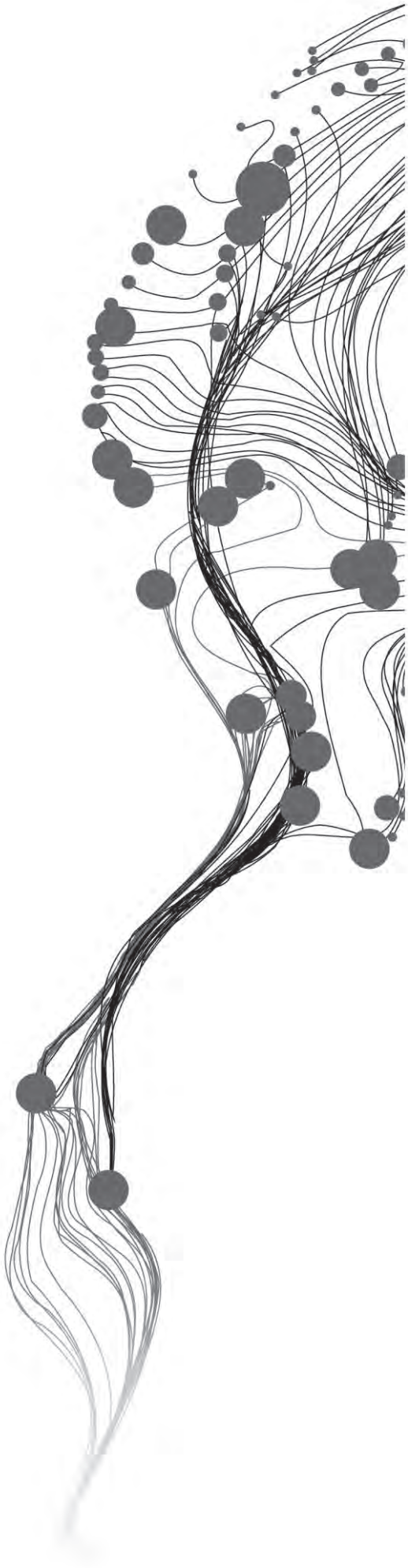
PARTICIPATORY MAPPING TO ASSESS THE DECLINE OF GROUNDWATER SOURCES:

The Case of Mtoni and Bububu-Mwanyanya Springs-Zanzibar

SAID S. UFUZO

February, 2012

SUPERVISORS:
Drs. J. J. (Jeroen) Verplanke
Ir. M. J. G. (Mark) Brussel



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Enschede, The Netherlands, February, 2012

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SUPERVISORS:

Drs. J. J. Verplanke

Ir. M. J. G. Brussel

THESIS ASSESSMENT BOARD:

Chair: Rd. R. V. Sliuzas

External Examiner: Rd. M. K. McCall, UNAM/UT

ABSTRACT

Globally, professionals and non-professionals discuss involvement of local people in identifying, analysing, planning and managing spatial issues. So far most of studies assessed groundwater by using scientific knowledge with very little use of Local Spatial Knowledge (LSK) that is believed is operative in assessing natural resources. However, less has been done from LSK to assess ground resources like groundwater. On that basis, this study developed its objectives for assessing the decline of groundwater in-order to come-up with LSK states causes, effects and coping measures of groundwater. Yet, it also assesses usefulness of LSK in assessing natural resources. By using participatory mapping approach and qualitative GIS methods with case study tactic, the LSK could be elicited, organised and analysed and then qualified by using conventional approach using secondary data sources. The results outline the understanding of groundwater decline, cause, effects and coping measures basing on local knowledge perception and in a conventional assessment it revealed that the LSK is useful in assessing natural resources particularly groundwater as a basic input to the full study assessment. It identifies qualitative information on causes, effects and coping measures suitable for analysing, and monitoring of groundwater.

Key words: Groundwater assessment, Local Spatial Knowledge, Participatory Mapping and Natural Resources Participatory Assessment.

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LIST OF ACRONYMS

3D Model	Three Dimensional Models
FG	Focus Group
FGD	Focus Group Discussion
Fig	Figure
FINNIDA	Finnish International Development Agency
GDP	Gross Domestic Product
GID	Global Image Database
GIS	Geographic Information System
GOs	Government Organisations
Ha	Hectare
HBS	Household Budget Survey
IDRC	International Development for Research Centre
ITC	Faculty of Geo-Information Science and Earth Observation – University of Twente
km^2	Kilometres
LAN	Local Area Network
LK	Local Knowledge
LSK	Local Spatial Knowledge
m	Metres
m^3	Cubic metres
MFA	Ministry of Foreign Affairs (Finland)
MKUZA	Poverty Reduction Strategy - Zanzibar
mm	Millimetres
MSc	Master of Science
MS-Excel	Microsoft Excel
MWCELE	Water Construction Energy and Lands (Zanzibar)
NBS	National Bureau of Statistics – Tanzania
NGOs	Non-Governmental Organisations
PGIS	Participatory Geo Information System
PLA	Rapid Learning and Action
PRA	Participatory Rural Appraisal
RRA	Rapid Rural Appraisal
Shehia	Lowest Administrative Unit – Zanzibar
UK	United Kingdom
UN-HABITAT	The United Nations Human Settlement Programme
USAID	United State Agency for International Development
ZAWA	Zanzibar Water Authority
ZSGRP	Zanzibar Strategy Growth Reduction Plan

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CHAPTER ONE

1. BACKGROUND INFORMATION AND JUSTIFICATION

1.1. Background Information

Groundwater denotes to the natural water found underneath the earth surface. It may flow out naturally as springs or ground-rivers to lakes, rivers and seas/ocean (North Carolina Department of Environment and Natural Resources - Division of Water Resources, 2004). The water may also be extracted up in boreholes or shallow wells for human use, irrigations, animal breeding and other uses.

Decline of ground water level refers to the decreasing amount of water in aquifers. The decrease occurs during extraction of groundwater without recharge or when the recharge is lower than extraction or when the rate of natural discharges (runoff) is higher than the recharge. Hence, the assessment of groundwater decline in this research concerns with the assessment of decreased groundwater, its causes and results to the inhabitant living in the study area.

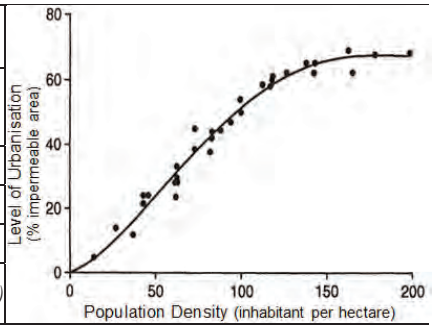
1.1.1. Problems Associated with Groundwater:

According to hydrological process, natural water system flows in a regular manner from rainfall, infiltration, runoff, groundwater flow and recharge, evaporation, solute transport and sediment transport (Brussel, 2011). The flow is somehow complex in an urban environment due to human impacts on groundwater where its recharge depends on population and built-up densities of an area. Thus, if the built-up and population densities are high, the groundwater recharge is low due to poor permeability. This means the possibility of groundwater level decline is high.

Figure 1-1:Development Density and Groundwater Recharge

Developme nt Density	Percentage Recharge	Percentage Runoff	Percentage Evaporation
Low	35%	50%	15%
Medium	25%	65%	10%
High	10%	85%	5%

Source: *Butler and Davies 2004 (Effect of urbanisation on urban storm water runoff patterns)*



1.1.2. Urbanisation:

The United Nations (UN-Habitat) has defined urbanisation as a movement of people from rural to urban areas. The projected population shows people living in urban areas was half of the world's population by the end of year 2008 (2008). Urbanisation is associated with many spatial aspects such as spatial development of urban areas for settlements, recreations, services, and social economic activities. These aspects lead to an increase of hard and compacted land surfaces and affect the hydrological process particularly with respect to the groundwater flow and recharge which leads to a reduced availability of water. Moreover, urbanisation results in increase of groundwater exploitation which for instant the potentials of Asia Mega Cities have decreased and land subsidence has taken place due to over pumping of groundwater in urban areas (Onodera et al., 2008). The situation also caused contaminations in transport of groundwater from households, industries, seepages and natural drainages as well as runoff streets water infiltrate to fresh groundwater zone (Butler & Davies, 2004).

According to the UN-Habitat, Zanzibar's rate of urbanisation is as high as Dar es Salaam and some other sub-Sahara Africa countries. The urban growth rate ranges between 7-11% per annum (UN Habitat, 2011a) and about 40% of its population is living in urban areas (NBS, 2011).

Basing on the 2002 Housing and Population Census, the Urban District of Zanzibar is leading in number of population as shown in table 1-1 below. The district is growing so first at a rate of 4-5% per annum to compare with the growth rate of Zanzibar which is 3.1% per annum (The Revolutionary Government of Zanzibar, 2007). The growth caused urban sprawl of more than three times beyond urban official boundaries (Murage, 2008) as per the 1978 Zanzibar Master Plan.

Table 1-1: Population Zanzibar, Urban-West Region and Districts (Urban & West) - 1978-2010

	1978	1988	2002	2005	2006	2007	2008	2009	2010
Zanzibar	476,111	640,685	981,754	1,077,524	1,111,361	1,155,065	1,193,383	1,176,000	1,211,000
Mjini-Magharibi	142,041	208,571	390,074	424,256	435,992	447,716	459,502	334,845	483,205
Magharibi	31,535	50,945	184,204	193,648	196,912	199,983	202,959	205,748	208,403
Mjini	110,506	157,626	205,870	230,656	239,080	247,733	256,543	129,097	274,802
Source: 2002 Zanzibar Population and Housing Census, NBS									

The population density of the district was 12,867 persons per square kilometre (p/Km^2) in 2002 and reached up-to 17,175p/Km^2 in 2010. The density is higher than other districts although it has a smallest land area to compare with other districts (as shown in table 1-2 below).

