis for Karst landscape approach.

Summary:

Karst disturbances index from Beynen and Townsend (2005) can only be applied on several parameters and factors in Karst Gunungkidul. Based on field observation and available secondary data, this study concluded that Bedoyo village has experienced a disturbed index due to its mining activities. The carbonate rocks in Bedoyo village is considered the most valuable one compare to other part in the Karst Gunungkidul.

7.2.2. Identification of Karst Disturbance based on Matching Method (HARYONO, 2012)

There has been a long history of land and forest clearance since the colonial times to meet human needs (PELUSO, 1992; NIBERING, 1991; SUNKAR, 2008). This has led to disturbances on landuse/land cover. The classification of Karst disturbances based on the matching method (HARYONO, 2012) uses vegetation cover and outcrop occurrences. It assessed several Karst region and used available data (see Map 7.3). Karst regions that are being used for comparison for different characteristics in the matching method are Maros in South Sulawesi, Raja Ampat in Papua, Alas Purwo National Park in East Java, Gunung Sewu (covers three different Regencies: Gunungkidul, Wonogiri, and Pacitan), Rembang Hills in Central Java, Citatah in West Java and Tuban in east Java. Percentage numbers are applied on disturbances classification criterion. The assessment's aim determine the scale and detail data to collected and analysed.



Map 7.3. Karst Gunungkidul Outcrop (see brown color) within Karst Classification (source: Gunungkidul Regency Spatial Plan 2010-2030 and Author draft 2014)

Karst areas with 60% by vegetation cover are classified as good. When the vegetation removal than 50%, there is disturbance. Perennial vegetation, including forestry plantations, and shrubs are used to determine the disturbances on Karst regions from land cover classification. Vegetation removal indicate the disappearance of the *cutaneous* layer which act as a hidrology regulator in Karst regions. Decreasing vegetation removal reduce water storage up to 15% on Karst region. The disappearance of the *Epikarst* layer which may be up to 50 m in depth can affect a decrease of water storage by 80%. Water discharge in *Epikarst* layer as springs decline reduces to 45% - 55% of normal, ensuring that the during dry season springs dry up for six months or more.

Special objective criterion are also used to complete the matching method assessment. Caves, doline ponds, springs and hill condition are indicators designated to identify disturbances on Karst region. Remote sensing for image interpretation and field observation, and also secondary data collection from related institution are conducted to support the disturbances classification in Karst areas (HARYONO, 2012). The use of satellite images or aerial photos for identifying landcover certainly require scale consideration and the type of images used, either using high spectral or detailed scale depending on the aim of study or assessment.

Based on the assessment by HARYONO (2012), Karst Gunung Sewu is classified as damaged or disturbed because only 10% to 50% of the vegetation cover exists. In several locations in Gunungkidul Regency, there is increasing percentage of vegetation disturbance or damage due to mining and land clearance, i.e. Bedoyo village and other hills mined for road fill due to road expansion (Figure 7.16). Law enforcement of Karst mining is still difficult due to the numbers of complaints between outside mining companies and some local miners.

Figure 7.16. Hill excavation on the side of the road to Girisubo sub-district (Author, 2013)

Special object disturbances are included to support the matching method by considering caves and archaeological site disturbances, doline ponds deterioration and hills mining. The classification of damage or disturbance uses percentages. Assessment to collect data is conducted through field observation and secondary data acquisition from related institutions.

However, it needs to be considered that baseline data is not precisely available and could not reveal a previous record until first exploration of caves or sinkholes in Karst Gunung Sewu began. Hence, the matching method work depends on the availability of data from the project by MACDONALD and PARTNERS (1984); and works of cave exploration and archaeological site excavation by archaeological scholars such as SIMANJUNTAK (2002), and YUWONO (2000, 2009), and the *Acintyacunyata* Speleological Club (1984 - 2013) as baseline data. Based on the research initiated by HARYONO (2012), and field observation (2012, 2013) the most affected or disturbed indicators are shortened doline ponds period for retaining rain water. During field observation and FGD's, it was confirmed that doline ponds in the sub-districts and villages dried up faster, and lasted for only two to four months on average after the rainy (wet) season ended.

The correlation between outcrops condition and springs based on available references, limited data availability over time, show caves and archaeological site disturbances are good (less than 10 % disturbance) and nearly disturbed condition (10% - 25% disturbance). The good condition is the west part to the middle part of the Karst Gunungkidul like in Purwosari, Panggang, Saptosari, and Tanjungsari sub-districts. The nearly disturbed one is in the north of the Karst Gunungidul like in Bedoyo and Gombang village in Ponjong sub-district. In the most visited caves and sites accessible to tourism location, the caves are in the nearly disturbed condition, mostly in the North Eastern part of Karst Gunungkidul. The disturbances of caves affect the cave inhabitants such as bats and other endemic species, although no precise data is sufficient on this. *Acintyacunyata* Speleological Club (ASC) Yogyakarta and related clubs, who do research on biodiversity, have initiated a record of cave inhabitants.

Springs in the Karst Gunungkidul based on references and field observation, still run annually but water capacity decreases during the dry season. Thus the springs have been classified as being in good condition. However, the quality of water requires further detailed investigation related to possible pollutants from agricultural and mining activities or others. Hill volume relates to spring water capacity; a decreasing hill volume correlate with a higher percentage of spring disturbance. Mining activities indicate descending hill volume, and this can be determined from detailed satellite images and aerial photos to support secondary data from government institutions. Most mining activities are located in Ponjong sub-districts and the surrounding area, but land clearing also occurs in many hills in other sub-districts which complicate water source condition. However, spring conditions remain good (field observation, 2012 and 2013). Meanwhile, land cover on Karst hills show disturbed condition in the 10% to 50% range (HARYONO, 2012). Overall observation leads to the conclusion that Karst Gunungkidul is disturbed.

7.3. Ecosystem services and ecological balance on Karst Landscape

An ecosystem is a community of plants, animals and smaller organisms that live, feed, reproduce and interact in the same area or environment. Organisms inhabiting volcanoes different are to those inhabit riverine environment, or hilly Karst regions. Gunungkidul Regency is differentiated into three different ecosystems which determine their inhabitants. Living organisms in Baturagung Range are different to the ones living in the Karst and Wonosari Basin. Each ecosystem has specific organisms which have adapted to their environment, either naturally or as modified by humans. The Karst ecosystem has different landscape and ecological meaning. The three ecosystems in Gunungkidul Regency show agriculture and agroforestry landuse/landcover on its landscape, but differ in field practices due to the characteristics.

Crafting an understanding of cultural ecosystem services (TENGBERG, FREDHOLM, ELIASSON, KNEZ, SALTZMAN, and WETTERBERG, 2012) and ecosystem service (MILLENNIUM ECOSYSTEM ASSESSMENT, 2005) in this study are interpreted and derived from seasonal based local knowledge, known as *Pranata Mangsa*, and consists of early warning for annual weather changes, based on hazard and risk. It is the people who need to develop the skill on keen observation "*ilmu titen*", to enhance their knowledge of the surrounding environment. Ecosystem and ecological based adaptation occurs when plants and animals adjust their physiology, behaviour or distribution to changing environmental conditions (KATRIN, ARIANE, ALEXANDER, HERMAN, and WOLFGANG, 2012). This study tries to link Karst landscape sources to ecological balance and environment services in consideration of water resilience to manage the quality of the landscape for human and other inhabitants. Ecosystem services and cultural landscapes both have cross cutting subjects and complement human environmental connections where geography deals more with cultural landscapes (SCHAICH, BIELING, and PLIENINGER, 2010). The challenge is to analyze the conceptual ecosystem services aspect and empirical aspect of cultural landscape derived from seasonal based local knowledge application in the Karst region Gunungkidul.

Inherited seasonal based knowledge *Pranata Mangsa* with local adaptation is considered a cultural heritage and identity in this study. Thus, a cultural ecosystem services approach is considered important in a cultural landscape approach. This study tries to correlate the understanding of ecosystem and ecological essence based on local knowledge *Pranata Mangsa*, and the agricultural transformation of *Tumpangsari* with adaptation to *Tajarwo* or other farming methods in the future, as the artifacts of cultural value and behavior in the rural Karst Gunungkidul landscape. The landscape also express collective realities of social cultural community, differentiaton and the relation between humans and the nature (CLAVAL, 2005:13). The rural Karst Gunungkidul landscape has witnessed past and present relationship between humans and the natural and built environment (DIMITRIADI, 2000:3).

Understanding Ecosystem functioning from the local seasonal calendar *Pranata Mangsa*

Gunungkidul Regency is differentiated into three different landforms which provide different ecosystem services. Each ecosystem carries different functions and therefore require supporting planning and management with formal legal regulations. The ecosystem services coupling with landscape services characterize Karst rural people's behavior (see Figure 7.17).

Understanding Karst landform characteristics and the ecosystem (see Map 7.4) in application of seasonal based local knowledge require different scales and levels in decision making. The Gunungkidul Regency government has put ecosystem consideration into the Spatial Plan 2010-2030, but the enforcement of the regulation is another challenge.

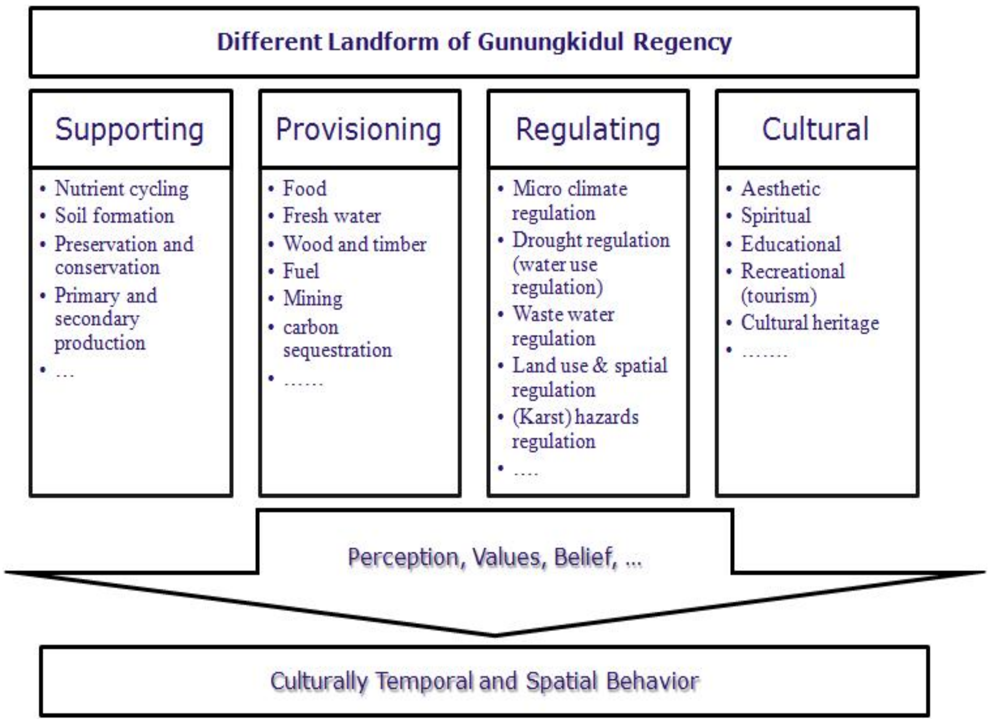
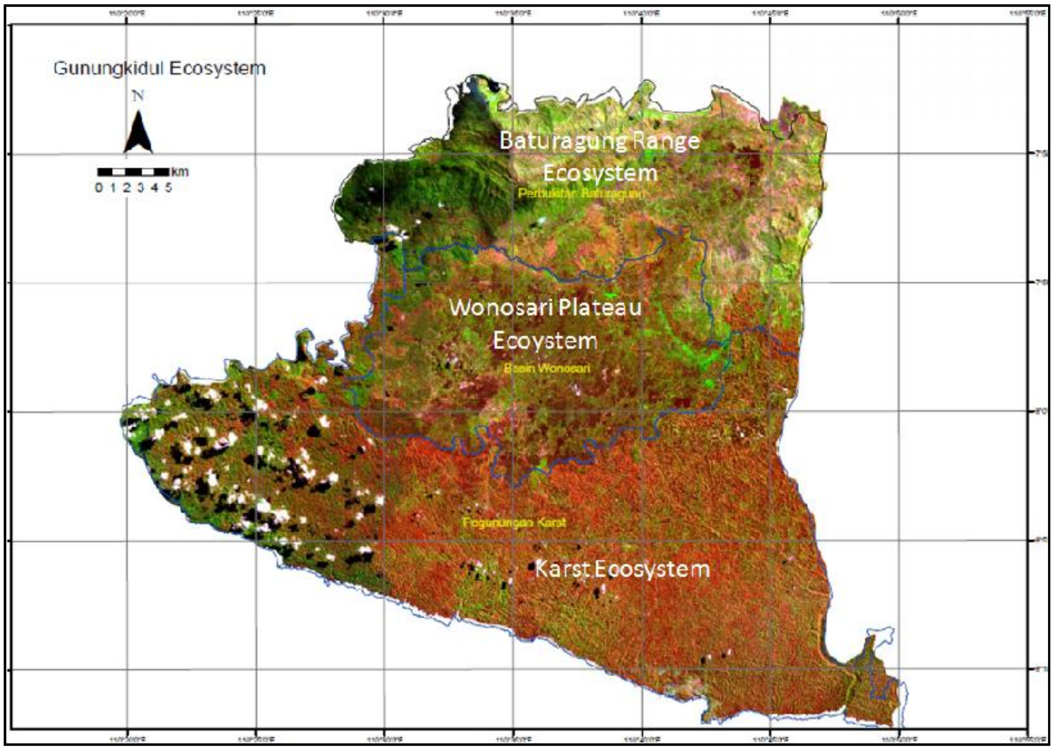


Figure 7.17 Ecosystem services approach and cultural behavior (adaptation from MILLENNIUM ECOSYSTEM ASSESSMENT/MEA, 2005)

Local knowledge *Pranata Mangsa* with its phenology or bio-indicators, on a comprehensive time frame, teaches and guides people, in particular farmers, to understand the ecosystem service. It has the intangible elements of an ecological approach. When it comes to *Mangsa Labuh Kapat* and *Kalima* (end of September to early November), and the rain starts falling, the provisioning and regulating ecosystem services work. People need to be prepared to cultivate and manage the land, calculate water consumption for certain periods of time based on the crop types, and educate the next generation in their cultural identity of keen observation "*ilmu titen*". When *Mangsa Mareng Terang* comes (mid May to the end of June), the dry season starts and farmers fallow the land, allowing nutrient cycling to starts.

Understanding the cycle is challenged by economic reasons in harsh Karst conditions.



Map 7.4. Gunungkidul Ecosystem Differentiation into three areas based on Landform and Ecosystem (source: BAPPEDA Gunungkidul, 2010 and Author draft 2014)

Ecosystem services also face uncertainty during the assessment (HOU, BURKHARD, and MÜLLER, 2013) due to scale and spatial data, and bias in classification. This study tries to see the ecosystem service based on field observation and correlates it with local knowledge application and adaptation. Karst ecosystem services based on field observation conducted between October 2012 - January 2013 and November 2013 - January 2014 in Gunungkidul, coupling with secondary data and information here described qualitatively, characterize the human ecological imprint.