Table 1-2: Population Density Zanzibar, Urban west Region and Districts (Urban & West)-1978-2010

	1978	1988	2002	2005	2006	2007	2008	2009	2010	Area (Km^2)
Zanzibar	179	241	370	406	419	435	450	443	456	2,654
Mjini-Magharibi	634	931	1,741	1,894	1,946	1,999	2,051	1,495	2,157	224
Magharibi	152	245	886	931	947	961	976	989	1,002	208
Mjini	6,907	9,852	12,867	14,416	14,943	15,483	16,034	8,069	17,175	16
Source: 2002 Zanzibar Population and Housing Census, NBS										

1.2. Justification

Worldwide researchers, practitioners and non-professionals discuss the involvement of local people in identifying, analysing, making decisions, planning and managing of spatial issues. PGIS has been mentioned as an effective practice for eliciting LSK (McCall, 2003) for such purposes. It incorporates GIS with local knowledge to identify and map spatial features for decision making, planning and managing resources (such as forests and water). It involves local people, local experts, relevant organisations (GOs & NGOs) for confirming integrated participation in policy point of view, grass root perspectives and interested sectors.

This research aims to discuss the concepts and use of Participatory Mapping to assess the decline of groundwater sources in the case of Zanzibar's urban periphery. The assessment will look at causes, effects and coping strategies according to the residents' perceptions. The results of the assessment are expected to contribute in the uses of Participatory Mapping for natural resources assessments and might be an input in resolving and managing water sources issues for urban water supply system of Zanzibar which proved un-satisfactory to many of its customers.

1.3. Research Problem

Decline of water level in ground water sources might be a result of natural and manmade causes. In general the natural cause is mostly influenced by climate changes that alters average temperature and rainfall (Ahamed et al., 2009). Examples of such results are shortage of rains, drought and natural

discharge of ground sources. For example the mean recorded rainfall from 2005-2008 was 2878, 4003, 3651, and 2655 mm per annum (Tanzania Meteorological Agency, Zanzibar Office, 2009) which shows in consistencies rainfalls. This situation contributes to poor ground water recharge. The manmade cause is mainly triggered by urbanisation process from which people initiate land developments and socio-economic activities (such as agriculture and tourism). The process involves vegetation clearance and covering of the earth surface which results into decreased aquifer recharge and a lower infiltration rate (due to increases of hard surface) and increases of discharge (due to high water consumption).

Zanzibar urban periphery is also being converted from natural forest to subsistence agriculture and informal settlements (Myers, 2010). Some of these areas are water catchments for the urban water supply sources such as Bububu, Mtoni, Kaburi-kikombe, Fuoni and Kianga.

In both cases of groundwater decline (natural and manmade) local people are part of the environment where the decline happens. They might have potential knowledge to describe the situation in an effective manner. The knowledge might be also determined from their familiarisation with the situation before and during the decline as well as strategies they use to overcome the effects resulted from the decline. Hence, their knowledge probably can be used for assessing the extent or severity of the decline of groundwater decline.

On the other hand, various techniques have been used to assess water quantity such as the use of meteorological data (Ministry of WCELE Zanzibar & Ministry of FA Finland, 1991c), HRI and smart sensor (Srikanth, 2004) which are purely objectively but not descriptive. Instead, researchers have to interpret the results to describe causes and effects as well as suggestions for coping measures based on researcher's perception. (Ali, 2006). Participatory Mapping is an alternative technique that integrates local and scientific knowledge in assessing natural resources (such as water and forest) (Heyns, 2008), and (Kalibo & Medley, 2007) but not much research has been conducted to assess groundwater by Participatory Mapping, especially in Zanzibar. Hence this study is expected to contribute on natural resources assessment researches framework by using local knowledge as the main tool for the assessment.

1.4. Research Objectives

1.4.1. General Objective

The aim of this study is to assess decline of water level in groundwater sources from local knowledge perspective. And in-order to achieve this aim, the study specifies the following objectives.

1.4.2. Specific Objectives

i. To come up with Local Spatial Knowledge (LSK) states, causes and effects of groundwater level decline in their locality.
ii. To elicit local based coping measures to counter the effects of groundwater level decline.
iii. To find usefulness of Participatory GIS in assessing natural resources particularly water sources.

1.5. Research Questions

1.5.1. Research question for specific objective one

- What causes decline of water level in groundwater sources in the study area according to the local people?
- How does the water decline affect local people in the study area?

1.5.2. Research question for specific objective two

- What coping measures are taken by local people in the study area to deal with groundwater decline?
- How local people resolve spatial problems among themselves

- How local people resolve spatial problems with official institutions.

1.5.3. Research question for specific objective three

- Is there significant different between genders LSK in assessing groundwater decline?
- What is the relevance of the local knowledge in assessing groundwater sources?
- What are potentials and shortfalls of using P-GIS in assessing groundwater sources?
- What are the similarities and contrasts of the local knowledge data set and secondary data set?
- How the qualities of local knowledge and secondary data sources can be assessed?

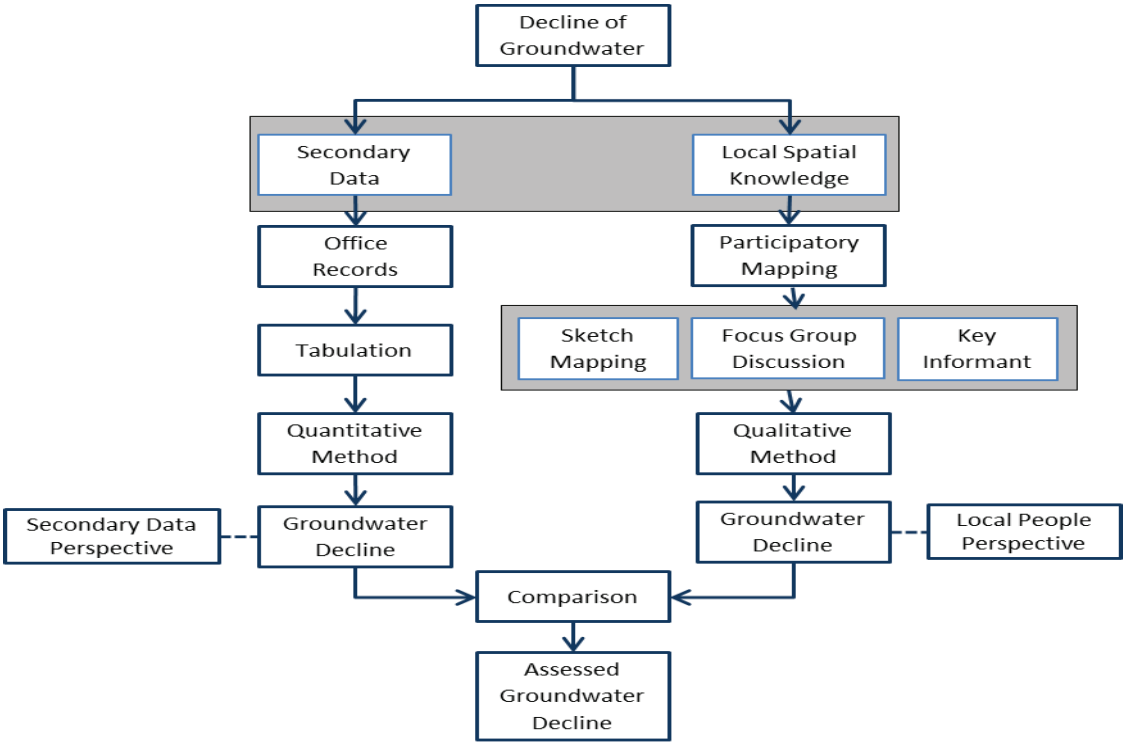
1.6. Conceptual Framework

The study's concept is based on a logical framework that assesses the decline of groundwater level by Participatory Mapping Approaches. It starts with local knowledge data collection from local people in the study areas simultaneously with collection of primary and secondary data from Water Authority Records. The local knowledge is elicited by using Participatory Mapping tools (i.e. Sketch Mapping, FGD and Key informant Interviews) from which local people map their living environment with important spatial features such as location of water sources in-relation to other features that they regard are relevant to give description of water sources.

By using FGDs the local people outline causes and effects of groundwater decline and coping measures they are taking to deal with such situation. Key informant interviews are used to the identified needs of data for justifying information which are collected in FGDs. Conversant respondents for the interviews are selected based from their special knowledge they have. In both cases, relevant office records are collected and reviewed from the Water Authority and Metrology Section of Zanzibar.

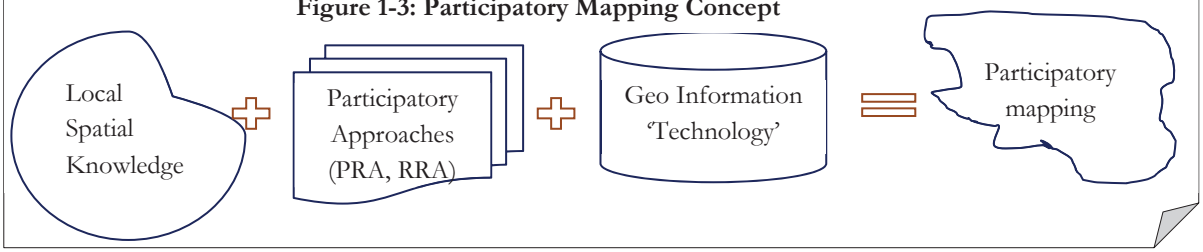
The collected primary and secondary data are qualitatively analysed to come-up with assessed decline of groundwater from local people point of view and from secondary data records. Finally comparisons of people's perspective and official records are done to come-up with study's findings from which a conclusion is drawn as well as recommendations for further studies. The summary of this methodology framework is as shown in a Fig 1-2 below.