1) The provisioning on water supply, agricultural, wood, fuel

Karst Gunungkidul is classified into three distinct features, namely labyrinth, polygonal and tower cone or residual Karst (HARYONO, 2000:80). The ecosystem services are similar to one another. Therefore it takes consideration to manage water and land based on the characteristics. In the seasonal calendar cycle *Pranata Mangsa*, a parable of water availability is described during *Mangsa Labuh Kapat,* as guidance to manage water availability for life purposes. The practices with livestock in Karst Gunungkidul ensure cow dung is a source of bio-energy. The IWRM Indonesian-German project developed a pilot waste treatment project in Pucanganom village from cow dung as a source of biogas.

Figure 7.18 shows water source in Sadeng coast which supplies the surrounding villages of Girisubo and also outside the sub-district. Exploration of groundwater sources is regulated under national and regional law, which ensures that local people should receive equal water distribution and preserve the environment.

Figure 7.18. Water Source at Sadeng coast, Girisubo (Author, 2013)

2) The support of geo-biodiversity, nutrient cycling, land surface stability, and carbon sequestration

The *Tumpangsari* system with adaptation to *Tajarwo* method in agriculture supports the geo-biodiversity of Karst ecosystem (see Figure 7.19). Fallowing the land during the dry season lets the nutrient cycle work. Two decades ago farmers grew *orok-orok* or Sunn hemp to increase the process but the practices had disappeared due to the use of chemical fertilizer (Indepth interview, 2012). Karst landscape has the potential for carbon sequestration (HARYONO, ADJI, WIDYASTUTI, and TRIJUNI, 2009). Being located on three different ecosystem and geomorphology, Gunungkidul Regency needs to evaluate comprehensively each ecosystems supporting functions. For example Baturagung Range and Wonosari Plateau have landuse and landcover regimes which determine underground water availability and flow in the Karst ecosystem.

Figure 7.19 Agrobiodiversity from *Tumpangsari* or intercropping system at Kenteng village, Ponjong sub-district (Author, 2012)

3) The regulating on springs and ground river flows, soil moisture, ponds lake, and micro-climate

Figure 7.20. Groundwater pumping in Bribin cave[22]

Groundwater flows supply is determined by the upper stream management. Figure 7.20 shows Bribin cave water tapping network, which is connected to an underground river via in both the caves located upper and lower stream.

[22] The construction inside Bribin cave was once broken due to earthquake in 2006, and people unable to get the tapping service through household connection.

Regulating the surface land use is necessary for the water quantity and quality of fresh water. The Spatial Plan Gunungkidul Regency 2010-2030 has taken into consideration the protection, conservation and restriction of space utilization. The provisioning micro-climate service can be initiated from local knowledge *Pranata Mangsa*, which literary means "organizing season".

4) The culture of education, tourism and spirituality

The Karst Gunung Sewu system was once a site for cave inhabitants. Artefacts were found reflecting evolving culture and civilization from ancient human inhabitants to the Kingdom era (1800s-1900s). Caves became shelters for human and also other inhabitants, such as cave bats, arthropods and other Karst endemic creatures (see Figure 7.21). The Karst environment, both on the surface and underground, is an educational and touris assest and is also sacred landscape.

Figure 7.21. Rancang Kencono cave, Semanu[23]

Assessment of ecosystem service on Karst Gunungkidul need to be taken into consideration to determine Gunung Sewu Geopark management sustainability, proposed to UNESCO by Gunungkidul, Wonogiri, and Pacitan Regional Governments. Cultural value imprint on the landscape is important to assess as cultural ecosystem services. Figure 7.22 shows the ecosystem assessment driven factors in Karst Gunungkidul derived and interpreted from field observation, FGDs (2012, 2013), indepth interview (2013), and

[23]The cave is famous for spiritual purposes and considered sacred, thus the surrounding environment preserved

available secondary data. Water plays important role on Kart ecosystem, thus important to understand and interpret the value of water in physical and cultural values, including water footprint education. Caves and water sources in certain location of Karst Gunungkidul are considered sacred, such as Rancang Kencono caves and doline ponds in Saptosari sub-district, thus the surrounding environment well preserved. However, the 'modernisation" development and extreme religion belief have gradually eroded and shifted the sacred perception, and correlate with un-environment friendly behavior to water source treatment (SULASTRIYONO, 2009).

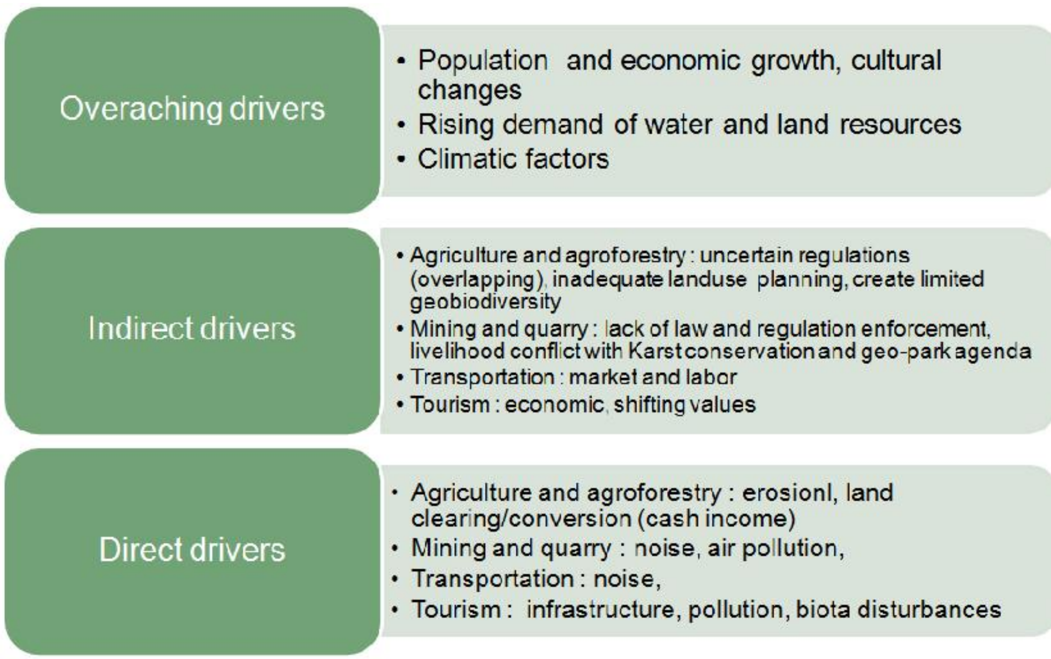


Figure 7.22. Ecosystem assessment driven factors in Karst Gunungkidul (adapted from MEA, 2005)

7.4. Synthesize and Model Karst Landscape based on Local Culture by Means of Information Communication Tool (ICT)

An ecosystem approach bridges environmental and human welfare, and local knowledge with cultural values requires a bridging tool to be transformed into a landscape model. In the recent digital era, it is possible to combine local data and information with scientific based knowledge and make use of remotely sensed data and the interface information (ICT) to develop digital cultural landscape modeling. The ICT, by means of ArcGIS and an environmental modeling, can be applied to bridging "traditional" local knowledge and "western" knowledge (RETNOWATI and DITTMANN, 2013) and knowledge sharing online (DIEDEN, 2010). Other scholars also take into consideration the application of participatory approaches in assessing cognitive spatial knowledge from local people on particular hazard prone areas, aiming to reduce such risk (REICHEL and FRÖMMING, 2014). The model in this study is developed from the basis of people's keen observation on natural signs. People in Karst Gunungkidul have developed local landscape ecology adaptation through their local knowledge.

A model is expected to be an interactive tool to educate, transfer and share knowledge and media messages. Part of Knowledge Management is to enhance local people capacity to collect, store, use, update, interpret, adjust and protect their knowledge and experience for themselves and future generations within evolving changes. Disturbances or human induced activities on Karst Landscape reflect and depict the human footprint. These include any activities which leave marks or imprints that can be seen using frog's eyes or a bird's eye perspective. Agricultural activities, either farming and forestry, both left human imprint on the landscape besides other activities. This study proposes the use of simple Karst landscape model using available terrain data as one of tool to develop knowledge management from local knowledge on "Karstscape" Gunungkidul (see Figure 7.23).

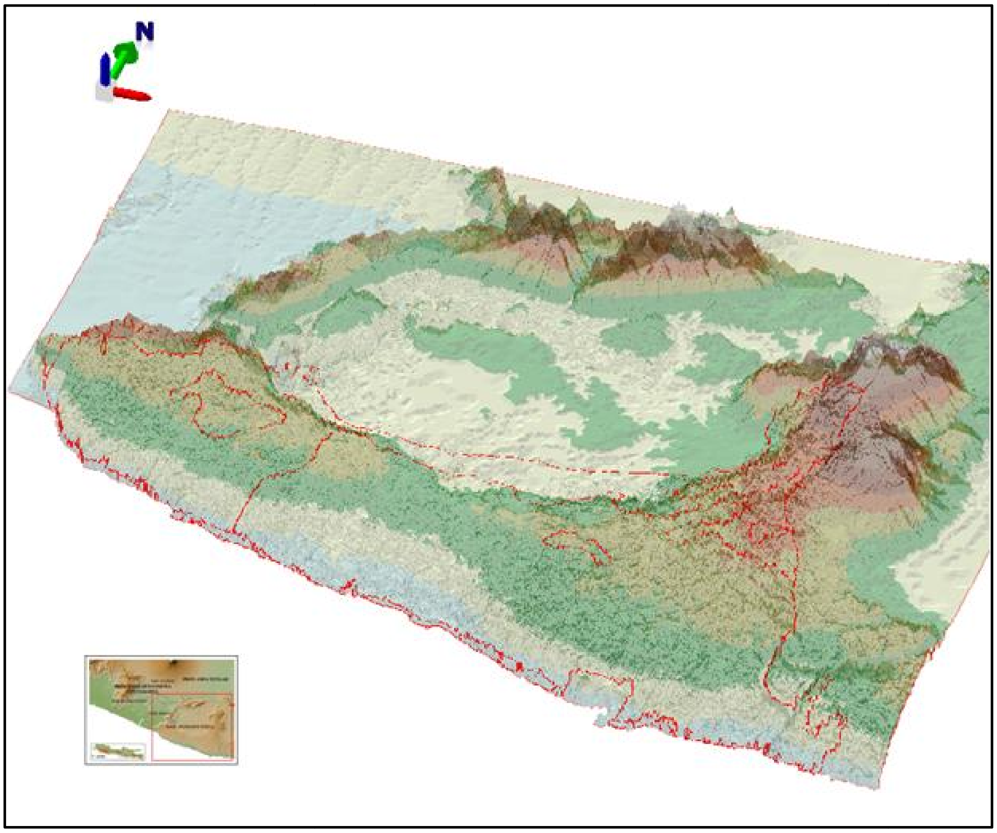


Figure 7.23 Karst Gunungkidul (red polygon) overlaid on Gunungkidul Regency Landscape (Source: IWRM Gunungkidul Project 2008-2013, Gunungkidul Spatial Plan 2010-2030 and Author draft, 2014)

Three or four dimensional landscape models are is useful to analyze landscape changes for planning and management (BENDER, 2009:139). Landscape analysis requires both scale and local spatial knowledge. Modelling water and land management based on culture and risk needs to take into consideration who is involved reflecting the significance of roles and participation in dominating systems or process direction. Using landscape model can support governmental Act PP 43/2002 on groundwater regulation, in the aim to develop information system of groundwater with consideration of local ground water characteristics. CHOWDHURY and HAQUE (2008) expressed the use of risk communication to transfer climate change environmental risk knowledge between experts and public.

7.4.1. Making and Marking Identity through Landscape Management for Water and Land Issues: Connecting Philosophy to Landscape Management, Participatory Landscape Modeling

A phenomenology of landscape illustrated by many photographs and diagrams, can be used as a tool to assess and analyze prehistoric monuments and landscape in archaeology, anthropology, architecture and geography. Within human geography, landscape has been approached in several ways, starting with cultural geographies in the 1980s. In cultural geography, landscape has been understood as a way of seeing, as a visual representation or metaphor of cultural meanings with emphasis on critical interpretation and symbolization of social and cultural formations (COSGROVE and DANIELS, 1988). The concept of landscape iconography and phenomenology, each derived the meaning and value of landscape through symbol and perception.

" In any iconological study it is only through context that meaning and influence can properly be unravelled. Such contexts may be defined as the circumstances in which maps were made and used. They are analogous to the ‘speech situation’ in linguistic studyz4 and involve reconstructions of the physical and social settings for the production and consumption of maps, the events leading up to these actions, the identity of map-makers and map-users, and their perceptions of the act of making and using maps in a socially constructed world. Such details can tell us not only about the motives behind cartographic events but also what effect maps may have had and the significance of the information they communicate in human terms" (COSGROVE and DANIELS, 1988:281).

7.4.1.1. *Tumpangsari* (intercropping) Landscape for Karst Gunungkidul as Bio-cultural Landscape an Cultural Ecosystem Identity

From the Northern to the Southern part, Gunungkidul Regency has different landscapes which affects the way people cultivate and adapt to water and land availability. The southern part is confirmed as the harshest environment compared to the middle and upper part. Key persons described local spatial knowledge in land or space utilization. The interaction between humans and Karst environment in the southern Gunungkidul characterized the region in the sense of homogeneity and heterogeneity in the application of water and land management, which lead to different landscape ecology and defined ecosystem identity. Figure 7.24 to 7.26 show spatial dimension of agriculture system applied on different morphology Karst landscape.

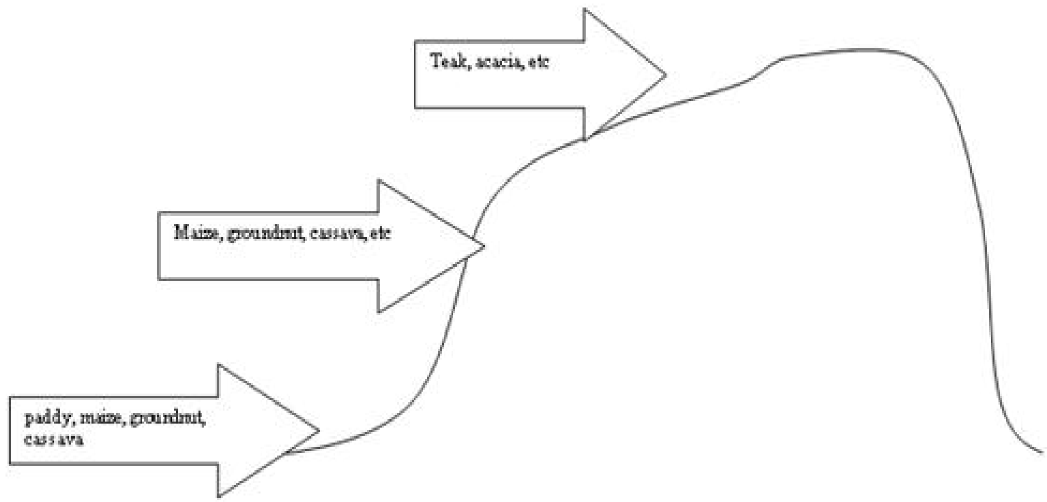


Figure 7.24. Spatial differentiation of *Tumpangsari* application in a sketch model (Author, 2014)

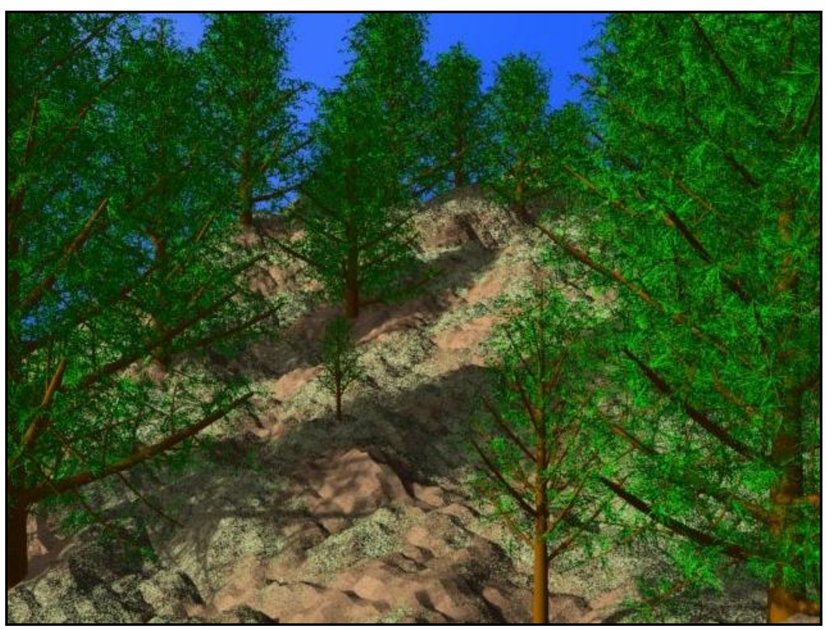


Figure 7.25. A model on Karst terrace to accommodate *Tumpangsari* system and agroforestry derived from field survey (Author, 2014)

a) Panggang landscape

b) Saptosari landscape

c) Ponjong landscape

d) Sadeng landscape

Figure 7.26. Spatial distribution of *Tumpangsari* application on different Karst morphology landscape (Author, 2013)

The direction of past landscapes (Karro, Maegi, and Palang, 2014) has been debated and considered helpful as a philosophical approach to learn from the past for the future. By phenomenology, it is not possible to reconstruct landscape, but it is closer to the aim of animatedness. By using the traditionally inherited seasonal calendar *Pranata Mangsa*, this study tries to understand how people in Karst Gunungkidul perceive their surrounding landscape to support their livelihood. Present community experience the different phenomenon from the past, but still the inherited knowledge remains. Changes in Karst Gunungkidul in terms of conical hills represent different and changing development programs established by Government Institutions and adjusted to local characteristics. The rural community in Karst Gunungkidul have developed a resilient landscape to support the sustainability of their resources. Local people's interpretation of their environment shows geographic literacy, yet social and economic changes from the broader region influence turn this literacy into landscape illiteracy.

Cultural landscapes of continuing traditional land use are recognized as having the potential to contribute to maintaining biodiversity (SMITH, 2011). Thus water and land use management based on seasonal calendar local knowledge and the natural conical hill itself need to be preserved to maintain the nature of Karst Gunung Sewu. Landscape change leads to environment change in two potentially different ways, a positive one or negative one, which affect human and other inhabitants' life.

7.4.1.2. Seasonal Landscape Changes in Karst Gunungkidul

The seasonal landscape scenarios built in this study are based on local spatial knowledge related to onset rainy season, collected during in-depth interviews with key informants who are considered to understand the cultural behavior representing their region. People have actually inherited the knowledge to read the natural signs related to climatic factors like how and when the rain starts. However, detailed information on equatorial climate and monsoon, from macro climate to micro climatic scale, is only inherited by certain people. Each individual person developes a different perception of climatic factors, but all share a basic common knowledge through the seasonal calendar *Pranata Mangsa*, particularly the idea that *Pranata Mangsa* is outdated and old fashioned. Insecurity came when the government policies failed to support the people, particularly those in marginalized sector, such as peasant farmers and fishermen.

The cyclic seasonal based *Pranata Mangsa* knowledge, with twelve months time frame from *Kasa* to *Sadha* (see Figure 7.27), is a climate service for the community that needs to be adjusted to specific local physical settings, namely geomorphology, geology, topography (relief) and human activities. People need to adjust to their environment according to *Pranata Mangsa* month. The knowledge is dynamic, thus each individual and community deserve to develop their cognitive knowledge to be prepared for the uncertainties changes of climatic factors. Farmers who deal with climatic factors play a significant role as part of support system in knowledge management of climate pattern observation within a long period frame.

Hence, this study assesses the knowledge of rain fall pattern from key local informants to develop the seasonal based knowledge management that is correlated with seasonal landscape change.

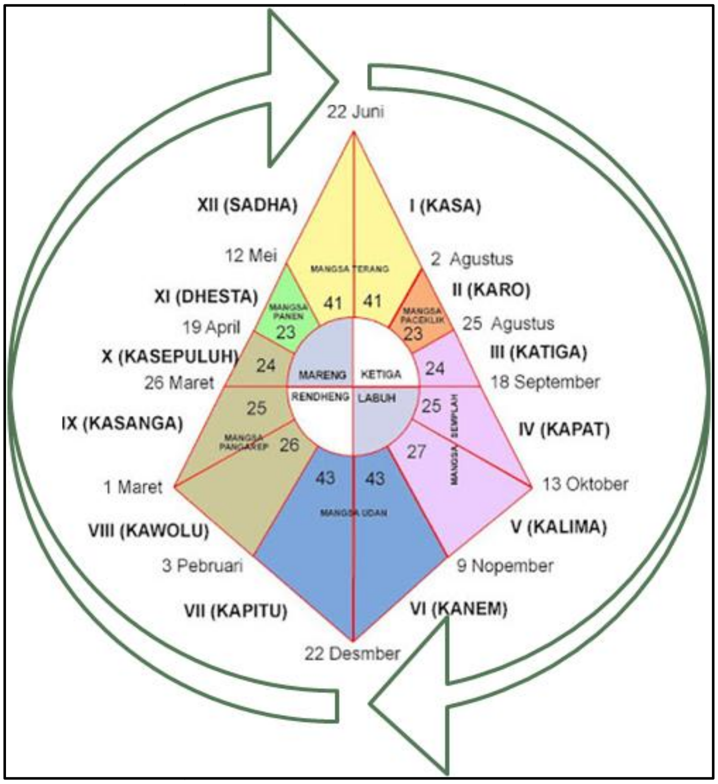


Figure 7.27. The cycle seasonal based *Pranata Mangsa* as steping-stone of Knowledge Based Landscape Management (source: DALDJOENI, 1978)[24]

Karst Gunungkidul landscape picturesque present different view during dry and wet season. By spectral images, it can be distinguished the seasonal changes of land cover and vegetational landscape (see Figure 7.28 - 7.29). The application of Remote Sensing phenology to support landscape analysis as a bridging tool to interpret the seasonal changes on Karst Gunungkidul landscape, coupling with the spatial and cognitive understanding of the rural people who inhabit the region. The use of remotely sensed data is determined by the scale and temporal dimensions of the study. Human behavior imprints on the landscape, representing their knowledge and environment ethics.

[24] interpretation of *Pranata Mangsa* issued by Surakarta Palace, http://www.karatonsurakarta.com/pranotomongso.html, accessed 21st October 2014

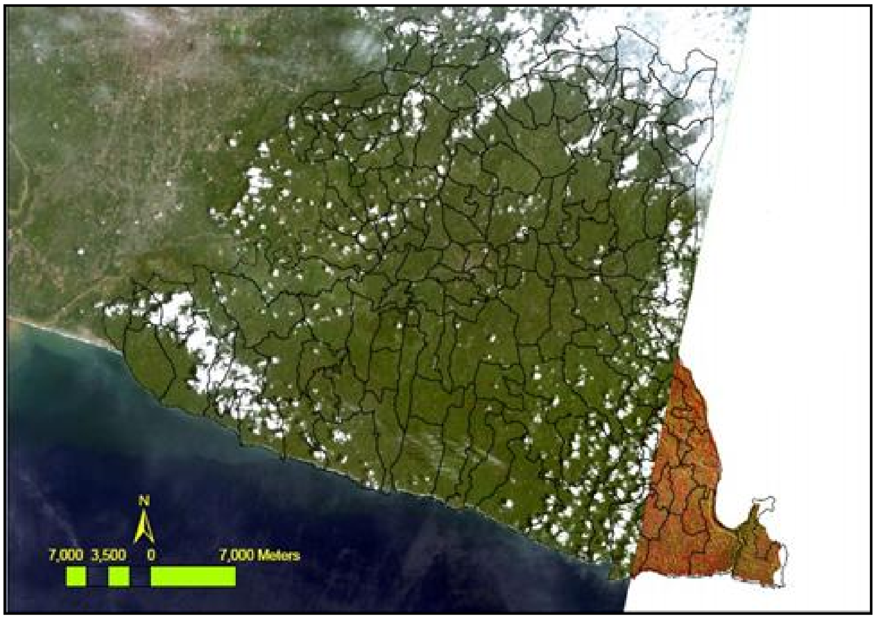


Figure 7.28. AVNIR-2 January 2008 satellite image overlay on village administration boundary and Landsat image, showing wet season land cover on Gunungkidul (Author's draft 2014)

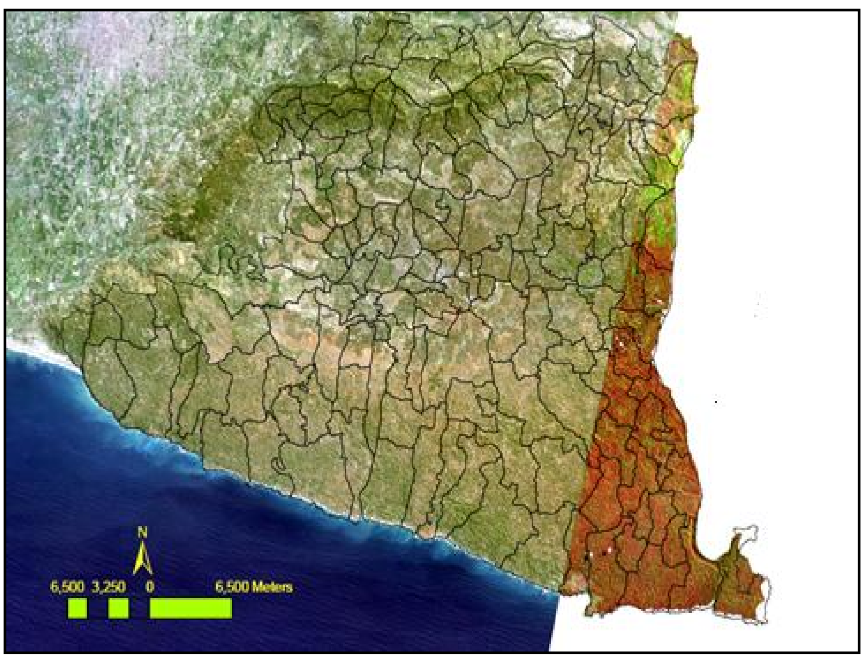


Figure 7.29. AVNIR-2 June 2008 satellite image overlay on village administration boundary and Landsat image, showing dry season land cover on Gunungkidul (Author's draft 2014)

Mean annual rain fall in Gunungkidul ranges between 1,800 - 2,000 mm/year (BMKG). Rainfall distribution is affected by monsoons, the annual passage of the sun, and local influences (mainly the mountains, hills effect). The rainfall distribution on Karst landscape Gunungkidul is observed by local people based where the rain onset starts regionally, either from the North, South, East, or West. People, mainly farmers between the age 40 - 65 years old, who have observed and experienced the direction of rain onset know what effect this change in direction on crop growth and yields. They have cognitive spatial knowledge regarding changing or shifting weather patterns in the Karst Gunungkidul landscape, and where microclimate factors contribute their influences. The main factors of microclimate are surface temperature, relative humidity, wind speed, solar insolation and precipitation (rainfall), within localized topographic elements. Topography of the Karst landscape is characterized by (doline) water ponds which create anomalies in relative humidity, air flow pattern, local wind shear and surface runoff which alter soil water retention, and local temperature.

The collection of local knowledge on microclimate factors in Karst landscape Gunungkidul need to be further explored and analyzed. However, during in-depth interviews with key informants from each of the sub-districts (Panggang, Purwosari, Paliyan, Ponjong, Semanu, Tepus and Girisubo, the influence of rainfall onset direction to crop growth, yields and pest outbreak possibilities was clear. Southern Java is affected by the Australian Monsoon. Baseline of the model is using terrain and isohyet map. Herewith, the scenario using rainfall onset between October and November in adjustment to the seasonal calendar *Pranata Mangsa* time frame and field findings according to people's experiences (knowledge) and the Meteorological record, applying three different onset directions:

1. Scenario 1 when the rain starts from Northern part (see Figure 7.30)

The northern part of Gunungkidul is affected by the Baturagung Range and Wonosari Plateau (Basin Wonosari). Hilly and mountainous and the basin's topographic elements, coupling with wind speed, sun angle exposure, characterize the rainfall onset influence from north direction to other parts of Gunungkidul. During an interview (2013), the key informant who lived on the Southwest part of Karst Gunungkidul said that the rain onset from the Northern part has no big influence on crop growth. The location of this informant, based on Karst morphological differentiation (HARYONO and DAY, 2004) and gravitation anomaly (KUSUMAYUDHA, 2005), is an exceptional. In the Southwest part of Karst Gunungkidul, the Oyo River (watershed) influences the microclimate parameters coupling with soil type and vegetation cover, in a manner different to other parts of Karst Gunungkidul.