Figure 1-2: Methodical Framework for Assessing the Decline of Groundwater Sources



Apart from that, conceptually participatory Mapping is modelled by three major components which are local knowledge, scientific knowledge and participatory approaches. The local knowledge which here referred as local spatial knowledge is elicited with participatory approaches and tools such as PRA and RRA then integrated with geo-information approaches and tools like GPS, I-pad fibre-track, and GIS software to produce the participatory mapping or participatory GIS. (see also fig 1-3 below). Hence, we can say that participatory mapping (or PGIS) is a geo related scientific practice which uses local spatial knowledge with participatory approaches and geo information technology for specific purposes of project, communication and information.

Figure 1-3: Participatory Mapping Concept



1.7. Thesis Outline

Thesis of participatory mapping to assess the decline of groundwater sources composed of eight chapters. It start with information background and justification for conducting research, literature review, information of the study area, research design and methodology, research findings, findings discussion and ends with the research conclusion and recommendations.

i) Background Information and Justification is the first chapter of this thesis that outlines seven sections. The first section gives the background of groundwater and participatory mapping. It also highlights problems associated with groundwater and urbanisation. Section two describes justification for undertaking this research. The research problem, objectives and questions have been discussed in section three, four, and five respectively while in section six briefs research and methodological concepts. Finally, section seven outlines structure of the thesis and flows of chapters.

ii) Literature review chapter is an appraisal of participatory mapping and groundwater assessment concepts and overviews of assessing natural resources through participatory mapping. The chapter analyses participatory practices in natural resource assessment, participatory mapping in the resource identification and mapping, participatory practices and spatial development in resources catchments, participatory practices and resource management and integrating P-GIS in planning and management of water supply as was applied in precious researches. The chapter ends with conclusion that justifies the selection of the study's approach.

iii) Chapter three provides background information of the study area (i.e. Shehia of Mtoni and Mwanyanya) and their significance of groundwater sources to the urban water supply of Zanzibar municipality.

iv) Chapter four gives detail description of the study methodology that includes research design, data collection and analysis. It also discusses data collection tools of this study in details.

v) Chapter five is providing research findings that show LSK assessing groundwater from level of understanding the groundwater decline, causes and effects to coping measures of the groundwater decline.

vi) Chapter six talks about conventional assessment of the groundwater decline in respect to the LSK findings.

vii) Chapter eight is the discussion chapter where study findings are reflected to the studies objectives to see their implications for making the study's conclusion.

viii) The thesis ends with chapter eight which provides research conclusion, limitations and recommendations for further studies regarding to the revealed study's findings and limitations.

CHAPTER TWO

2. REVIEW OF PARTICIPATORY MAPPING IN ASSESSING NATURAL RESOURCES

2.1. General Introduction:

Numerous researches have been conducted to assess the groundwater decline in various aspects. Mostly, the studies associate the assessment with groundwater availability, extent, quality and sustainability or forthcoming situations. The study of groundwater impacts due to conservation reserve program in Texas Country - Oklahoma for instant, examined the relationship between the Conservation Reserve Program and the change in the groundwater level with the hypothesis that there is a significant spatial correlation between the groundwater decline and the conservation project. To fulfil its objectives, the study employed Soil and Water Assessment Tool-Model and GIS-based analysis (Rao & Yang, 2010). Purely, the assessment relied on statistical interpolations of significant spatial correlation and confidence level from the selected points (high plains aquifer) to conclude. Likewise, the Spatial and Temporal Changes in Runoff Caused by Climate Change in Complex Large River Basin in Oregon-Study estimated potential changes in seasons and runoff with association of uncertainty for the Willamette River Basin (Oregon). The study used Precipitation-Runoff Modelling System combined with General Circulation Models and GID analysis methods to measure spatial and temporal changes in forthcoming runoff (2040s and 2080s)(Heejun & Il-Won, 2010). The conclusion was drawn based on estimated calculations which tried to assess different season's projections and scenarios.

On the other hand, the study of Groundwater Monitoring Using of Smart Sensors was conducted in the United State for the purpose of assessing the groundwater levels with low costs through acquisition, transfer and display groundwater level data in graphical user interface from various selected ground points in real-time by using Field Programmable Gate Arrays and Wireless LANs (IEEE 802.11) (Anumalla et al., 2005) which resulted to the real-time groundwater monitoring system.

From these few mentioned examples we can say that assessment of groundwater decline is mainly refer to water resource itself to see its extent and influencing factors. The methods used to assess are purely scientific that based on objective collected and analysed data and tools even though the Oklahoma Conservation Reserve Program study proved the surrounding environment has major influence in the decline and raise of groundwater level. This provides opportunity of involving local people in groundwater assessment their areas and sees to what extent their knowledge is useful or not in the assessment. In fact, The World Water for Cities Programme call for involvement of local citizen in water management project (UN Habitat, 2011b) which also include groundwater assessment. Therefore this study is going further to assess groundwater decline by using LSK.

2.2. Cause Effect Concept:

Cause and effect is a philosophical concept of causality that determines relationship between matters or events from which one enhances or results to the other or vice versa. It is also a logical framework for problem analysis developed among other organisations The United State of Agency for International Development (USAID) in 1970s for conceptualisation and management of development projects. Planners use in researching the factual basis in terms of frequency and extent of the problem, link study problem and objective and establish log framework by resting causes as means and effects as ends (Grant, 2007). The concept is useful for developing logic planning frameworks for interventions and predictions outputs from the developed logic objectives and strategies. It enhances proper analysis such

in the Evacuation Planning using the logic framework to analyse planning process of SICURO Project (Italy) (Russo & Rindone, 2008), which analysed the planning process of urban systems in emergency conditions.

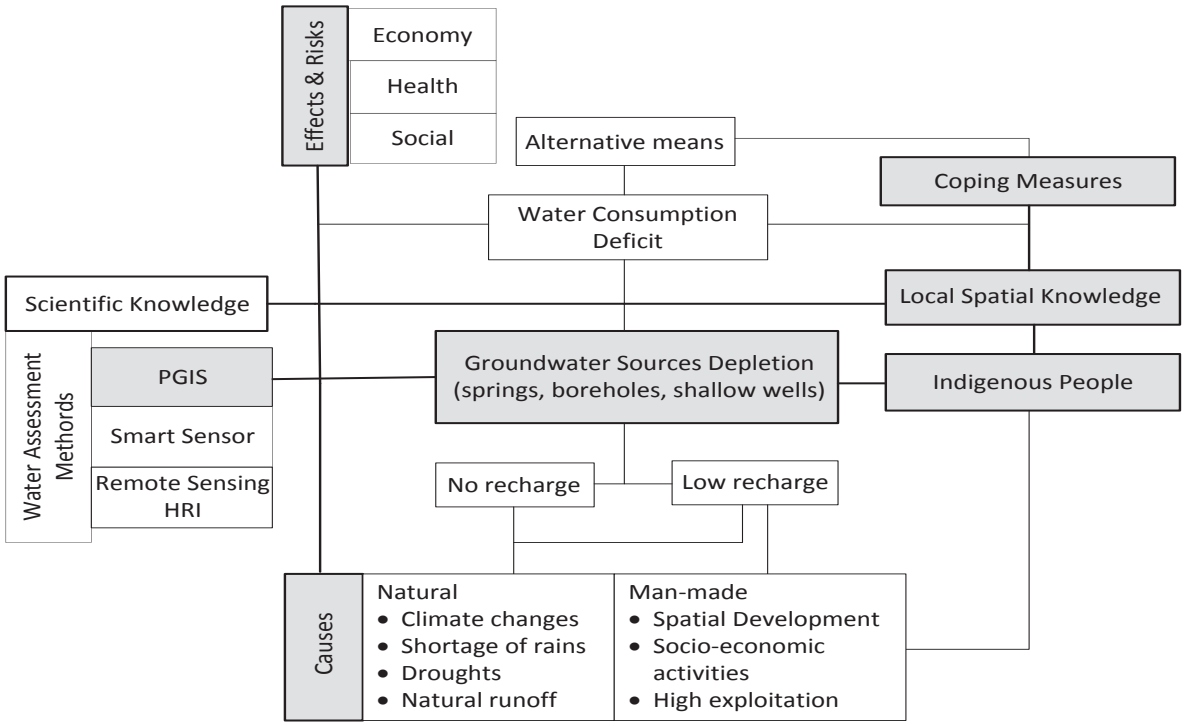
Thus, the concept of this study reflects on causes and effects of the groundwater decline, assessment methods and position or value of local people and the knowledge they have suitable for the assessment. This concept centralised the issue of groundwater sources depletion and associate it with local people. Considering metrological condition and man intervention on groundwater resources and their dependant ecosystems have major influence to aquifer water balance (Gemitzi & Stefanopoulos, 2011). In the case of urbanisation, human activities and increase of water demand causes excessive groundwater pumping which leads to groundwater related problems such as brackish water contamination in coastal areas and land subsidence (Kagabu et al., 2011). People also are victims of the groundwater declines; they suffer because of limited water supply and freshwater intrusion as was reported in some parts of the Zanzibar Islands (Ali, 2006).

The other side of the concept, concerns with elicitation of local knowledge in assessing groundwater decline. Participatory mapping tools are selected to elicit local knowledge since it enhances local people to develops, share, enhance and analyse their understanding of life and conditions (Chambers, 1994) appropriate to identify causes, effects and coping strategies from groundwater decline. There is no doubt that scientific tools are also used in groundwater assessment such as the use of smart sensor in groundwater monitoring (Anumalla, et al., 2005), and use of Landsat TM and ETM+ images in integrated assessment of land use and cover changes in catchments (Kashaigili & Majaliwa, 2010). In fact participatory mapping tools proved effective in assessing resources (Kalibo & Medley, 2007).

Fig 2-1 below summarises the integration of the above assessment concepts from which groundwater decline is resulted from no or low recharger due natural causes such as change in weather condition and man-made causes such as socio-economic activities. Simultaneously, groundwater decline results to deficit of water resource that leads people to look for alternative sources that can either be too costs, insecure or competitive with other users. Thus, affects a community healthy due to using of harm water, economy due to spend of extra costs in time and money, and social due to conflicts and stresses.