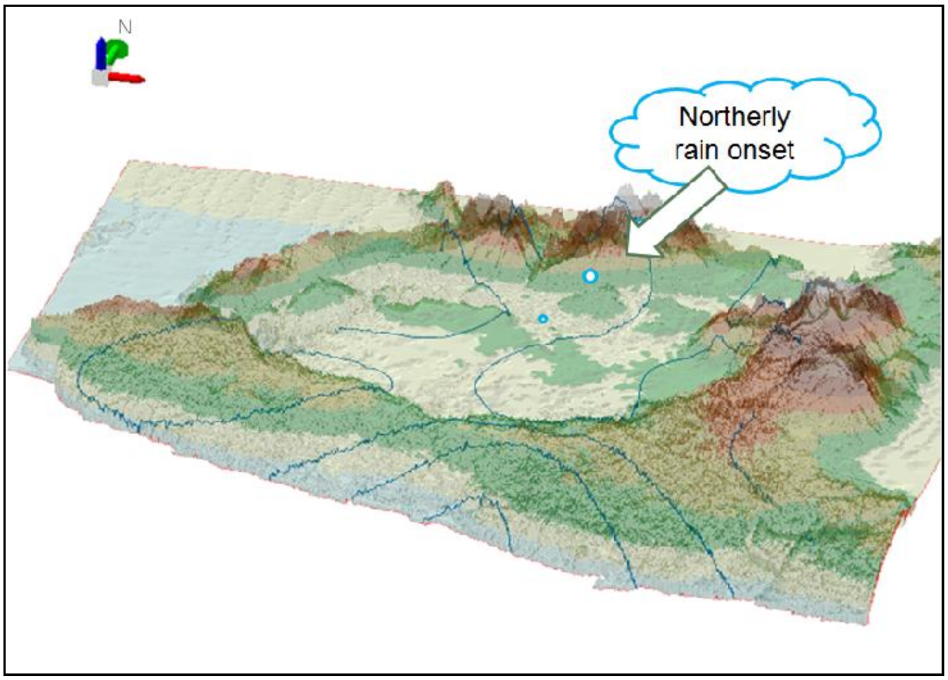


Figure 7.30. Northerly Rain Onset Model (reflecting people's knowledge)

2. Scenario 2 the rain starts from Eastern (middle) part (see Figure 7.31)

Rainfall onset from the East to the South is influenced by the hilly part of Karst Gunungkidul in the East. When it reach the middle part, it is affected by Wonosari Plateau settings. During field observation in November 2012 to January 2013, the Eastern part of Karst Gunungkidul was greener than the others, indicating that the rain onset had been from the East that year. This was confirmed by a key informant from Tileng, Girisubo. The phenomenon correlates to farmers behavioral culture, whether they still follow *Pranata Mangsa* or depend merely on the rain onset timing to start cultivation.

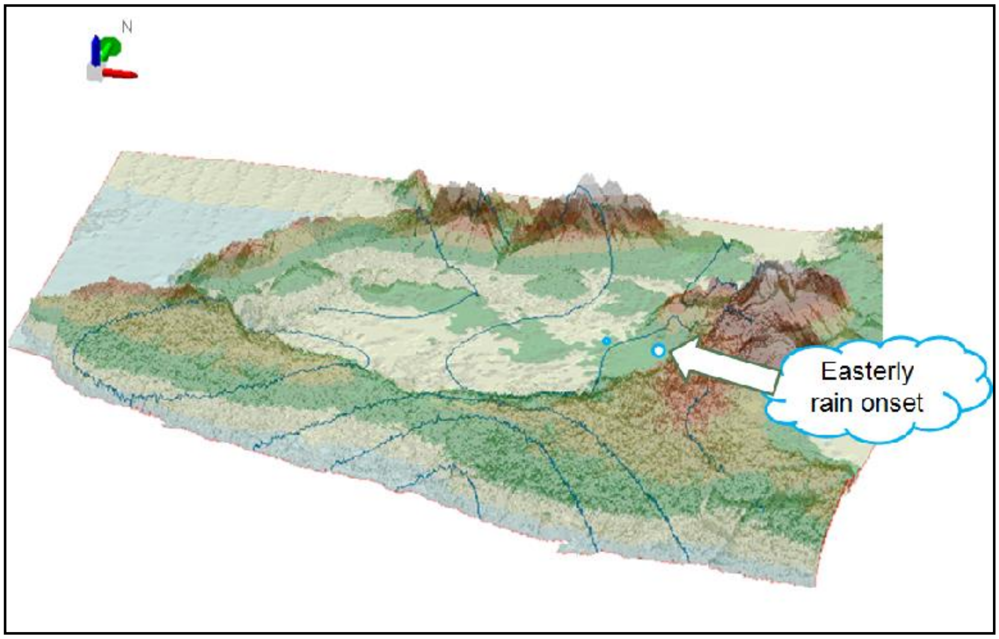


Figure 7.31. Easterly Rain Onset Model (reflecting people's knowledge)

3. Scenario 3 the rain starts from southern part (see Figure 7.32)

All key informants revealed and confirmed that rain onset from the South brings good influence on crop growth and yields.

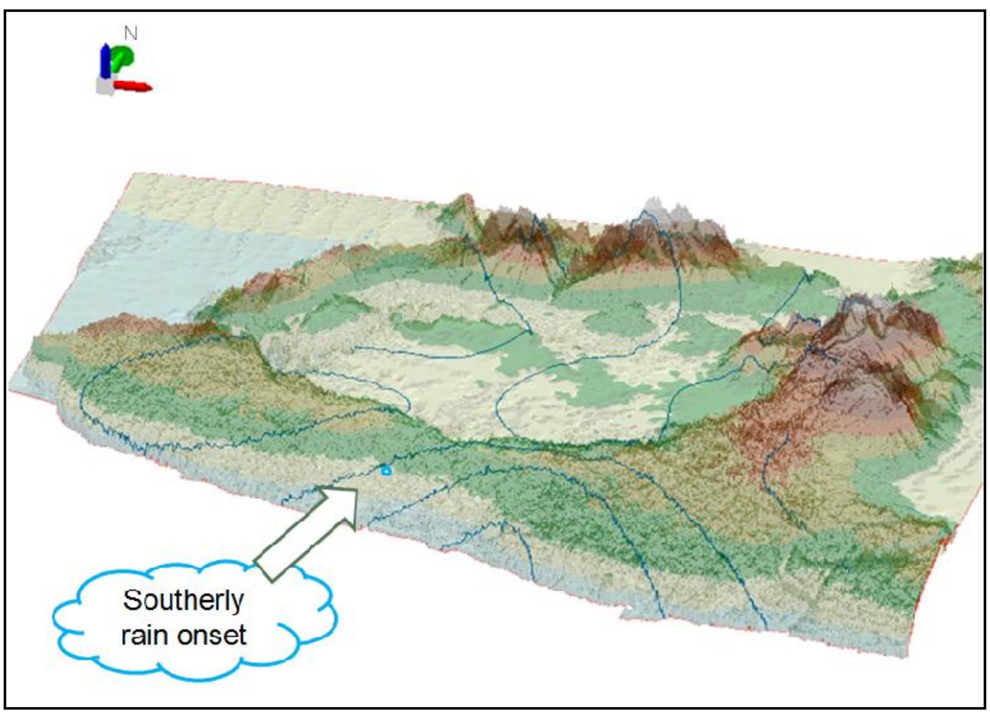


Figure 7.32. Southerly Rain Onset Model (reflecting people's knowledge)

The Southern part of Karst Gunungkidul is adjacent to the Indian Ocean and is topographically on the lowest level compare to other parts of Gunungkidul Regency. The wind is generated from the ocean, more vaporized than continental wind, which is considered better for rainfall for crops. However, other factors also play a crucial role determining the microclimate in the Southern part Karst Gunungkidul.

Karst Gunungkidul people, who have developed their *ilmu titen* skill and knowledge of their surroundings, are aware of what hazards might occur, and apply preparedness and mitigation strategies based on their experience and inherited knowledge. However, only few people sharpened their keen observation skill and reached a level of applicable knowledge sufficient to manage available resources at the mainly household level. Hence, the need of knowledge bridging is important by any means to collect, classify, analyze, distribute, share and re-analyze.

7.4.2. Building Environmental Scenarios in Karst Landscapes by Bridging Knowledge

An ecological scientific principle is to work towards a shared understanding of various key processes that overlap the disciplines. Simple landscape models in this study are considered one way to understand how 'scientific' evidence from observations and experiments of local and non-local experts can integrate the use of remote sensing and local knowledge.The models can monitor, analyze and manage climatic phenomenon changes and the adaptation followed where local community becomes the observer as the local scientist. They live in their local specific area and for such periods of time that they become local experts who can identify (potential) water resources, the threats and the risk.

Information communication technology (ICT) combines with participatory 3-D mapping to collect and gain Karst landscape knowledge. A geo-cultural landscape derived from seasonal based local knowledge and physical features identification through keen observation (*ilmu titen*) can be created using ICT. The typology of Karst Gunungkidul landscape services includes microclimate factors and related parameters, coupling with the cultural behavior of the people. Modelling (landscape) from the embodied and embedded community and institutional knowledge, is a way to comprehend changes in Karst landscape Gunungkidul. A participatory approach spreads knowledge from community to community, rather than dictating from institutions (FROST, CAMPBELL, MEDINA, USONGO, 2006). Preferably institutions would support by offering to assess landscape services (FAGERHOLM, KAYHKO, NDUMBARO, and KHAMIS, 2012).

The International Research Institute for Climate and Society (WINARTO, STIGTER, HESTU, ANANTASARI, and KRISTIYANTO, 2011) indicates the use of a science-based approach to enhance society's capabilties to understand, anticipate, and cope with the impacts of climate variability and improve human welfare and the environment. Gunungkidul's landscape can be read as a text that interprets to people' knowledge of water and landscape management. Historically, the landscape of Gunungkidul's hills reflect the cultural changes and policies applied, both top-down and participatory. NIBBERING (1991) has showed landscape changes on different periodic time and SUNKAR (2008) revealed the landscape changes based on historical settlement stages. If the change is correlated with the seasonal based knowledge *Pranata Mangsa* calendar, which was introduced in 1855/1856 as agricultural guidance, no significant effect can be discerned from the application of it, rather the influence came from institutional policies or government programs.

The Gunungkidul Karst landscape model executed in this study is an empirical model, derived from real data (DEM images) that supports a theoretical concept. Seasonal based local knowledge of *Pranata Mangsa* consists of ecological knowledge in terms of interactions between organisms and their environment, and the spatial aspect matters profoundly for resources competition and accessibility. The Karst landscape model here is to be built to formally organize data from local knowledge and symbols concerning the community concept on water and land management. Landscape reconstruction (modeling from the past) has subjectivity

(KARRO, MAEGI, and PALANG, 2014), whilst Millenium Assessment Ecosystem needs to consider the scale and knowledge system as applied at different levels. The Karst landscape model in this study is initiated in the hope of promoting further discussion to:

1) incorporating 3-D landscape model on water and land management to meet adaptation and mitigation strategies to cope with annual annual water scarcity in Karst Gunungkidul.
2) optimize remotely sensed data to monitor local specific geo-biodiversity in Karst Gunungkidul using ICT and spatial dimensions of local knowledge.

The landscape model in this study is derived from DEM USGS, field observation and spatial knowledge extracted from people's knowledge. Environmental modeling in this study is using Bryce, where landuse/landcover type, rock types, crops, vegetation, seasonal factors can be selected. However, Bryce has limitations in the application of texture and structure settings. Therefore, the user needs to use field observation to develop a landscape model with different landuse/landcover, in order to more realistically represent real condition like the thickness of the stem, stalk texture, number of branches and the length, or the pattern of leaf.

The modeling application in this study is still considered prototype to bridge local spatial knowledge to be integrated and developed into spatial knowledge management. This model is a baseline or platform to accommodate seasonal based local knowledge and transform into the spatial and visual dimension, coupling with temporal dimensions following the climatic factors and environment changes. In future research, the model can be developed with more detail at varied spatial scales in a landscape approach. Modelling of different conditions based on field observation towards the assessment of application of water and land management on Karst Gunungkidul are presented as follows:

1) Terraces or outcrops between conical hills

Land and water management in application of seasonal based local knowledge *Pranata Mangsa* on the Southern part Gunungkidul landscape require the knowledge of Karst physical features. Figure 7.33 shows the terraces and outcrops model between conical hills. Agriculture practices on hilly land require terracing, which sometimes left outcrops mark. Terraces and outcrops model support the assessment of disturbances on Karst Gunungkidul landscape due to agriculture activities or other anthropogenic influences.

Figure 7.33. Terrace and outcrops model between conical hills

2) Landuse on the low lying area of Karst hills

Rural people cultivate paddy for the first cropping rotation system on the low lying area and apply *Tumpangsari*. Figure 7.34 shows low lying paddy field model on Karst valley. On a patch field, during the first period of the wet (rainy) season, farmer cultivate only paddy or combine with corn, groundnuts or soya. In the meantime, they also put cassava stem.

Figure 7.34. Low lying paddy or other crops field model on a Karst valley or a dry pond

3) Water source from underground river water

Water sources on Karst landscape are mostly underground water which emerge to the surface. Local people of Karst Gunungkidul know where the closest water sources are. Unfortunately, most of the water sources are uneasy to access. Modeling point source of underground river water and springs helps to develop their spatial distribution and the flows, in correlation with water discharge changes due to annual season change (see Figure 7.35). The model can support to the piping network development and takes consideration of the landscape.

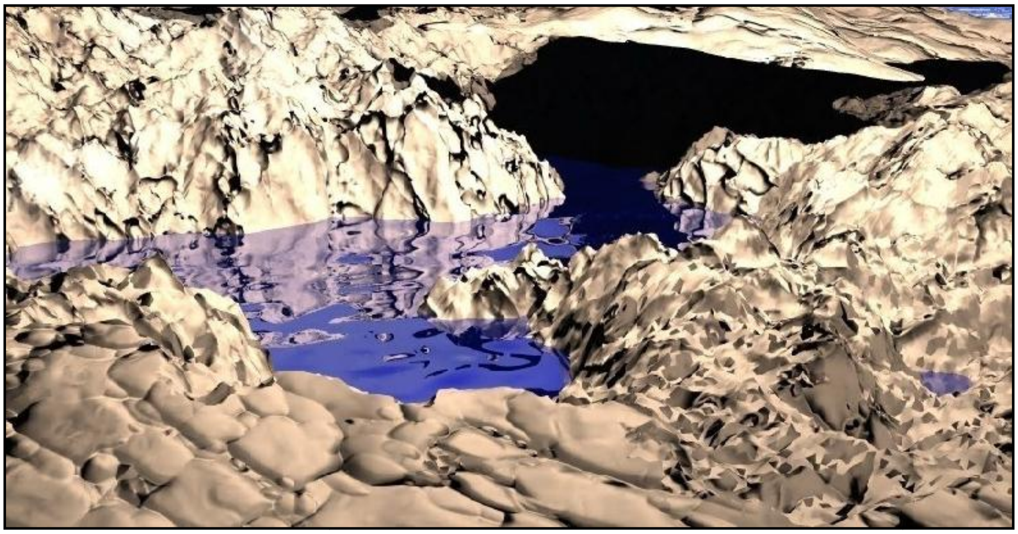


Figure 7.35. Water Source from underground river water model

4) Hill slopes differentiation between dry season and wet season

Landscape view during the dry and wet season of Karst Gunungkidul landscape is different. Figure 7.36 and figure 7.37 show different landscape view model during different season. Identifying different landscape view lead to analysis of human behavior changes in adjustment to climatic factors and environmental changes.

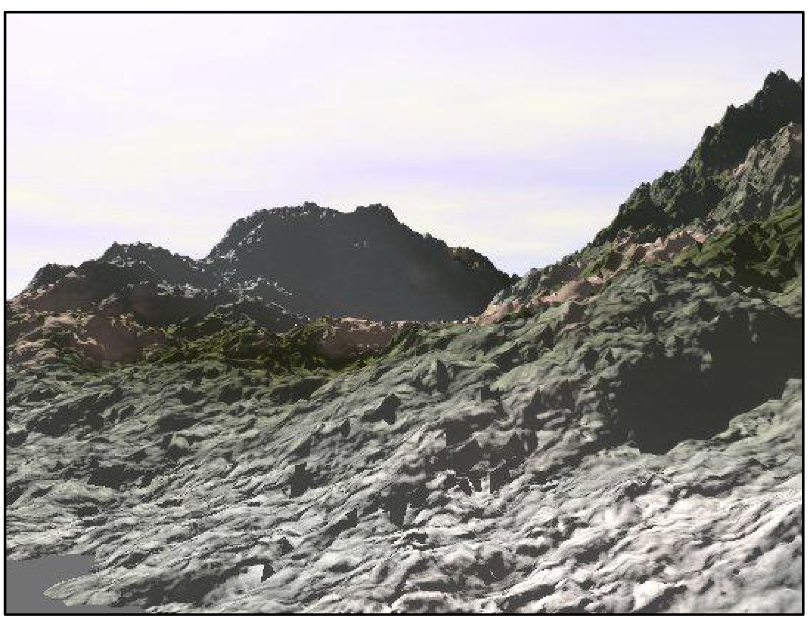


Figure 7.36. Hill slopes during the dry season on bare land

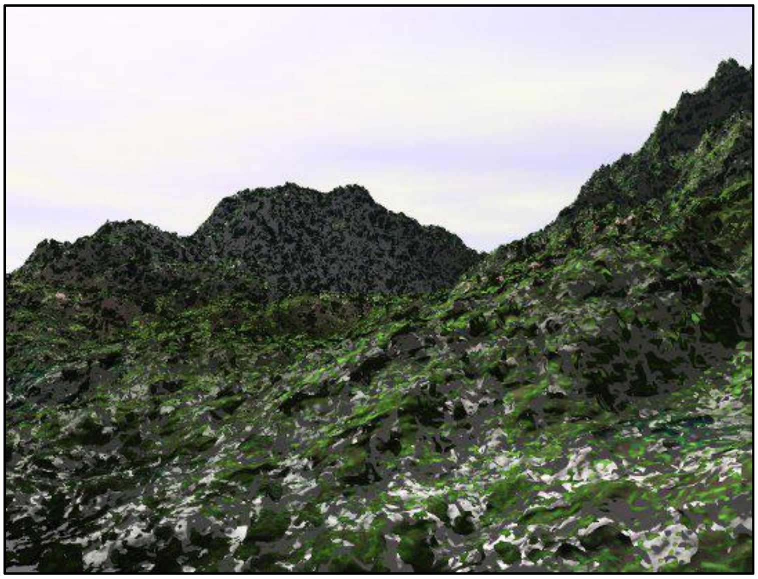


Figure 7.37 Hill slopes in the early wet season on bare land

5) Landuse/landcover model at night and in daylight

Modeling landuse/landcover in consideration of day light or night (see Figure 7.38 - 7.39) is aimed to support evapotranspiration assessment and other related activities. Daylight and night landscape models combine with conical hills features support the analysis of hazard with potency to become disaster, to determine the evacuation route or safe shelter if an excessive raining occurs which hinders the visibility.

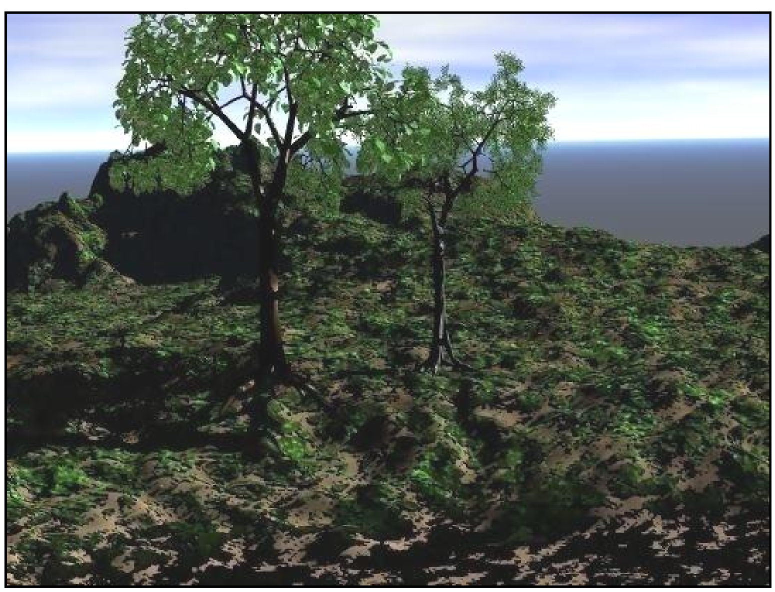


Figure 7.38. Landuse/landcover model on Karst Landscape at night

Figure 7.39. Landuse/landcover model on Karst Landscape in daylight

6) Landuse/landcover between two conical hills

Karst Gunungkidul type is known as conical hills with different morphology from the west to the east (HARYONO and DAY, 2004). The Eastern part of Karst Gunungkidul is a residual cone Karst type area with excessive mining in less than a decade, particularly in Ponjong sub-district. Modeling two conical hills (see Figure 7.40) helps to develop landscape changes and the effect on landuse in the Karst valley when a conical hill vanished due to uncontrolled mining or other activities.

Figure 7.40. Landscape Model Between two conical hills (residual karst)

7) Model on application of phenology or bio-indicators for annual season change

Single vegetation or crop can be modeled to monitor the generative and vegetative growth stage. Figure 7.41 shows a model which is derived from Tamarind tree. The tree is an indicator of the wet season beginning. If the indicators are dissapearing, then we can substitute with existing plants. Different stages of vegetation growth indicate climatic factors role coupled with physical features, particularly the soil properties, and human behaviour on land and water resources.

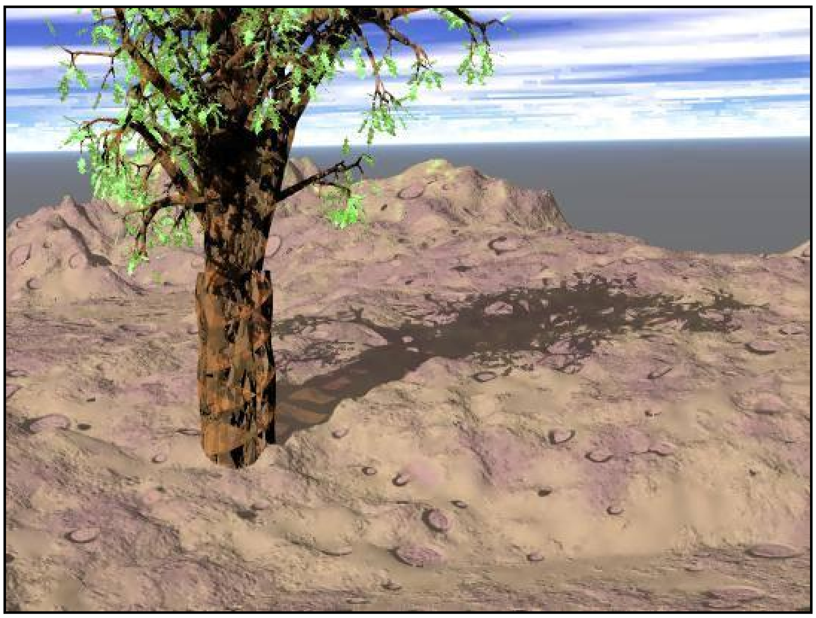


Figure 7.41. An application of Phenology model on blossoming leaves

The models in this study is aimed to be developed further to accommodate changes due to local knowledge application *Pranata Mangsa*, with its twelve months timeframe, to collect and analyze the changes which then manage into spatial knowledge management. Each *Mangsa* or month in *Pranata Mangsa* is accommodated and supported by filling form to collect any changes to be modeled in accordance to real time condition and future possibility based on data collection (see Appendix 2). The model can support and promote healthy lifestyles and well-being, related to water and land management based on landscape approaches and the application of local knowledge towards landscape changes due to climatic factors and environmental changes. Healthy landscape provides sufficient nutrient for cropping systems, whilst coping with seasonally affected climate factors changes. Local resources on Karst Gunungkidul landscape are adapted into spatial modeling, particularly those related to water and land management as part of local identity.

Water and land resources have a spatial and temporal dimension. The settlement and other human imprints represent a cultural landscape and describe how humans have impacted upon the environment. Most of the settlement and main activities of people on Gunungkidul Regency occur the low area, mainly on Wonosari Plateau (see Figure 7.42).

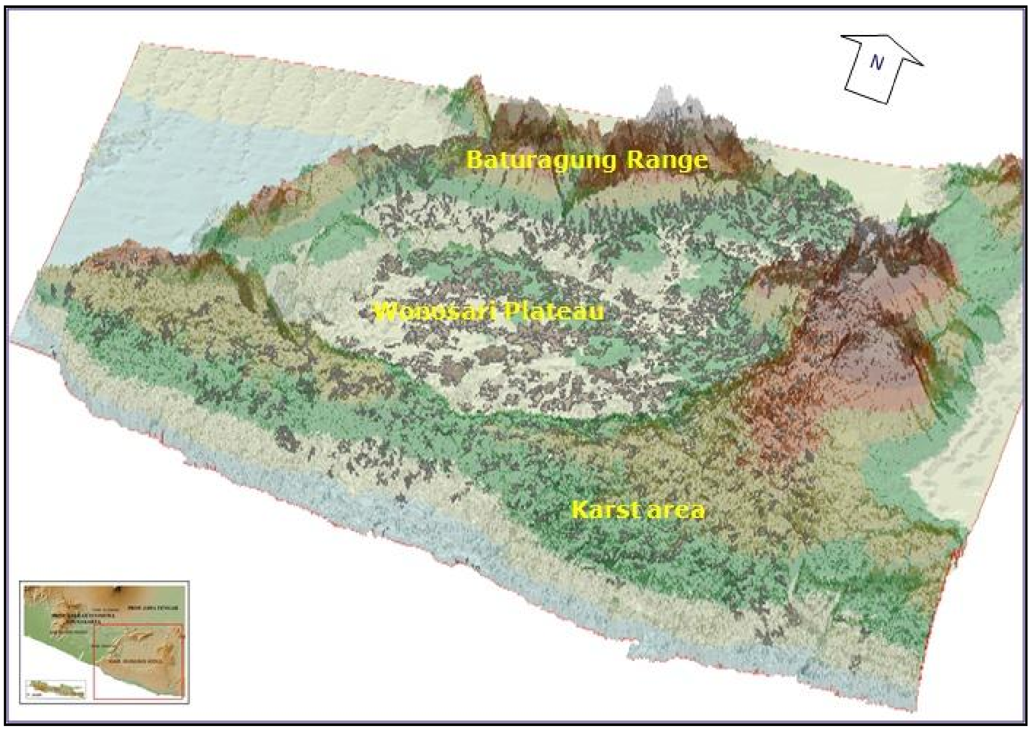


FIgure 7.42. Settlement on Gunungkidul Landscape Terrain Model (source: Gunungkidul Regency Spatial Plan 2010-2030, IWRM Gunungkidul Project 2008-2013 and Author draft 2014)

Home gardening practice (see Figure 7.43) among rural people on Karst landscape represents adaptation and mitigation strategies to food security at household level. However, this practice can be and should be considered as water safe adaptation of local knowledge due to limited availability of land and water, which experiences severe or prolonged dry seasons. Small scale *Tumpangsari* application on home (yard) gardening is a way to build a water and land sensitive landscape.

Figure 7.43. Water safe Landscape on Karst region home (yard) gardening (Author, 2013)

The most suitable trees for Karst landscape, not only for economic values but also for onserving water and land shoul be planted. Ecosystem services from household and community level apply at homegardening. Home gardening is small scale in the household level of landscaping, thus, a water sensitive or water harvesting landscape requires communal and regional level scale. Home gardening represents water and land knowledge management derived from the need of sustaining livelihood, therefore it is interesting to notice the values, beliefs, norms, and behavioral patterns from households when the scale of research on reading landscape start at that level of detail.

Home gardening coupling with the optional location of rain water tanks (PAH) are considered an adaptation to available space and water access. The spatial dimension of household landscape build the whole region's landscape and characterize the region. *Tumpangsari* in home yards and rain water tanks (PAH) shape Karst Gunungkidul identity, its adaptation, mitigation strategies and capacity to cope with specific environmental condition.

7.5. The Importance of a Groundwater Spatial Plan Derived from a Landscape Model of Water Efficiency on Karst Gunungkidul

Gunungkidul Regency covers Baturagung Range, Wonosari Plateau, Panggung massive and the Karst geo-ecosystem. The upper stream area plays an important role as a retention and catchment area. Through FGDs, in-depth interviews and field observation (2012, 2013), Karst communities understand the role of upper stream areas for lower stream conditions, where Karst area populations are mostly located. People understand that water flows Southward to the ocean. Water management on Karst landscape differs from other landscapes. KUSUMAYUDHA (2005) has clustered hydrogeology of Karst Gunungkidul into three different sub-system of hydrogeology (SSH), namely SSH Panggang, SSH Baron-Wonosari, and SSH Sadeng, which correlate with groundwater flows (see Figure 7.44). As consequence, it is important to develop groundwater spatial plans to support surface spatial planning and land management.

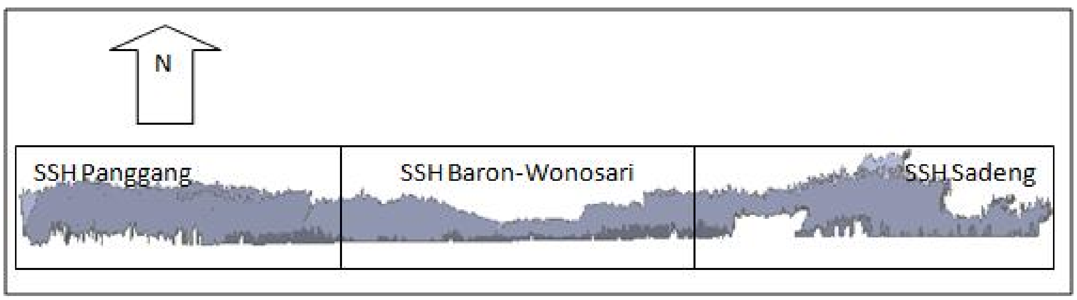


Figure 7.44. Hydrogeology Sub-system of Karst Gunungkidul on 3-D landscape, not to scale (adapted from KUSUMAYUDHA, 2005)

Figure 7.45 shows the road network and piping network which was built along with the road network. The decision to co-locate both networks was to ease accessibility. The Southern cross road network known as *Jalur Lintas Selatan* (JLS) cuts through some conical hills with the possibility of disturbances to Karst's morphology, including the road's function as a dyke or wall, and speeding up the infiltration of groundwater flows. The construction of a road or other man-made "artefacts" involves cultural landscape change on Karst Gunungkidul.