Indigenous people are natives live in source areas. They own knowledge about the groundwater decline, causes and its effects. They also have knowledge about coping measures that they use to combat against the decline. That local knowledge is the interest of this sturdy which will be elicited by Participatory mapping approaches.

Figure 2-1: Research Conceptual Framework



2.3. Participatory Mapping:

Participatory Mapping is an interactive practice of integrating spatial information with local knowledge and facilitating communication management between technocratic and stakeholders (eg. local people). It enhance generation and managing of spatial data that represent people's voice in decision making through harmonising dialogue, and supporting advocacy and actions (Integrated Approaches to Participatory Development (iapad), 2001). It has been emerged from PRA/PLA (Chambers, 1994) and wide spread in 1990s (Chambers, 2006). The practice is useful in planning and management processes, inventory and mapping of resource (Heyns, 2008), (Kalibo & Medley, 2007), mapping land tenure in conflict resolution process (Lamptey, 2009), and was used in the case of Ostlänken (case study), to collect and represent a local perspective on the landscape in focus and contribute in the decision making process (Wu & Isaksson, 2008).

2.4. Participatory Mapping Tools:

Participatory Mapping Tools refers to methods and technics used with other purposes in stakeholder's identification, decision making, planning, conflict management, landscape assessment and information collection (Evans et al., 2006). Number of tools has been developed to fulfil the specific need for purposes such as Ground Mapping and Sketch Mapping for plotting information about the study area in-order to identify opportunities or vulnerabilities (Chambers, 2006); Transect Walking for collecting descriptive information of locations on distribution of resource, land scape and land use along the given transect (Integrated Approaches to Participatory Development (iapad), 2001); Imagery Mapping, Orthophoto Mapping, and Scale Mapping for collecting relatively scalable information from people (Lamptey, 2009); and Focus Group Discussion for obtaining in-depth information on perceptions, concepts and people's idea (Varkevisser, 2002). Moreover, Interviews (Key informant, Semi structured and Household interviews) are specifically for collecting individual qualitatively and quantitatively information (Groenendijk & Dopheide, 2003), while Global Positioning Systems Mapping, Participatory Geographic Information Systems and Internet based

Mapping (like cyber tracker, multi-media and community information systems) are scientific tools for recording geographical positioning, audio and video social information documentary and tracking of information roots (Integrated Approaches to Participatory Development (iapad), 2001). The Social Mapping as well is for generating spatial referenced information on demography, health, economy, religious and culture, ethno-linguistic characteristics and even infrastructure whereas Participatory 3D Model on the other hand is useful for merging Local Traditional Spatial Information with people creation knowledge to come-up with 3D models (Integrated Approaches to Participatory Development (iapad), 2001).

2.5. Study's Participatory Mapping Tool:

This section aims at assessing specific identified tools of participatory mapping to understand its uses and relevance to this study. Those tools are Sketch Mapping, FGD, Imagery Mapping, Key Informant interview and Semi Structured Interview.

2.5.1. Sketch Mapping

It is also known as informal technic of collating and plotting spatial resources information (Integrated Approaches to Participatory Development (iapad), 2001) to roughly identify its presence, demarcations and its importance to the related community. The technique is useful to attain a general overview of the study area for initiating focus group discussions about the targeted topic and since it is lacks consistence scale and geo-referencing, it provide a room for subjective interpretation (Rambaldi et al., 2006) which is transposed to a standard scale map (Lamptey, 2009).

2.5.2. Focus Group Discussion

It is a group discussion of about 6-12 persons guided by a facilitator (Varkevisser, 2002). The discussion is run by the focus group team whereby Facilitator coordinates the events and recorder keeps proceedings of the discussion. The focal idea is that group members discuss the topic among themselves, with guidance from the facilitator and archived by the recorder.

According to the Data Collection Techniques developed by International Development for Research Centre (IDRC-CRDI), the major considerations on conducting FGD include recruitment of participants and focus group team that could enhance freely and spontaneously discussions about a specific topic regarding their social status, age or sex and enable facilitator and recorder to understand their basic roles in the discussions. Likewise, the selection of FGD participants should reflect the needs of the study and preparation of the discussion guidelines (written list of topics to be covered).

During the discussion Facilitator ethically introduces sessions, encourages discussions, avoids playing expert roles, controls rhythm of the meeting, and finally summarise the discussion's main issues for checking agreements. The recorder on the other hand, keeps among other records date and time, list and characteristics of participants, general description of group dynamics, key statements and options of participants, discussion emotions, used vocabularies and spontaneous relevant discussion during breaks (Varkevisser, 2002).

The FGD data processing and analysing starts immediately after ending of discussion by recorder to completing FGD notes and develop a report. A transcript is prepared for coding according to discussion topics and put discussion statements. Sub-codes are made to put comments and basic interpretation of statements. A compilation sheet is used to organise findings for each discussed topic from FGD categories which then are summarized into group statements in the compilation sheet. To draw conclusion from FGD findings are dawn based on systematic comparisons between groups for all topics reflecting to the study's objectives and questions (Varkevisser, 2002).

2.5.3. Imagery Mapping

To compare with sketch or ground mapping, imagery mapping is more standard drawn by the community for generating relatively accurate geo-referenced data which can be compared with other maps (Corbett et al., 2006). The base imagery are used to generate number of map outputs to be transferred to GIS applications (Müller & Wode, 2003).

According to the developed methodology by Müller, D., & Wode, B in their manual "Participatory Village Mapping Using Photomaps-Trainer Guide", the mapping process which starts from printout of geo-referenced imagery (preferable A-0 size), are done on transparent papers of similar size to produce number of feature maps according to the research needs on the same map boundaries and fixed land marks (2003)

The mapping output are processed through scanning or digitizing and transferred into GIS applications. Additional marks can be added to the transparency maps to enable alignment of other spatial information with final scale map. The final map is produced from imagery community map through projection in GIS put in parameters or converted with GIS applications. The maps are vectorised and inserted with attribute data ready for further analysis and visualizing the results into GIS applications.

2.5.4. Key Informant Interview

Is the conversation between interviewer and interviewee that enables to capture in-depth qualitative information (National Centre for Sustainability, 2010) of a certain research issue such as spatial development history of the locality. Local elders, community leaders and local experts are targeted by this study (as resource persons) (Chambers, 1994) to provide precise narrative historical development of the settlements or other spatial development associated with the study issue. The interview and way of questing has no significant different from semi-structured interviewing that both give a wide range for interviewee to express their view about the asked questions. This does also enhance processing and analysing of the interview to the similar techniques with semi structured interviews as was described by Vickers and Offerdy (2011).

2.5.5. Semi-structured Interview

It is an in-depth interview conducted as a two way dialog between interviewer and interviewee. The interview may be structured or unstructured but interviewer is aware of the targeted information to be acquired agreeing to studies objectives and questions. The interview question mostly are open ended and some require short answers to enable respondent to provide informative descriptions but also probes and prompts are used to tease out from the interviewee various stands of their narrative to complete the story (Peter Vickers & Maxine Offerdy, 2011).

According to Evaluation Tool Box developed by Australia National Centre for Sustainability, to use this tool needs to prepare for the interview, brief the respondent about the research and reasons for questioning, ask targeting questions and record the answers. After the interview analyse and make sense of the collected data by organizing and manage response. That leads to identify, interpret and emergent themes and analysing patterns amongst themes (2010)

2.6. Essence of Participatory Mapping in Natural Resource Assessment

2.6.1. Participatory Practice in Natural Resource Assessment

Authors have revealed that P-GIS is an effective assessment tool for natural resources from applied cases. For example, the use of participatory resource appraisal and scientific field observations enhances to determine vulnerable hotspots, identifying driving factors (both anthropogenic and natural processes) (Banerji & Basu, 2010); the use of LSK comes with causes of the resource depletion (Kalibo & Medley, 2007) and a good P-GIS practice share LSK with experts through its

tools and method (i.e. mapping and modelling, transect walks, matrix scoring, seasonal calendars, wealth ranking and grouping, change analysis, and well-being analytical diagramming and applied natural resources management, agriculture, poverty, food security and health (Chambers, 1994).

The challenge aspect of participatory practice in resource assessment is where the locals are a part of sources of the resource threats and hesitate to reveal the truth. This situation may need the use of local experts and government organisations responsible for such resources (Heyns, 2008) that could help to solve or sometimes acerbate the problem. Hence, probing techniques are needed to ration the LSK in a scientific ways during the transect mapping.

2.6.2. Participatory Mapping in Resources Identification and Mapping

The effective participatory mapping is conducted by the community themselves with very little external expertise directives or facilitations. In the adapting to climate change of Himalayan cold deserts for instance, PRA was used to identify areas for interventions (Banerji & Basu, 2010) while in the Participatory resource mapping for adaptive collaborative forest management the identification and mapping distribution of the forest resources were done by the local people with the facilitation of researcher (Kalibo & Medley, 2007). Both exercises were time consuming and needed introductory mapping skill to the local people. In the case of water level determination in the catchments it is also feasible to integrate local knowledge and hydrological environmental skill and instrument (Heyns, 2008) rather than relying only on physical instruments like water gauges and periodic statistics as it was carried-out in the integrated assessment of long-term changes in the hydrology of three lowland rivers in eastern England project to measure temporary variability of rainfall (Hiscock et al., 2001). In the case of this study local people will be given great opportunity of identifying and mapping water sources, boundaries and buffer areas to their knowledge of understanding with short stimulation introduction by the researcher.