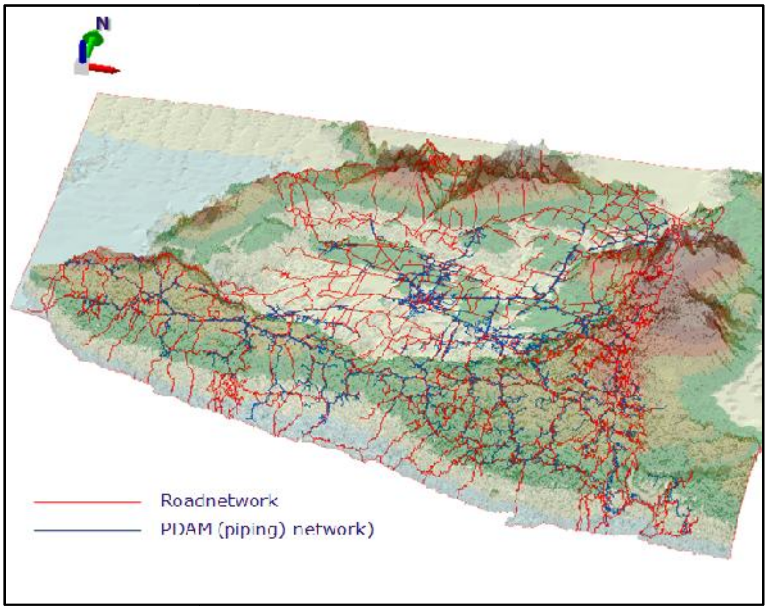


Figure 7.45. Road network and water network on Karst Gunungkidul landscape (source: Gunungkidul Regency Spatial Plan 2010-2030, IWRM Gunungkidul Project 2008-2013 and Author draft 2014)

7.6. Landscape and Disaster Management (Risk Reduction) : Understanding Local Seasonal Calendar and Government Regulations

The Social Resilience concept by ADGER (2000), KECK and SAKDAPORLAK (2013), and DEARING (2008) show socio-ecological factors imprint on the landscape. Conservation in uncertain and changing climate applies an imprint on the landscape that reduce ineffective water and land management based on local community knowledge, but this needs to be incorporated into decision making at higher levels like the regional government. Gunungkidul Regency's government has tried to incorporate environmental aspect into spatial plan, but still no significance result on decreasing environmental stress.

Preserving indigenous or local plants and trees which have adaptated to Karst characteristics would be useful as learned from arid the environment of Namibia (DIAMOND, 2011) and other arid or sub-arid places where local environmental adaptation has taken place. Conserving native plants as indicators of local environment changes, which are also mentioned in the *Pranata Mangsa*, indicate a preference for condition from climatic factors that certain plants need to grow. Environment and ecological knowledge has been inherited through generations, whilst the reasoning or background depends on recent generations to seek the knowledge background. The changes in each bio-indicators become proxies to monitor, evaluate and justify environmental conditions and ecological changes.

In correlation to Sauer's work, what we see from Karst landscape in Gunungkidul is part of Gunung Sewu Karst range socio-spatial dialectical approach between humans and the environment. It is important to consider the social-culture value of ecosystem services and ecologically based decision making. There is a new focus on quality of life, embracing beauty, local character and the enjoyment of green, open spaces. Let remote upland areas be deliberately left to nature, becoming wilder in character. Incorporate cultural ecosystem services (TENGBERG, FREDHOLM, ELIASSON, KNEZ, SALTZMAN, and WETTERBERG, 2012) and cultural landscape, and link to risk management and reduction approach.

It takes a broad legal framework for the protection of property proposed as cultural landscape, involving legal decrees for conservation and protected areas within spatial planning, landuse and water management decrees, from national to regional level. The regional decree is based on and derived from National Law 26/2007 and National Government Act 26/2008 concerning spatial planning and the establishment of National Strategic Areas for conservation of critical cultural landscapes. Also, the National Act 32/2009 concerning protection and management for environmental. Knowledge management incorporates local knowledge of ecosystem and ecology values, within disaster risk reduction and management and cultural ecosystem services. In the end, a culture and risk based Karst landscape management can be established (see Figure 7.46). The landscape management can be developed through a participatory approach, assess local knowledge with the spatial and temporal dimension as consideration of risk management of Karst Gunungkidul.

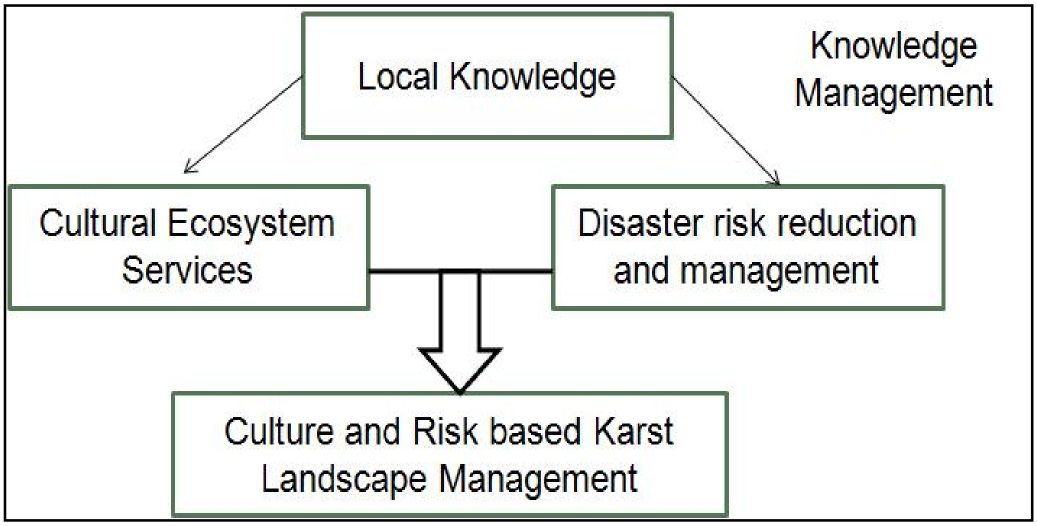


Figure 7.46. Culture and Risk based Karst Landscape Model

VIII. Hypotheses Review, Conclusions, and Recommendation

8.1. Hypotheses Review

This study proposed some hypotheses to be tested based on the research questions and problems. The hypotheses are open for further discussion consideraring that the human-environment bond is dynamic and complex. The Karst Gunungkidul environment in this study, is a canvas or media for its inhabitants to develop knowledge based Karst management in consideration of local characteristics and identity, while sharing similar challenges due to evolving global changes.

(1) The interaction between human and the environment, natural hazards have been taken into account in application of water and land management in rural community Karst Gunungkidul based on local knowledge of *Pranata Mangsa*.

Rural people of Karst Gunungkidul have a long history of adaptation to the harsh environment of Karst characteristics since pre-historic inhabitants. The natural cycle in the Karst region has evolved the people to become hard workers to struggle, survive, adapt, mitigate and build strategies to cope with annual season changes. The recognizable natural hazards in Karst Gunungkidul are annual water scarcity during the dry season, the possibility of sinkhole occurrence and underground river floods during the rainy season. Water scarcity is considered part of natural cycle and part of people's lives. People have shaped "living harmony with Karst hazard" and the their focus is to sustain their livelihood.

During the Kingdom era (1800s) people have develop keen observation towards natural cycle and built local knowledge in response to their environment. Keen observation (*ilmu titen*) on climatic factors has led to the establishement of *Pranata Mangsa* calendar with a twelve month time frame. Each time frame of *Pranata Mangsa* is represented by nature signs indicating behavioral changes in plants and animals as climatic factors changes. These time frame is also described in parables phrases. Thus, to deriving natural hazard information from the *Pranata Mangsa* cycle as guidance in land and water management requires a depth of understanding and comprehensive interpretation, which is why this study applies phenomenology hermenutics approach. Land and water management, particularly in agriculture, apply most distinct signs of the natural cycle, which is *Mangsa Ketiga* (the dry season) and *Mangsa Labuh* (the cultivation time). The parable phrase in the *Mangsa Ketiga* (dry season) presents "cracking soil", indicating no humidity or water, whilst *Mangsa Labuh* presents flowing water. By reading the parable phrase, people interpret the natural cycle and the following hazards. Awareness of environmental variability and changes have been practiced and lead Karst Gunungkidul inhabitants to respond in adaptation with coping mechanisms for adequate water resources and land availability in Karst areas.

(2) Considering and understanding the local value on water and land management as embodied and embedded knowledge mangement, with the support from government in policy making and other actors in planning and management scheme, local knowledge can address the uncertainty of environmental disturbance on water and land management and increase people’s capacity.

Environmental and ecological values from local knowledge *Pranata Mangsa* is derived from whole kinship observation known as *ilmu titen* on physical features, climatic factors, and plant and animal behaviors. Knowledge of seasonal changes requires observation, experiences, and records (mostly un-written) through different time epoch. Transfered knowledge through generations has been inherited by story-telling, copying and experiencing within centuries and decades since *ilmu titen* of physical features environment and of climate factors on *Pranata Mangsa* were formulized as guidance for agriculture, particularly to prevent or reduce crops failure. Thus, the keen observation or *ilmu titen* skill and *Pranata Mangsa* knowledge are embodied and embedded in farmers' lives.

The changes on climatic factors within the last two decades, particularly since extreme weather related to ENSO in 1997/1998, have challenged individual's and comunities' knowledge and experience of the *Pranata*

Mangsa seasonal calendar. Shifting time of *Mangsa* (month) has occurred and unpredictable or "unwritten" parable phenomenon now occur. Farmers turn to government institutions which have responsibility and authority for agriculture at regional and local level, and to the BMKG on climatic issues (BMKG) at regional level. Both institutions work together to 'educate' farmers and enhance their knowledge of agricultural innovations and climatic changes. The inherited knowledge, which is considered old fashioned, is tested and validated using 'modern' scientific knowledge. Extreme weather and the shifting time frame of *Pranata Mangsa* are explained by BMKG from recent knowledge of climate in correlation with land management by agricultural institutions. However, different experiences of farmers need to be considered in locality adaptation. Farmers have developed skill towards uncertainties changes and shifting time frame of seasonal calendar, and live with acceptable or tolerable risk with minimum loss of their livelihood.

(3) Synthesizing local spatial knowledge of Karst Gunungkidul people can be developed into a Karst landscape model based on local knowledge as a bridging tool for future transforming and transferring of spatial knowledge.

In correlation with hypothesis number two, embedded and embodied knowledge of Karst Gunungkidul rural people consists of spatial knowledge which then transform into spatial modeling with some adjustment to available tools. Annual season landscape change expresses the characteristic human and environment relationship. Only certain farmers or people sharpen the keen observation skill and knowledge towards climatic factors and environmental changes. These few people among Karst Gunungkidul communities are the ones who have the ability and knowledge to interpret the environment - human relationship. Starting from key persons or informants' spatial knowledge, coupling with literature review and field observations, this study synthesized and then developed a prototype of landscape modelling.

Synthesizing local spatial knowledge related to certain phenomenon, particularly the rainy season onset, the real conditions of the Karst landscape encourage people to re-learn their knowledge on on how to read nature, despite those who only copy others. A Karst landscape model can be assessed and synthesized from local spatial knowledge and need to be validated on the field using certain instruments or tools. Environmental landscape modelling, developed from local based characteristics, aims to accommodate seasonal calendar *Pranata Mangsa* and assess the changes or the shifting time frame which occur in the landscape. Transforming local spatial knowledge into landscape modelling requires consideration on details or scale and temporal dimensions.

8.2. Conclusions

The conclusions in this study are open for further discussion, not merely answering the hypotheses but also to reach broader understanding of local knowledge understanding and application to meet challenges on environmental and climatic factors changes upon specific landscape, such as the Karst Gunungkidul landscape.

(1) Analyze natural hazards and the risk, based on the cultural behaviour of the inherited seasonal calendar system *Pranata Mangsa* as local knowledge in Karst rural community Gunungkidul, Indonesia.

Through the cycle, local knowledge *Pranata Mangsa* teaches and advocates that people adopt an attitude towards seasonal changes within their experiences to put humanity in the scale of minimizing environment pressures. The most recognizable hazard from seasonal based local knowledge *Pranata Mangsa* in Gunungkidul Karst region is water scarcity and unproductive land following the scarcity of water, coupling with regional and local characteristics. People are already aware of the seasonal hazard during the dry season in accordance with the inherited knowledge, their own experiences and observations, based on the application of climatic factor changes. Early warning or signs of natural hazard due to the dry season is presented on *Mangsa Katiga* (dry months) when the leaves fall and water sources decrease. By reading natural signs and observed experiences, people have already prepared to minimize the use of water sources, selling livestock, or timber, which are considered as elements at risk. Meanwhile, when the leaves of certain vegetation starts to blossom, i.e. the Tamarind tree or yam tube, the rainy season is starting. Natural hazard during the rainy or wet season in Karst region is unrecognizable, except for the Baturagung Range in Gunungkidul Regency where people prepare for landslide possibilities and water-borne diseases. The characteristic of landscape determines natural hazard that can be derived from seasonal based local knowledge. Spatial or geographical context differentiate the application of hazard and risk identification from *Pranata Mangsa*.

(2) Analyze the essence of seasonal calendar *Pranata Mangsa* for managing available water and land due to risk of water scarcity and promote it as embodied and embedded knowledge management.

Local knowledge derived from keen observation or *ilmu titen*, consists of empirical understanding of the surrounding environment. The skill of observing and recording seasonal changes through time has urged people to develop a culture of awareness, particularly to climatic factors changes in correlation with managing available land and water resources on Karst Gunungkidul. *Pranata Mangsa* consists of lesson " knowing what" from the nature cycle and then transforming this to "what to do and how to do" on human behavior.

Individual and households at local and regional level manage the changes of water scarcity during the dry season based on their understanding of seasonal based knowledge. They leave the land fallow or bare after harvesting the last crops on farming land, but for agroforestry, the vegetation still stands with falling leaves. Harsh conditions of Karst areas have prompted people on Karst Gunungkidul to develop knowledge to respond to their environment, for example employing the practice *Tumpangsari* cropping system and minimizing the use of water for domestic uses. The knowledge of managing resources is attached to people within evolving changing processed. People have developed varied adaptation strategies at different levels from household to regional level due to seasonal changes. Knowledge based water and land management is embodied and embedded at individual and group or community level where keen observation skill and knowledge has become its cultural identity.

(3) Synthesizing local spatial knowledge and modelling Karst landscape for Karst management based on local knowledge in Gunungkidul Regency.

Karst people in Gunungkidul are aware that their landscape is different from other parts of Gunungkidul Regency and Yogyakarta Province. They understand that the landscape needs specific management in correlation with climatic factors, particularly rains, and the physical environment constraints. Human behavior toward Karst landscape in application of local knowledge from the seasonal calendar for agriculture determines their livelihood. People can describe the landscape changes during different development eras, from the New Era (*Orde Baru*) government to recent government development programmes. Landscape changes are not only determined by natural cycles but are also shaped by human behavior through their activities.

Microclimatic factors, and topography affect the adaptation and mitigation strategies to cope with annual season changes on Karst landscape, which shape local spatial landscape knowledge. The response of Karst landscape to natural cycles and human activities is modelled by using environmental modelling. A Karst Landscape model is considered as a bridging tool derived from the understanding and interpretation of seasonal based local knowledge on water and land management, deriving geographical aspects from the *Pranata Mangsa* cycle and its application to landscape phenomenon. The modelling application in this study is still considered prototype or a baseline to bridge local spatial knowledge to be integrated and developed into spatial knowledge management, considering scale and temporal dimensions.