2.6.3. Participatory Practice and Resources Management

Management of local resources highly depends on specific environments and concerns of those who are living in. Often locals in those areas are vulnerable due to poor economy, infrastructures and marginalisation but are strong dependence on few resources they have (Banerji & Basu, 2010). It is impractical for policy makers to enact management policies (such as permits and licenses) just to control the use of resources (Heyns, 2008) regardless the locals whose lives are impossible without it. They are capable to develop sustainable adaptation measures from resource utilization pattern over time (Kalibo & Medley, 2007) and their long time experiences, ability of resolving conflicts among themselves and protect resources (like water), generates specific knowledge that can be integrated with GIS to give solution on resources management.

2.6.4. Participatory Practice and Spatial Development in Resources Catchments

In most cases the natural resources have been threaten by expansion of spatial development such as settlements, industries, and commercials centres. It is relevance for a community to map/sketch the spatial development of their own area according to their recall. In the adapting to climate change of Himalayan cold deserts study, community draw historical land scape (developed and nature) from time to time showing spatial development (Banerji & Basu, 2010) while the researcher in the Participatory resource mapping for adaptive collaborative forest management study, facilitated the compilation of historical time lines of forest resources by the community (Kalibo & Medley, 2007). It should be noted that elders are the most reliable source of time-line information due to their long time habituation of localities but it is likely they may lack knowledge or memory of normal time calendars; instead they use events to describe the time such as during the second world war or during the severe hunger period, etc. Thus, a researcher has to have tad or basic knowledge of events-calendar to grasp knowledge of such people. Common events were used (such as 2nd world war,

agriculture development and industrialization) to describe the spatial development in the study of integrated assessment of long-term changes in the hydrology of three lowland rivers in eastern England (Hiscock, et al., 2001). Promptly, the Participatory GIS in Assessing Decline of Water Level in Ground Water Sources study suggest deploying of experienced locals to describe spatial development growth in water sources and its surroundings.

2.6.5. Integrating PGIS in Planning and Management of Urban Water Supply

Utilising and integrating local knowledge with scientific knowledge is an alternative means of planning and managing or improving urban water supply systems (Heyns, 2008) (Mathenge, 2011). Combining of PGIS approaches such as qualitative GIS methods (Cope & Elwood, 2009) and GIS methods which also has been utilised by Mathenge, (2011) to collect LK from local people, process and analyse the collected data in a scientific and systematic way and came up with valuable results suitable for planning and managing of urban water supply system in a participatory manner.

2.7. Conclusion

Regarding the study issue of groundwater decline and the concept of cause and effect, which centralised the human being in one hand and his spatial knowledge on causes and effects of groundwater decline to the other hand, devote the selection of the participatory mapping method to assess groundwater decline. As was mentioned above, the method is quite famous and disclosed effectiveness in natural resources assessment, mapping and management and that the selected tools of sketch mapping, interviews, FGDs and imagery mapping are proper for meeting the study's objectives which requires local perspective in assessing groundwater sources of the study area.

CHAPTER THREE

3. MTONI AND MWANYANYA STUDY AREAS

3.1. Zanzibar

3.1.1. General Introduction:

Zanzibar is a semi-autonomous one of the two countries form the United Republic of Tanzania. It consists of two main sister's islands with other 50 small archipelagos in the Indian Ocean. It sets at 6°08'South 39° 19' East and between 36 to 40 kilometres from the east coast of Tanzania mainland and East-Africa Coast. The islands lay between 5'40" and 6'30" South and 35'50" and 40'80" East for Unguja and Pemba Islands respectively (as shown in Map 3-1 below). Generally it has low lying land-area with the highest point of 120 metres above the mean sea level (i.e. Masingini hill).

The climate of Zanzibar is of tropical characterised by humid temperature ranging between 29 to 40 Degrees. Temperate varies between 18 to 37°C (winter and summer respectively) with the average annual temperature of 26.3°C. Monsoon winds blow from South-East (Kusi) in March to September (cold season) and North-East in October to February (hot season). Rainfall seasons match with Monsoon of winter and summer as shown in table 3-1 below.

Table 3-1: Zanzibar Rain Seasons

Month	March - May	June - August.	September - November	December -mid-Feb
Rainfall	Masika	Pupwe	Vuli	Kiangazi
Description	Wet long-rainy	Cold drizzly	Hot heavy short- rainy	Hot and dry

The average annual rainfall is 1,500mm and the rainfall range is 667mm to 2,661mm (Tanzania Metrological Agency, 2011).

Map 3-1: Zanzibar Location Map

3.1.2. Natural Resources:

The major natural resources available in Zanzibar include water, forests, land, marine and coastal resources. They represent the value of Zanzibar which provides the basis and attractions for the economic industry of Zanzibar which is highly dependent on agriculture and tourism.

Water Resource consists of groundwater, surface water, rainwater and seawater. The groundwater is a primary source of the freshwater of Zanzibar which its balance highly depends on recharge from rainfall. According to the 2008-2013 ZAWA Strategic Business Plan, Zanzibar has official 110 wells (76 in Unguja and 34 in Pemba) (2008) while the major existing springs are Mwanyanya, Mtoni, Kianga and Machui in Unguja and Bungumi, Gawani, Kwa-pweza, and Kwa-mwanamwari in Pemba.

The surface water resources include coastal rivers that flow to the West Sea of Unguja Island which are Bububu, Zingwe-zingwe, Kitope, Mto-mchanga, Mwanakombo and Kipange; and in-land Rivers that do not flow to the sea such as Mwera, Pangeni and Kinyasini which are the major contributors to the groundwater recharge. In Pemba Island there are well ridges that form high runoff in rivers such as Weni, and Minyenyeni. According to ZAWA rainwater is found in all metrological zones of Zanzibar and hydrological statistics revealed 39-52% of rainwater is lost to the sea. (Zanzibar Water Authority, 2008). Either, the seawater is surrounding the Zanzibar archipelagos and in few Inlands Sea-River particularly in Pemba Island. The water is salty and in some coastal areas like the Stone-town, small islets and east-coasts it salinizes the fresh groundwater.

Forest Resource comprises of five main habitats which are agro-forest, coral-rag forest, mixed woody vegetation, mangroves and plantation forest (Leskinen, 1997). According to the Land Capability Draft Report, Zanzibar has a total forest area of 227,868 hectares of forest. The main national reserved forests are Ngezi and Jozani which cover 2,900ha and 2,512ha respectively. (2010). The Masingini forest is a small forest reserve that covers about 556ha. It is found in Urban West Region 10 Km from Zanzibar town. The forest bears significant importance to the urban groundwater, and is the root of river Mtopepo and Bububu which recharge the Mtoni and Mwanyanya Springs.

Land Resource is a sensitive resource of Zanzibar due to its size of 265,400ha (2,654Sq.km) which not adequate to cover the increases demand of growing population, socio-economic activities, residential settlements, social services, tourisms, infrastructures and recreations. Urban land area has been expanded dramatically from Urban District to West District from 1990s to 2010 for more than 10 km. Among issues that land resource faces are permitted and illegal sand excavation and coral quarries, informal housing construction, deforestations, and land tenure system (Traditional and Government Grants which provide loophole in development control).

Land resource has been classified into categorises basing on its use intensification (Comission for Lands and Environment Zanzibar, 1995). These are agriculture land that covers total of 1,222,566ha (i.e. 50% of the total land of Zanzibar), Forest land that covers about 46% of the total land, built-up land that covers about 2.1% of the total land, Tourism land that covers about 1% and other lands used for grazing and livestock keeping that covers about 0.9% (Department of Surveys and Urban Planning, 2010). None of the categories is stand still but forest land is much more eaten by agriculture and housing construction while tourism land keeps on increasing even for changing residential structures to hotels such as Stone-town dwellings.

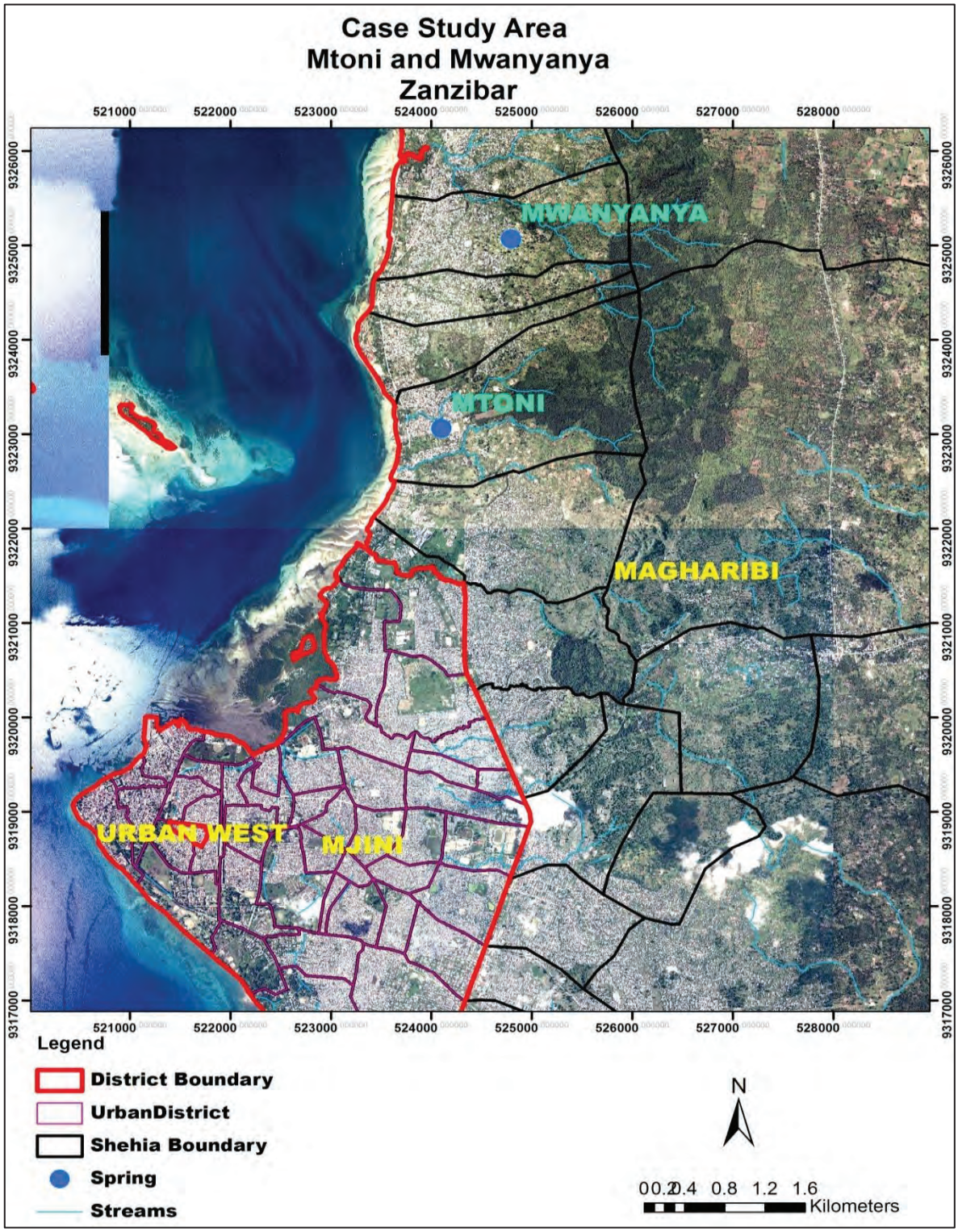
Marine and Coastal Resources include small islands, white sand beaches, coral-reefs, mangroves, coral and sand cliffs, sea-grasses and algae, demersal and pelagic fish species, seaweeds and seashells. All these make Zanzibar to be a potential spot for tourism industry which contributes 22% (The Revolutionary Government of Zanzibar, 2010) of the National GDP.

3.2. Shehia of Mtoni

3.2.1. General Information:

Mtoni Shehia is found in the West District of the Urban-West Region about 4 km North of Zanzibar Town. It bordered with Shehias of Sharifu-Msa on the North, Mtoni-Kidatu on the South, Kianga on the East and Indian Ocean-Zanzibar Chanel on the West (as shown in Map 3-2 below). It is encloses the main road Urban-North countryside road which is among the major attractions for urbanisation in the Shehia.

Map 3-2: Case Study Area Location Map



Total land area of the Shehia is 329.63 ha from which major land covers are build-up land (75.17ha), quarry (0.42ha), forest land (133.89ha), bare sand (3.25ha) and mix of cultivation, plantation, grasses and settlement (116.78ha).

Basing on the 2002 Housing and Population Census, the 2011 projected population is 20,717 people with average growth rate of 9.2% per annum and the population density is 628 people per square kilometre which is higher than the National one of 400 people per square kilometre.

The essence of the Shehia in this research is its location which is potential for urban expansion but profound due to its resources. Among the major resources found are Mtoni springs, Mtopepo River and forest that is located in its eastern side of the Shehia and border of Shehia of Kianga, which is also a part of Masingini Forest Reserve.

3.2.2. Mtoni Springs:

The Mtoni main spring which is located at 6°09'14" South and 39°13'01" East, 4km North of the Zanzibar town (as shown in Map 3-2 above) was established in 1920 by excavating the spring area and constructed a concrete chamber that collects water to the storage chamber and flows naturally to the stone-town. Operation of the spring at that time allowed natural streaming out and runoff to the sea without control. In 1923, the Zanzibar Government of improved the spring area and laid down steel-pipes to the constructed Water Mains Storage at Saateni that collected fresh water from Mtoni and Mwanyanya springs before transmitted to town areas. During the FINNIDA Urban Water Project in 1990s the Mtoni main spring was closed down due to detected contaminations from industries and cattle ranch that were closer to it and human activities that took place in Mtopepo River bank. In 1991 the Zanzibar Government operated the spring again after detailed studies conducted in the Urban Water Supply Scheme under the support of FINNIDA. The spring yields 150-500m^3 per hour and together with Mwanyanya Spring they yield up to 10,000m^3 per day(Ministry of WCELE Zanzibar & Ministry of FA Finland, 1991b) which is about 50% of the average production for Urban Water Demand of the Zanzibar Municipality of 20,500 m^3 per day (Shah, 2003). There is also another spring which commonly known as Chem-chem of Mtoni that is under the Mtoni community management and has similar characteristic but is smaller to compare with main one. It is located at 6°07'43" South and 39 °13'01" East and elevation of 15m (see also Map 3-2 Case Study Area Location Map). This spring is highly utilised by the Mtoni community and its water is not contributing to the urban water supply scheme, not well protected but the community built a small concrete cylinder and a foundation of cement blocks a chamber to protect against contaminations and control runoff.

Ledges of the area is mainly covered with Miocene sediments which ledges the source areas and the upstream of the sources (Ministry of WCELE Zanzibar & Ministry of FA Finland, 1991a). According to the Hydrological Map of Zanzibar, the late Miocene rock covers about 3m and is represented by marl, sandy clay and clayed sands.

The hydrological situation is maintained by vegetation surface over the sources, marl, sandy clay and clayed-sand of Miocene sediments that form aquifer of the groundwater. The Mtopepo River is the main recharge source of the springs supported by infiltration from high elevated areas of Masingini which is in eastern side of the springs.

3.3. Shehia of Mwanyanya:

3.3.1. General Information:

The Shehia of Mwanyanya is located in the West District of the Urban-West Region Zanzibar about 7km North of Zanzibar town. It bordered with Shehias of Bububu to the North, Kibweni to the South, Dole to the East and Indian Ocean-Zanzibar Chanel to the West (as shown in Map 3-2 Case

Study Area Location Map). The Shehia is passed by main road Urban-North countryside road which is among the major attractions of urbanisation in the Shehia.

The total land area of the Shehia is 212.38ha from which major land covers are build-up of 97.83ha, mix of cultivation, bushes, grasses and settlements of 91.15ha, forest area of 19.62ha and bare sand is 3.42ha. There are also plantation plots of 0.24ha.

The essence of the Shehia to this study is its location which is potential for urban expansion whereby its north neighbour Shehia (Bububu) the government had to establish planned neighbourhoods at Bububu-Kidichi in year 2000 to save the land resource from informal developments. The Shehia is very reflective from its resources particularly natural and planted forest, Bububu stream and Mwanyanya spring. The Shehia also consists of forest nursery and forest reserves (part of Masigini Forest) to its eastern border with Shehia of Dole. This forest is a potential source for groundwater recharge in the Shehia as well as Mwanyanya spring.

Basing on the 2002 Housing and Population Census, the 2011 Shehia projected population is 19,863 people living in 936 persons per Square Kilometre which is higher than the National one of 260-400 (2002-2011) people per square kilometre. The annual average population growth rate is 4.5% per annum basing on the regional growth rate and 9.2% internal (district) growth rate.

3.3.2. Mwanyanya Springs:

The urban water supply of Zanzibar town has started from the springs of Mwanyanya and Mtoni. In 1880s the Zanzibar ruler Sayyed Barghash bin Sultan developed the natural spring area by constructing the concrete dam and water drains of stone and soil from Mwanyanya to his palace Forodhani (in the stone-town). Later on in 1923, the spring area was improved and water line to the Zanzibar town was replaced with steel pipes and connected with Mtoni spring to the constructed water mains at Saateni where then was distributed to the established water supply system of Zanzibar town. Another water line was directly streamed its water to the Zanzibar harbour for export. That is to say the Zanzibar urban water supply system has its roots from Mwanyanya and Mtoni Springs since 1880s and 1920s. The spring yields about 166-500m^3 per hour that flows by gravity to the Saateni Water Works Station.

According to the 1991-2015 water demand projection for Zanzibar Town Urban Water Supply by the year 2015 the demand will be 12,600-18,900m^3 per day while the springs of Mtoni and Mwanyanya together would produce about 5,000-10,000m^3 per day (Ministry of WCELE Zanzibar & Ministry of FA Finland, 1991b).

The Mwanyanya spring which is also called the Bububu spring is located at 6°06'11" and 6°06'17" South and 39°13'26" and 30° 13'33" East. It is in southern bank of the Bububu stream valley at the elevation of 15-20 m above the mean sea level. The source is surrounded by elevated forest and thick bush areas throughout its directions and it area covers about 3ha.

The main recharge source of the spring is Bububu stream which passes from the South East towards North West to the sea on the West coast and Dole-Masingini forest which is found on the eastern side of the spring.

The main land cover of the source is bamboo plantation, mango trees, thick grasses and palm. The Miocene sediments rocks mainly represented by marl, sand clay and clayed sand cover the geological features of the spring.

Hydrological situation of the spring is developed by the aquifer formed of marl, sand clay and clayey sands of Miocene and top vegetation which provides a thick cover of the groundwater.

CHAPTER FOUR

4. RESEARCH DESIGN AND METHODOLOGY

4.1. Research Design

This study is based on qualitative research design from which it will employ Participatory Mapping to elicit in-depth local knowledge on the decline of ground water sources. The reasons behind the decline are intended to be collected from local people with basic theme of understanding why and how the decline.

The study will use multi techniques in six stages (as shown in table 4-1 below) which will be operationalized in a sequential and logical manner as shown in Fig 4-1 below.