8.3. Recommendation

The skill of keen observation or *ilmu titen* on physical features and climatic factors as local knowledge has been decreasing for at least two decades due to the shifting time frame of the inherited seasonal calendar. People need to re-invent their skill and abilities to observe, collect, record and analyze their environmental changes. Government institution can support this by giving assistance to access information and gain knowledge from different sources, whilst Karst people Gunungkidul maintain the local characteristics of their cultural identity. The inherited local knowledge *Pranata Mangsa* as part of *ilmu titen* on climatic factors, may be outdated or old fashioned in the sense of the time when it was formulated. However, the essence of *ilmu titen* is reading natural signs and the effect of human activities on the landscape, and knowing how and what to do with changes. This study hopes to lead to a re-design of *Pranata Mangsa*, sharpening keen observation skill, develop culture of data recording and build knowledge management for Karst landscape Gunungkidul planning and management. The development of ethnometeorology and phenology in response to climatic factors and environmental changes needs to be supported from governmental institutions and non-governmental institutions.

Farmers should become local planners to manage the rural landscape which determines their livelihood, and boost the pride in a Karst Cultural Identity. The government Field School Program or *Sekolah Lapang*, Climate Field School (*Sekolah Lapang Iklim*), is a medium for farmers as agents of knowledge. Farmers are local scientist, together with agriculture officers should develop a culture of data recording, like a log book, to record any changes related to the environment. Understanding the natural cycle to identify hazards and cope with the following risk and sharpening their inherited knowledge to face dynamic challenges. Broadening farmers and also other members of Karst communities knowledge also requires enhancing their capacity by reducing or minimizing their exposure to selling their resources during harsh dry seasons. Harvests and livestock are sold during the dry season to fulfill the need for water. In consideration that crops and timber from Karst Gunungkidul are cultivated from limited water and land resources, it is time to label all products from Karst Gunungkidul as a fair trade product to re-pay the water footprint.

This research also promotes landscape model that are supplemented with seasonal based calendar knowledge and the phenology geo-bioindicators. Open communicative Karst landscape management involves water and land issues due to climatic factors change to meet challenges. Local spatial knowledge of Karst Gunungkidul can transform into landscape (environmental) models which in future research can be developed into participatory landscape models for a cultural landscape approach in Karst Gunungkidul. Participatory landscape models (see Figure 8.1) can be initiated through Field Schools (*Sekolah Lapang*), integrated into their modules, in consideration of locality characterictics like volcanoes, karst landscape, coastal landscape, riverine landscape and where microclimatic factors differ.

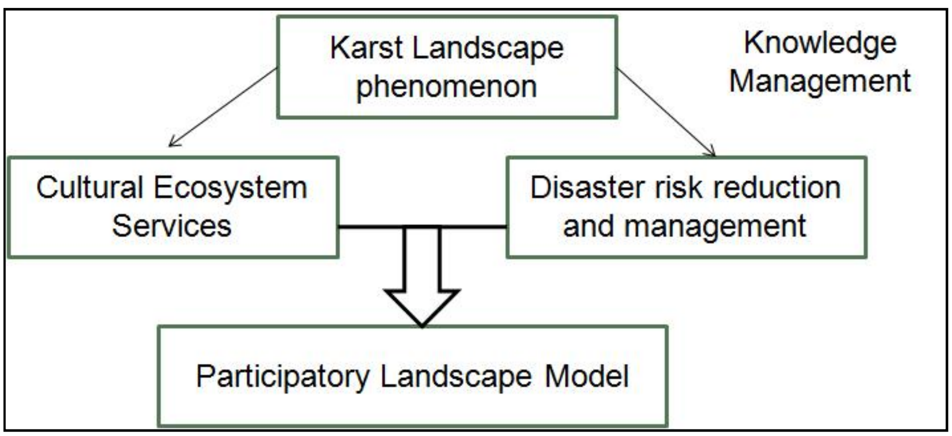


Figure 8.1 Participatory Landscape Model Framework

SUMMARY

In English

Karst Gunungkidul is part of the Karst Gunung Sewu system, and known as one of the most marginalised regions of Java due to its Karst characteristic. Its Karst characteristic has been recognized in many studies as a natural hazard and risk when coupled with uncontrolled anthropogenic activities. Geomorphological and hydrogeological conditions in Karst Gunungkidul are highly affected by climatic factors which lead to environmental changes. Coupling these with human adaptations can impact upon the environment in different ways to those intended.

Karst Gunungkidul people inherit local knowledge that is the result of a long history of keen observation of human response and adaptation to their environment, known as *Pranata Mangsa*. The local knowledge *Pranata Mangsa* cycle has indicators and parameters of changing weather. *Pranata Mangsa* symbolizes each parameter representing a climatic factor within a time frame. Each cycle is symbolized as an element of Earth representing the condition due to physical and climatic factors.

Farmers revealed that *Pranata Mangsa* has helped them to anticipate hazards or be prepared for any impacts due to environmental changes. However the shifting patterns they have experienced within the last two decades, particularly since 1997/1998, when extreme weather occurred related to ENSO phenomenon has caused them to question the *Pranata Mangsa*'s validity. *Pranata Mangsa* has a seasonal calendar time frame which gives early warning of potential water scarcity occurrences. Local people in Karst Gunungkidul have initiated a re-interpretation and re-invention of the seasonal based local knowledge in response to global changes in locality characteristics. Uncertainty event environment changes due to climate factors, encourage people to cope with annual seasonal changes and develop adaptation and mitigation strategies at the household to community level.

The Karst landscape in Gunungkidul reflects the human relationship with their environment and empirically describes their environmental knowledge. Rural people of Karst Gunungkidul have spatial knowledge of their Karst landscape. The narrative process of transferring seasonal based knowledge and its spatial context transform into a landscape model to bridge local people's spatial knowledge in consideration of

micro-climatic factors and topographical aspects. The environmental modelling built into this study is a prototype aimed to accommodate seasonal based local knowledge to be developed into more detail in scale and time dimensions.

In German

Die Region Gunungkidul ist Teil des GunungSewu Karstsystems und ist auf Grund ihrer Karst-Charakteristika bekannt als eine der am stärksten marginalisierten Regionen. Ihre Karst-Ausprägung wird in vielen Publikationen besprochen und stellt ein Naturrisiko dar, wenn sie mit unkontrollierten anthropogenen Aktivitäten gekoppelt wird. Die geomorphologischen und hydrologischen Bedingungen in der Karstregion Gunungkidul sind stark von klimatischen Faktoren beeinflusst, welche zu Veränderungen der Umwelt führen, insbesondere in Verbindung mit menschlicher Anpassung, die noch weitere Einflüsse auf die Umwelt hinzufügen kann.

Bewohnern von Gunungkidulwurde das lokale Wissen von ihren Vorfahren überliefert. Dieses Wissen resultiert aus einer langen Historie intensiver Beobachtungen der menschlichen Reaktion und Anpassung an ihre Umwelt, die als PranataMangsa bekannt ist. Der *Pranata Mangsa* Zyklus zeigt Indikatoren für und oder Parameter von Wetterveränderungen. *Pranata Mangsa* symbolisiert jeden Parameter der mit den verschiedenen Klimafaktoren korreliert innerhalb eines bestimmten Zeitrahmens. Jeder Zyklus symbolisiert Elemente der Erde durch Parabeln um ihren Zustand zu beschreiben, der durch physikalische oder klimatische Faktoren zustande kommt. Landwirte legten offen, dass *Pranata Mangsa* ihnen geholfen hat Klimarisiken vorauszuahnen oder sich auf Auswirkungen von Umweltänderungen vorzubereiten. Trotzdem wundern sie sich über die sich ändernden Muster, die sie in den letzten zwei Dekadenbeobachtetenn. Dies gilt insbesondere seit 1997/1998, als Extremwetterereignisse auftratendie im Zusammenhang mit dem ENSO-Phänomen stehent. Der saisonale Zeitrahmen im *Pranata Mangsa* Kalender lehrte Wissen über frühe Anzeichen potentieller Wasserknappheit. Einwohner der Region gunungkidul haben begonnen ihr auf Jahreszeiten basierendes lokales Wissen entsprechend globaler Veränderungen lokaler Charakteristika umzuinterpretieren und neu zu erfinden. Unsicherheiten bei Umweltveränderungen aufgrund der Änderung klimatischer Faktoren ermutigen die

Menschen sich mit den jährlichen Veränderungen der Jahreszeiten auseinanderzusetzten und Adaptations- und Mitigationsstrategien in Haushalten sowie auf kommunaler Ebene zu entwickeln.

Die Karst Landschaft in gunnugkidul spiegelt die Beziehung von Mensch mit Natur oder Umwelt wieder und beschreibt empirisch das umweltbezogene Wissen. Die ländliche Bevölkerung der Karst-Region Gunungkidul verfügt über räumliches Wissen zu ihrer Landschaft. Der erzählerische Prozess des Transfers des auf Jahreszeiten basierenden Wissens und seines räumlichen Kontexts wurde in ein Landschafftsmodell übertragen um das Wissen der einheimischen Bevölkerung mit mikroklimatischen Faktoren und topographischen Aspekten zusammenzubringen. Das Umweltmodell, welches in dieser Arbeit entwickelt wurde, ist ein Prototyp der darauf abzielt das auf Jahreszeiten basierende lokale Wissen abzubilden und es räumlich und zeitlich detaillierter weiterzuentwickeln.

In Indonesian

Karst Gunungkidul merupakan bagian dari sistem Karst Gunung Sewu, dan dikenal sebagai salah satu kawasan terpinggirkan/marjinal karena karakteristik Karst tersebut. Karakteristik Karst Gunungkidul telah banyak disebutkan dalam literatur, dan memiliki potensi bahaya alam dan risiko ketika dipengaruhi oleh aktivitas manusia yang tidak terkontrol. Kondisi geomorfologi dan hidrogeologi Karst Gunungkidul sangat dipengaruhi oleh faktor-faktor iklim yang mengarah pada perubahan lingkungan, digabung dengan adaptasi manusia akan memberikan dampak yang berbeda terhadap lingkungan.

Penduduk Karst Gunungkidul mewarisi pengetahuan lokal yang merupakan hasil pengamatan yang mendalam terhadap respons dan adapatasi manusia terhadap lingkungannya, dikenal dengan Pranata Mangsa. Pengetahuan lokal tersebut memiliki siklus yang menunjukkan indikator dan atau parameter perubahan cuaca. Pranata Mangsa menunjukkan simbol tiap parameter yang mewakili dan terkait dengan faktor-faktor iklim dalam rangkaian siklus waktu. Tiap siklus melambangkan elemen Bumi melalui ungkapan perumpamaan yang mencerminkan kondisi fisik lingkungan dan faktor-faktor iklim. Para petani menyebutkan bahwa Pranata Mangsa telah membantu mereka dalam mengantisipasi bahaya (hazard) atau bersiap-siap dalam menghadapi perubahan lingkungan. Namun, mereka juga mempertanyakan pergeseran pola yang dialami terutama sejak tahun 1997/1998 ketika terjadi cuaca ekstrem karena pengaruh fenomena ENSO. Kalendar musim Pranata Mangsa telah mengajarkan pengetahuan mengenai peringatan dini (*early warning*) terhadap kemungkinan kelangkaan air. Penduduk lokal Karst Gunungkidul telah menginisiasi untuk menafsirkan dan menciptakan ulang pengetahuan lokal berbasis musim sesuai karakter lokal untuk menghadapi perubahan global. Ketidakpastian perubahan lingkungan akibat perubahan faktor-faktor iklim telah mendorong penduduk untuk mengatasi perubahan musim tahunan dan mengembangkan strategi adaptasi dan mitigasi pada skala rumah tangga hingga komunitas.

Bentangalam Karst (*Karst landscape*) di Gunungkidul mencerminkan hubungan manusia dengan lingkungannya, dan secara empirik menggambarkan pengetahuan lingkungan mereka. Penduduk desa Gunungkidul memiliki pengetahuan keruangan (*spatial*) terhadap bentangalam Karst mereka. Proses narasi dalam mentransfer pengetahuan berbasis musim dan aspek keruangannya diterjemahkan menjadi bentuk model bentangalam (*landscape model*) untuk menjembatani pengetahuan keruangan penduduk lokal dengan mempertimbangkan faktor-faktor iklim mikro dan aspek topografis. Pemodelan lingkungan yang dibuat pada penelitian ini merupakan suatu prototype yang bertujuan mengakomodasi pengetahuan lokal berbasis musim untuk dikembangkan lebih detail dimensi skala dan waktunya.

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Appendix

Appendix 1 - Indonesia's draft National Resources Policy Action Plan 1994-2020

DRAFT NATIONAL RESOURCES POLICY ACTION PLAN (INDONESIA, 1994-2020)