Table 4-1: Research Phases and Techniques

Step	Technique	Relevance
Literature Review	Critical reading and review of PGIS related scientific researches & Water resource assessment Researches	Attain basic knowledge of research topic, techniques, concept and preview previous research attempts on assessment of water resource and Participatory Mapping
Problem Definition	Review groundwater issues and assessment methods	Analyse research problem and rationalise the need for the research
Research Design	Planning and Consultations	Define research objectives, questions and methods of conducting the research
Data Collection	Participatory mapping & Secondary data recording	Elicit local knowledge from study area and secondary data from office archives and database
Data Processing & Analysis	Data sorting, tabulation & comparative analysis	Data preparation, interpretation and comparison for study's discussion & conclusion
Data Presentation	Map visualization in ArcGIS & charts in Excel applications	Displaying study's results in text, figures and charts (i.e. simple and understandable manner)

4.2. Research Methodology

4.2.1. Literature Review:

It is a phase of studying documented information from literatures, office records and other secondary sources in-order to obtain secondary data, concepts and techniques suitable for analysing decline of groundwater sources. The information was used for developing the research theme and attempting appropriate methods of undertaking this study.

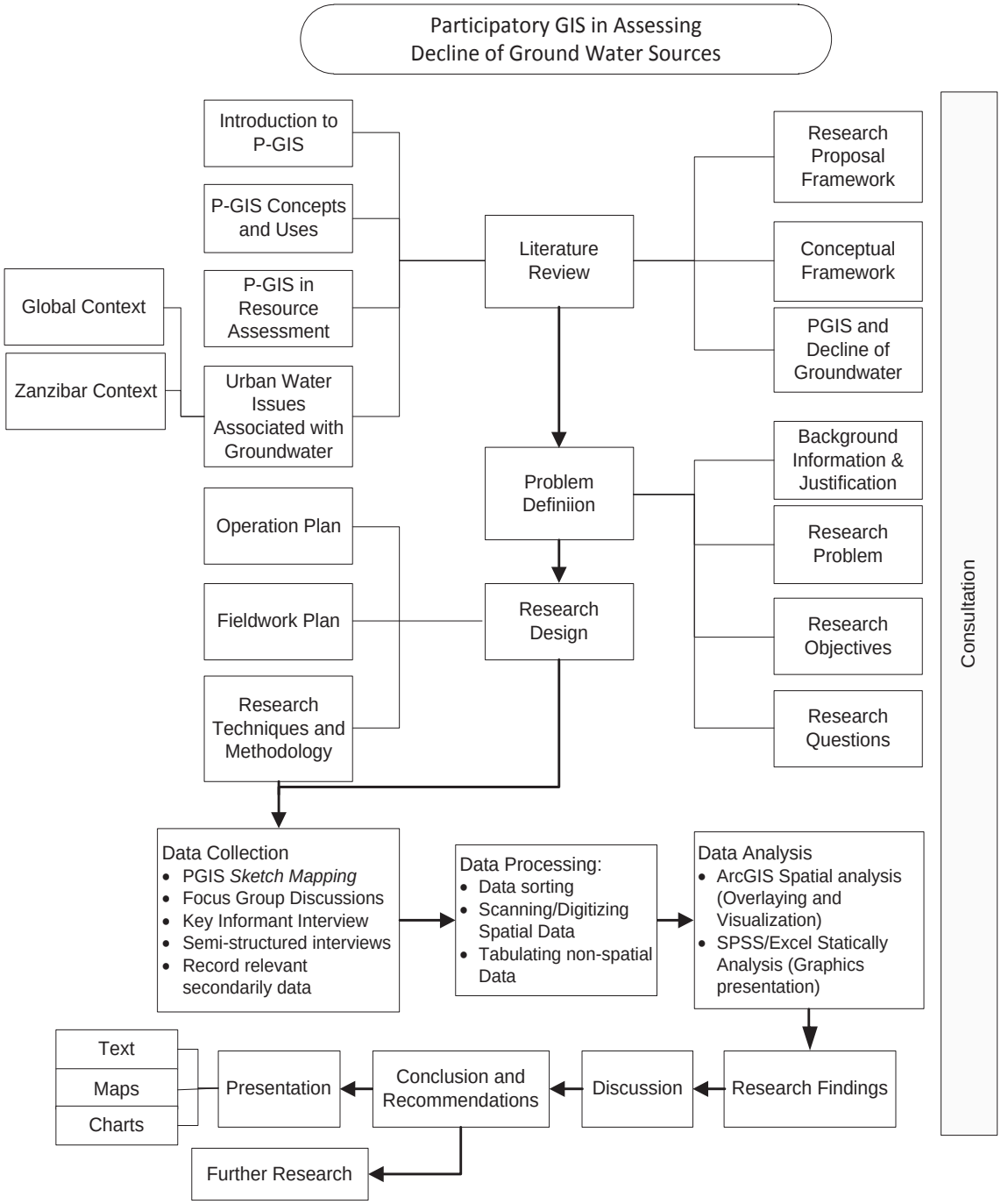
4.2.2. Problem Definition:

This phase included description of the real-world situation, justification and motive behind undertaking the research and defining the research problem.

4.2.3. Research Design:

The phase involved development of research theme, concepts, and operational framework from which the studying process followed to came up with the results that answer the study's questions. This stage was highly relied on the reviewed literatures, consultations and discussions whereby the researcher worked close with supervisors and guides of professionals researchers in ITC.

Figure 4-1: Operational Framework



4.3. Fieldwork and Data Collection:

Identification of data type and its relevance to the study were defined beforehand. That enabled to identify the appropriate data collection and analysis methods and tools in respects with the study's main objective and expected outputs as shown in a research matrix annex 1.

The fieldwork exercise was conducted as part of a thesis development. It involved data collection process from primary and secondary sources for assessing decline of groundwater in the study area. Field location is Zanzibar - Urban West Region at Shehias of Mtoni and Mwanyanya. The primary data was collected from the local community of the study area through focus group discussions and key informant interview while the secondary data was collected from Zanzibar Water Authority and Metrology Offices. The fieldwork was carried out from 26th of September to 24th October 2011. The exercise was accomplished through various activities including preliminary field survey, visiting

government organisations and local administrations, data collection preparations, actual data collection and feedback meetings.

4.3.1. Preliminary Survey:

The fieldwork started by visiting the field sites 1 and 2 (Shehia of Mtoni and Shehia of Mwanyanya for the purpose of meeting with the local leaders and have short discussions about the areas and the aim of conducting studies in their areas. The discussions also traced convenient time for undertaking meetings with local people and criteria of selecting appropriate participates for the focus group discussion such as long stayed adult citizens and who are living close to the springs. The local leaders did not take direct decisions on the date for meetings till after met with their people but preliminary suggestion was made to undertake the meetings during the week-ends due their socio-economic activities. They also suggested getting official permit of conducting the meetings in their localities from the district administrations.

The preliminary field visits helped to understand the convenient time for meeting with local people and starting of organising focus groups participants in advance.

4.3.2. Visiting Government Organisations and District Administrations:

i) Visiting the District Commissioner's Office:

Before seeking for the permission of conducting meetings in the study areas, the district office was also visited to meet the District Administrative Officer who is the in-charge of Shehia's Administration. The meeting was not so official but was done in advance for the purpose of setting official appointment and introduce the aim of conducting the research in the district. The official meeting was set in regard with Shehas regular meetings which takes place in the district office in Thursdays. Hence an appointment for the meeting was given to Thursday the 29th September in-order to discuss the matter with the Shehas.

During meeting with Shehas in the District Office under the chairs of the District Administrative Officer, the research proposal was presented in local language to give opportunity to the participants to understand it clearly. The District Administrative Officer expressed his expectations on the benefit of the research to the district and Shehias in generally. Shehas on their sides came with the validation of the convenient days of undertaking the survey and agreed themselves that Shehia of Mtoni will start on Saturday at 8.00 am the 8th and Shehia of Mwanyanya to be on Sunday 9th September. All meetings were suggested to be conducted near by the sources.

ii) Visiting the Second Vice President's Office:

The Visit to the Second Vice President's Office former Chief Minister's Office meant to follow data collection formalities in Zanzibar whereby the Office is the officially institution for granting research permits. The office provided procedures to be followed in-order to get a research permit which was worked-on to have the research permit.

4.3.3. Data Collection Preparations:

In the Department of Urban and Regional Planning Zanzibar offices, official letters were prepared and distributed to The Second Vice President's Office, District Commissioner, copied to Local leaders (Shehas) as well as Offices of ZAWA and Metrology. The letters were also attached with official support letters from ITC which introduced the student and the purpose of the field visit. The latters had to be followed up to ensure they have been attended in time.

On the other hand, a focus group discussion team (facilitators) was formulated and trained; data collection materials and logistics were prepared as well as translating the discussion guide questions into local a language (Kiswahili) for the fieldwork.

4.3.4. Primary Data Collection:

The exercise took place in two different sites. Site 1 was Mtoni and site 2 was Mwanyanya. The method of collecting data was focus group discussions and key informant interviews. Total of four group discussions were conducted two for each site and each site contained one group of men and women. Average number of participant was 18 people per group and all group members were above 18 years old and are the citizen of the Shehia lived for more than five years. The Shehas themselves in collaboration with their assistants were the key organisers of the meetings as criteria discussed in the preliminary field survey. On the side of key informant interview, one respondent was selected from each Shehia and both did not attend the FGD. Both were long-time residents of the Shehias and were identified during the FGD.

i) Focus Group Discussions:

The FGD exercise was conducted by the following prepared time table (table 4-1 below) and discussed with organisers during the preliminary field survey.