POLICY	WATER RESOURCES MANAGEMENT	SOCIO-ECONOMICS & FINANCE	ENVIRONMENTAL MANAGEMENT	LEGISLATION & ADMINISTRATION
I. WATER UTILIZATION				
	Objective;	Objective:	Objective:	
1. TO PROVIDE ALLOCATION AND UTILIZATION CONDUCIVE TO ECONOMIC AND SOCIAL DEVELOPMENT AND ENVIRONMENTAL SUSTAINABILITY	To make efficient and equitable allocation and utilization of surface and groundwater among sectors considering long-term impacts: 1. To base water allocation on water balance in River Basin Plans. 2. To administer, implement and enforce an integrated national licensing mechanism of surface and groundwater abstraction and use based on River Basin Plans. 3. To review and assess options for and develop allocation mechanisms for inter-River Basin transfers and water exports	To link the water sector with and respond to demographic shifts and changes in the social and economic sectors: 1. To use cross-sectoral analysis, planning and development to evaluate and implement present water utilisations and in particular: - compile River Basin baseline descriptions on linkages between water utilization and interactions between the water sub-sectors and (a) macro- (fiscal, monetary and trade) and economic policy instruments and (b) inter-sectorial, intrasectoral, distributional and environmental impacts - identify and address related trade-offs and ways of accommodating them in and between the River Basins 2. To identify and formulate the role of water security within the context of national economic security 3. To assess and optimise influence of water policy (a) between economic sectors (b) between national and regional levels and (c) among households and firms 4. To identify options for water policy as rational strategy for	To adapt water allocation to ecosystem management approach: 1. To establish water resources accounting systems for sustainable utilization at national and River Basin levels. 2. To identify and study the linkages between water utilization, public health and environmental protection. 3. To design and implement programmes for the enhancement of public awareness of water availability and utilization economy, and related rights and responsibilities	1. Issue and enforce Guidelines for implementation of water licencing regulations. 2. To issue a joint decree of the Ministers respectively responsible for water resources and for mining and energy delegating to the Minister responsible for water resources the allocation of surface and groundwater through a unified licensing mechanism. 3. To sub-delegate responsibility for combined water abstraction and wastewater discharge licensing to PERUMs

		economic and regional development 5. To adopt water resources management policy to fiscal austerity, reduced producer subsidy and reduced public share of public water resources investment and other structural adjustment measures as and capital instruments for effective utilization		
	Objective:			
2. TO IMPROVE THE EFFECTIVENESS AND EFFICIENCY IN THE UTILIZATION OF WATER.	To reconcile efficiency and equity 1. To institute a system of water service contributions from the users to improve water use efficiency 2. To encourage conjunctive use of surface and ground water through licencing system and water service pricing 3. To classify water resources for optimal utilization based on availability, quality, amenity and other values 4. To establish a system of bulk allocations of surface water by efficiency considerations through consolidated licenses	1. Improve technical efficiency by introduction of appropriate technology for reduction, re-use and recycling 2. Improve economic efficiency by developing (a) reduced water production costs (b) higher production per unit of water (c) cross-subsidies within the River Basin (d) cross-subsidies between River Basins 3. Establish and enforce use-based water service charges to achieve allocative and cost-recovery objectives for water management in the River Basin. Water service charges will be based on actual long-term marginal water costs	1. Identify and address environmental trade-offs of efficient water utilization 2. To respond to requirements for effective integrated natural, human and man-made resources management in the River Basin Plan 3. To design and implement programmes for the evaluation and management of long-term cumulative impacts of water resources development 4. To establish independent screening procedures for EIA 5. To ensure proper timing of EIA in the project cycle 6. To ensure informed and alert end-consumers of product-related effects on water through environmental labelling	1. To incorporate in existing water licencing regulations provisions to the effect that water saved through efficient use of license holder's entitlement is for Government to dispose of under River Basin Plans 2. To include in the Guidelines for the implementation of water abstraction licensing regulations: a. provisions for water and water resources use-based service charges b. provisions for the routine inclusion in water abstraction licences of clauses for technical and economic efficiency of water use. 3. Limited to Provinces which have not yet done so, draft Provincial Government Regulations for the implementation of the wastewater charging provisions of Government Regulation 20/1990 on water pollution control 4. To review legislation on EIA and incorporate independent screening procedures and ensure proper timing of EIA in the project cycle
II. WATER QUALITY				
3. TO PROVIDE LEVELS OF QUALITY IN INDONESIA'S WATER RESOURCES WHICH ARE CONDUCIVE TO ECONOMIC AND SOCIAL DEVELOPMENT AND ENVIRONMENTAL SUSTAINABILITY	1. To administer and enforce a combined national licensing system for water abstraction and waste water discharge based on River Basin Plans. 2. To establish priorities for water quality control based on population density. 3. To strengthen national and regional capacity for R&D in water quality	1. To establish mechanisms for cross-sectorial policy analysis, planning and development 2. To review policies on agricultural inputs and their effect on water quality 3. To establish and enforce water service effluent charges for efficient water management and	1. To inventory and assess flora and fauna threatened by water pollution and ensure their protection 2. To design and implement programmes for water quality management in coordination with existing and on-going activities	1. To institute and enforce a combined licensing system for water abstraction and wastewater disposal based on River Basin Plans by mutually reconciling Min PW Decree 45/1 990 on water pollution, Min PW Decree 49/1990 on water abstraction licencing, Government Regulation 22/1982 on Water Resources Management and Government Regulation 20/1990 on Water Pollution Control.

	management by: - improving water quality information - developing appropriate technology for wastewater treatment - identifying needs, activities and resource requirements for water pollution control - coordinating with urban and rural sanitation strategies 4. To identify and declare water resources protection areas 5. To control sedimentation through adequate watershed management	recovery of water pollution control service costs within the River Basin 4. Establish and enforce a water resources conservation charge on land uses in the catchment with an impact on water quality 5. To review and assess the effectiveness and efficiency of the current and proposed water quality standards for water resources management	3. To review economic and policy measures to increase compliance with pollution control measures	2. To include in the standard forest logging concession agreement payment of a water resources conservation charge on land uses in the catchments with an impact on water resources. 3. To draft legislation restricting social and economic activities in and around water bodies, catchment and recharge areas, consistent with Spatial Land-use Plans, to protect water sources
III WATER RESOURCES DEVELOPMENT				
	Objective			
4 TO DEVELOP WATER RESOURCES UNDER THE NATIONAL WATER RESOURCES DEVELOPMENT PLAN (NWRDP) BASED ON RIVER BASIN PLANNING	To move to a planned programme approach for water resources development 1 To develop end establish a participatory, interactive and consensus seeking process for River Basin Planning for national and provincial River Basins 2 To integrate river basin planning processes and instruments with spatial planning processes and instruments 3 To identify priorities for the formulation of River Basin Planning based on (a) water balance (b) water pollution (c) River Basins as Special Development Areas 4 To complement existing flood control programmes with zoning of floodplains and disaster preparedness in coordination with Spatial Land-use Plans 5 To create capacity for River Basin Planning, secure collection and processing of data for River Basin Planning	1 To establish a River Basin Planning process interactive with mainstream planning for preparation of NWRDP 2 To prepare regional development strategies based on River Basin Planning in regions with water scarcity and in particular regions with (a) critical water availability and/or subject to flooding (b) upstream downstream interdependence for water availability and/or flood divided by administrative boundaries 3 To give recognition to and reflect changes in macroeconomic policies in development of River Basin Planning 4 To address and accommodate trade-offs between development objectives in the development of River Basin Planning 5 To establish the interactions between water producers and users in the River Basin Plan 6 To introduce efficient flood plain	1 To establish and implement a participatory and interactive process for EIA of River Basin Plans and of Spatial Plans 2 To protect aquatic habitats including lakes, wetlands and coastal waters through regulation, incentives and in River Basin Plans 3 To design and implement conservation programmes with increased public participation 4 To manage soil conservation and water-shed management in the formation of River Basin Plans 5 To reflect and give recognition to traditional and cultural values in the formation of River Basin Plans	1 To draft and implement legislation regulating River Basin Planning consistent with Spatial Land use Planning 2 To incorporate in existing EIA regulations and implementing mechanisms a requirement for EIA of River Basin Plans and Spatial Plans 3 To enact and implement legislation water resources related disaster preparedness 4 To investigate water related customary law and practices and assess their relevance and impact on River Basin Planning

		management under River Basin Plans		
5. TO ENHANCE PRIVATE SECTOR AND COMMUNITY PARTICIPATION IN FINANCING OF WATER RESOURCES DEVELOPMENT	1. To establish, under the control of the Government: (a) New River Basin branches of PERUM Jasa Tirta, and Provincial State Companies (PERUMDA), as organizations for water resources development (b) Formal Water Users' Groups 2. To identify and prepare viable programmes for private participation in water resources development through joint ventures with the Government 3. To establish schemes to encourage controlled self-development of surface and groundwater	1. To identify viable financial schemes and instruments to attract financial resources from private interests and the public, in accordance with deregulation policy and, in particular, - review, under River Basin Planning, the potential for acquisition of private financial resources for water resources management and development 2. To review water service charges for compatibility with private sector participation	1. Delegate financial responsibilities and benefits to the immediate beneficiaries	1. To draft legislation to give User's groups legal status before the law and to enable them to function in a corporate capacity 2. To draft legislation to enforce the beneficiaries' responsibility for O&M of main water works 3. To draft legislation enabling and motivating the public, including financing institutions to participate in financing water resources management and development and establishing relevant procedures and requirements
6. TO ESTABLISH A SUSTAINABLE BUDGET SYSTEM FOR WATER RESOURCES MANAGEMENT.	1. To establish independent annual and multi-annual capital budget components, based on River Basin Plans for Water Resources: (a) Water management administration (b) Water Resources Planning (c) River Improvement	1. To make balanced appropriation of budgetary resources between management including improved services to the public, development and O&M 2. To institute a system of water abstraction and wastewater discharge contributions. 3. To secure specific Government budgetary appropriations for water resources enhancement for all purposes.	1. To secure budgetary resources for water conservation and environmental protection measures 2. To provide budget for environmental management and monitoring plans at the River Basin level, out of project funds	1. To adjust legislation on national budget structure so as to accommodate a sustainable budget for water resources management
IV. WATER RESOURCES MANAGEMENT STRUCTURE				
7. CREATE A WATER RESOURCES MANAGEMENT STRUCTURE CONSISTENT WITH INTEGRATED MANAGEMENT OBJECTIVES	1. To coordinate water resources management activities, 2. To establish a structure and capacity for water policy development and for monitoring of water resources planning, management and development. 3. To establish central government water resources management capacity including River Basin Planning and allocation for water abstractions, waste	1. Subsidize the implementation of River Basin Plans as required 2. To identify and confirm the financial viability of river basin management areas based on economy to support and populations served by water resources management	1. To develop institutional to integrate water resources management within the frame of natural resources management	1. To consider: (a) structuring the National Water Resources Council as a Committee of Ministers at policy making level, and a Technical Committee of Directors-General: (b) coordinating the Council with the National Spatial Planning Committee through the Council chairman becoming an ex officio member of the said National Committee.

	water discharges and other water uses of surface and ground water resources (National River Basins) making use of existing structure and manpower. 4. To entrust operational water management functions at basin level in National River Basins to branches of Perum Jasa Tirta in (a) River Basins or groups of basins that are financially viable; (b) non-viable basins or groups of basins to be supported by inter-basin cross-subsidies. 5. As an intermediate arrangement in river basins that are not financially viable, to entrust operational water management with non-structural Technical Units (UPTs) 6. At the Provincial level, to structure Technical Units (UPTs) along River basin lines for River Basin Planning and the integrated quantity and quality management of surface and ground water resources of Provincial River Basins			

APPENDIX 2

Mangsa												
	Land Unit											
		Valleys										
			VEGETATION									
				Species								
					Branch/Trunk							
						Distribution						
						Brances per Segment						
						Segment						
						Brach Start Angle						
						Branc End Angle						
						Trunk Thickness						
						Branch Thickness						
						Texture						
					Tree							
						Shape						
						Gravity Aspect						
						Randomness						
					Foliage							
						Shape						
						Scale						
						Number of Leaves (per branch)						
						Distribution						
							Stacked					
							Staggered					
							Spiral					
							Bunched					
							Coniferous					
						Texture						

							Color						
								Diffuse					
								Ambient					
								Specular					
								Specular Halo					
								Transparency					
								Volume					
							Value						
								Diffusion					
								Ambience					
								Specularity					
								Metallicity					
								Bump Height					
								Displacement					
								Anisotropy					
							Optic						
								Transparency					
								Reflection					
								Refraction					
				Spatial Distribution									
				Frequency									
			TERAIN										
				Morphologycal Fractal									
					Ridged Multifractal								
					Perlin Hills								
					Rounded Dunes								
					Classic Fractal								
					Round HIlls								
					Slickrock								
					Ridges								

					Rolling Hills					
					Apline Valleys					
					Chaotic					
					Pocked					
					Crystaline					
					lava					
					Metamorphism					
					Metamorphosed					
					Fractured					
					Weathered Dikes					
					Warped Dikes					
					Warped Slickrock					
					Warped RIdges					
					Zorch					
					Warped Zorh					
					Mordor					
					Shattered Hills					
					Cauflower Hills					
					Mud Crack					
				Morphologycal Noise						
					High					
					Medium					
					Low					
				Height Noise						
					High					
					Medium					
					Low					
				Spike Aspect						
					High					
					Medium					

					Low						
				Mound Aspect							
					High						
					Medium						
					Low						
				Damped Aspect							
					High						
					Medium						
					Low						
				Subcontours							
					Yes						
					No						
				Erotion Aspect							
					High						
					Medium						
					Low						
				Height							
			SKY								
				Sun							
					Visibility						
						Disk intensity					
						Glow Intensity					
					Sun Shadow						
						Intensity					
					Shadow Softness						
						Soft					
						Medium					
						Hard					
					Sun Intensity						
						Diffuse					

						Specularity						
					Azimuth							
				Cloud Cover								
					Stratus							
						Cloud Cover						
						Cloud Height						
						Frequency						
						Amplitude						
						is Sperical Clouds?						
						Cloud Motion						
							Speed					
							Turbulence					
					Cumulus							
						Cloud Cover						
						Cloud Height						
						Frequency						
						Amplitude						
						is Sperical Clouds?						
						Cloud Motion						
							Speed					
							Turbulence					
				Atmosphere								
					Fog							
						Density						
						Thickness						
						Base Height						
					Haze							
						Density						
						Thickness						
						Base Height						

					Color Prespective						
						R					
						G					
						B					
					Rainbow						
						Radius					
						Opacity					
						is has secondary bow?					
					Blend with Sun						
						Color					
						Luminance					
						is Blended Haze?					
						is Blended Fog?					
					Volumetric World						
						Density					
						Quality					
		Hillslopes									
			VEGETATION								
				Species							
					Branch/Trunk						
						Distribution					
						Brances per Segment					
						Segment					
						Brach Start Angle					
						Branc End Angle					
						Trunk Thickness					
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					Tree						
						Shape					

						Gravity Aspect							
						Randomness							
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						Shape							
						Scale							
						Number of Leaves (per branch)							
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							Stacked						
							Staggered						
							Spiral						
							Bunched						
							Coniferous						
						Texture							
							Color						
								Diffuse					
								Ambient					
								Specular					
								Specular Halo					
								Transparency					
								Volume					
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								Ambience					
								Specularity					
								Metallicity					
								Bump Height					
								Displacement					
								Anisotropy					
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								Reflection					
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					Slickrock								
					Ridges								
					Rolling Hills								
					Apline Valleys								
					Chaotic								
					Pocked								
					Crystaline								
					lava								
					Metamorphism								
					Metamorphosed								
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					Weathered Dikes								
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					Zorch								
					Warped Zorh								
					Mordor								
					Shattered Hills								

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					Low					
				Spike Aspect						
					High					
					Medium					
					Low					
				Mound Aspect						
					High					
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					Low					
				Damped Aspect						
					High					
					Medium					
					Low					
				Subcontours						
					Yes					
					No					
				Erotion Aspect						
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					Medium					
					Low					
				Height						

			SKY									
				Sun								
					Visibility							
						Disk intensity						
						Glow Intensity						
					Sun Shadow							
						Intensity						
					Shadow Softness							
						Soft						
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						Hard						
					Sun Intensity							
						Diffuse						
						Specularity						
					Azimuth							
				Cloud Cover								
					Stratus							
						Cloud Cover						
						Cloud Height						
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						is Sperical Clouds?						
						Cloud Motion						
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							Turbulence					
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						Cloud Height						
						Frequency						
						Amplitude						

						is Sperical Clouds?							
						Cloud Motion							
							Speed						
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				Atmosphere									
					Fog								
						Density							
						Thickness							
						Base Height							
					Haze								
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					Rainbow								
						Radius							
						Opacity							
						is has secondary bow?							
					Blend with Sun								
						Color							
						Luminance							
						is Blended Haze?							
						is Blended Fog?							
					Volumetric World								
						Density							
						Quality							

Erklärung

Ich erkläre:

Ich habe die vorgelegte Dissertation selbstständig 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 veröffentlichen 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.

Gießen, October 2014

(Arry Retnowati)