Table 4-2: Primary Data Collection Plan from the Local Community

Activity	Data Requirement/Purposes	Data Collection Technique	Responsible Person	Time (min)
Opening FGD	Draw intention of the FGD participants	General speech	Community leader	2
Introduction to FGD	Basic concept of the decline of groundwater sources and the importance of local community involvement in analysing the situation	Introduction speech	Facilitator	5
	Roles of FGD members in the discussion	Descriptions of roles of FGD	Facilitator	2
	Ground rules for the discussion	Discussion	All	2-5
Breaking the ice	General spatial overview of their locality in relation with water sources and spatial development	Sketch mapping	Facilitator/FGD members	15
Introduction of the discussion topic	Broad description of causes, effects and coping measures of water level decline in Zanzibar and other places of the world	Recording the discussion	Facilitator FGD members Recorder	10-15
Detail discussion of the topic	Specific description of causes, effects and coping measures of water level decline in their locality community	Recording the discussion	Facilitator FGD members Recorder	20-25
	Break			10
Time-line / events concept on causes	Specific time line spatial information to identify spatial development and groundwater level in the study area (target to get up 5 years ago annually)	Imagery Mapping and Recording the discussion	Facilitator FGD members Recorder	30
Wrapping discussion	General output of the FGD	Outlining major agreements and output	Facilitator Recorder	2
Closing FGD	Thanks remark	Closing speech	Community leader	2
	Total Time Duration			1.40-1.50

The groups came up with Sketch mapping, meaning of groundwater decline, causes, effects and coping measures of groundwater decline. The group also developed time line spatial development took place in their areas by using satellite imagery as base maps (imagery mapping). All participants had equal chance of contributing their views but the group views were consensus from discussion results of individual contributions. The detail FGD proceedings are attached in annex 2

ii) Sketch Mapping:

Sketch mapping is a free hand sketch of a study area showing common and preference spatial features according to citizen. It is un-scaled map drawn by community members in a FGD for the purposes of expressing their LSK in visualising locality boundaries, water sources, vegetation, access, services and other important spatial features. The technique was used to attain general overviews of the study areas by using FGD members who sketched in flip charts the shape of their Shehias and number of spatial features like accessibility, settlements, natural resources such as forest and water, social services like hospital and schools, and public institutions like camps.

Sketch Mapping Exercise in FGD

Plate 4-1: Men FGD Shehia of Mtoni - Oct, 2011

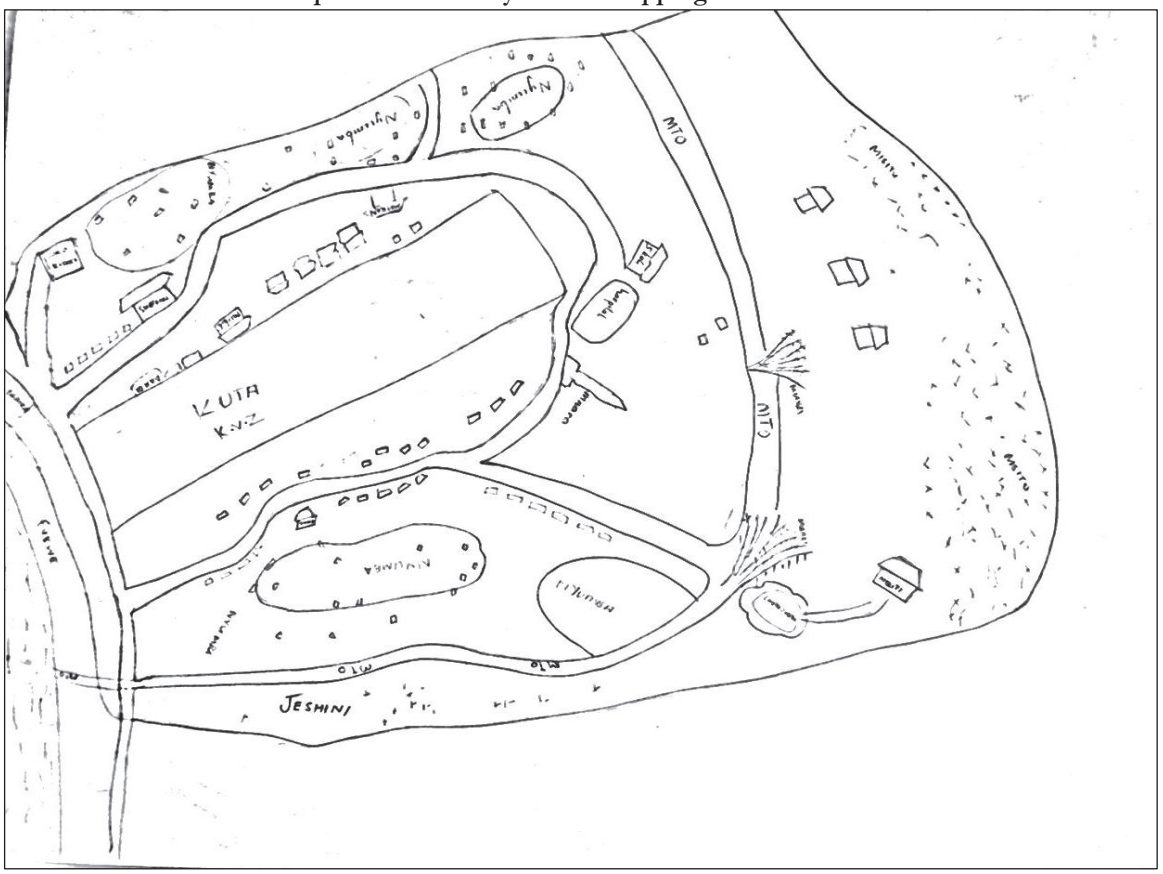
Plate 4-2: Women FGD Shehia of Mtoni - Oct, 2011

Plate 4-3: Men FGD Shehia of Mwanyanya - Oct, 2011

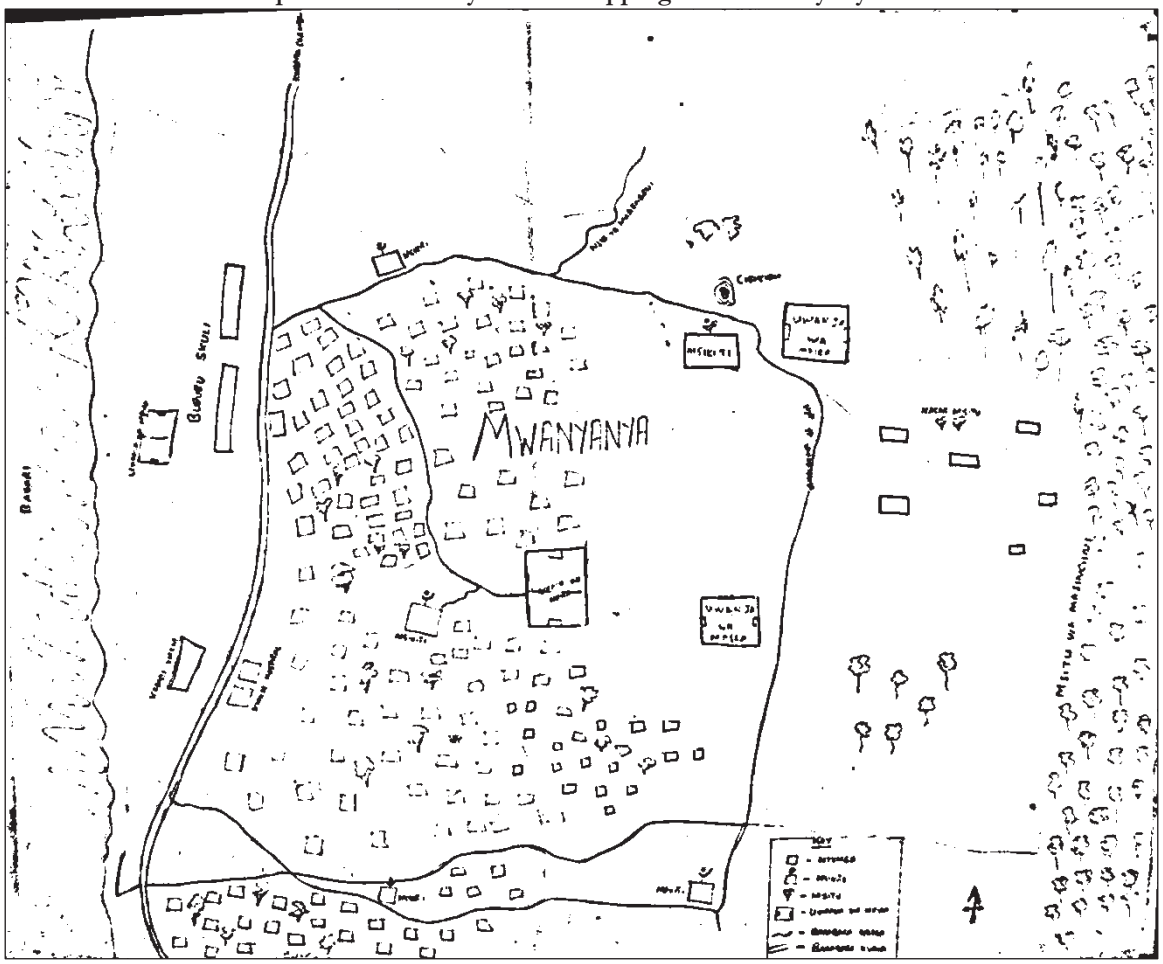
Plate 4-4: Women FGD Shehia of Mwanyanya-Oct, 2011

Before mapping exercise started, facilitators from the FGD team gave introduction to the group member describing what sketch mapping is. The group-members first brief discussed about how to go about making their maps and selected draftsmen among themselves. Almost all groups used to introduce features to be sketched and discussed how to arrange them as they seen in plate 4-1, 4-2, 4-3 and 1-4 above. The key discussions points and the produced maps are as shown in the screen shot map 4-1, 4-2 and fig 4-2 below.

Map 4-1: Community Sketch Mapping FGD-Mtoni



Map 4-2: Community Sketch Mapping FGD-Mwanyanya



iii) Group Discussion:

The FGD members had deep discussion on key subjects of the study which were grouped in five main topics:

- Meaning of groundwater decline
- Way of groundwater took place
- Effects of groundwater decline
- Community management of land related conflicts
- Community coping measure from groundwater decline

Each group discussed the topics one by one and the agreed consensus among themselves were written into flipcharts as shown in fig 4-2 below.

Discussion of Study's Key Topics

Plate 4-5: Men FGD Shehia of Mtoni - Oct, 2011

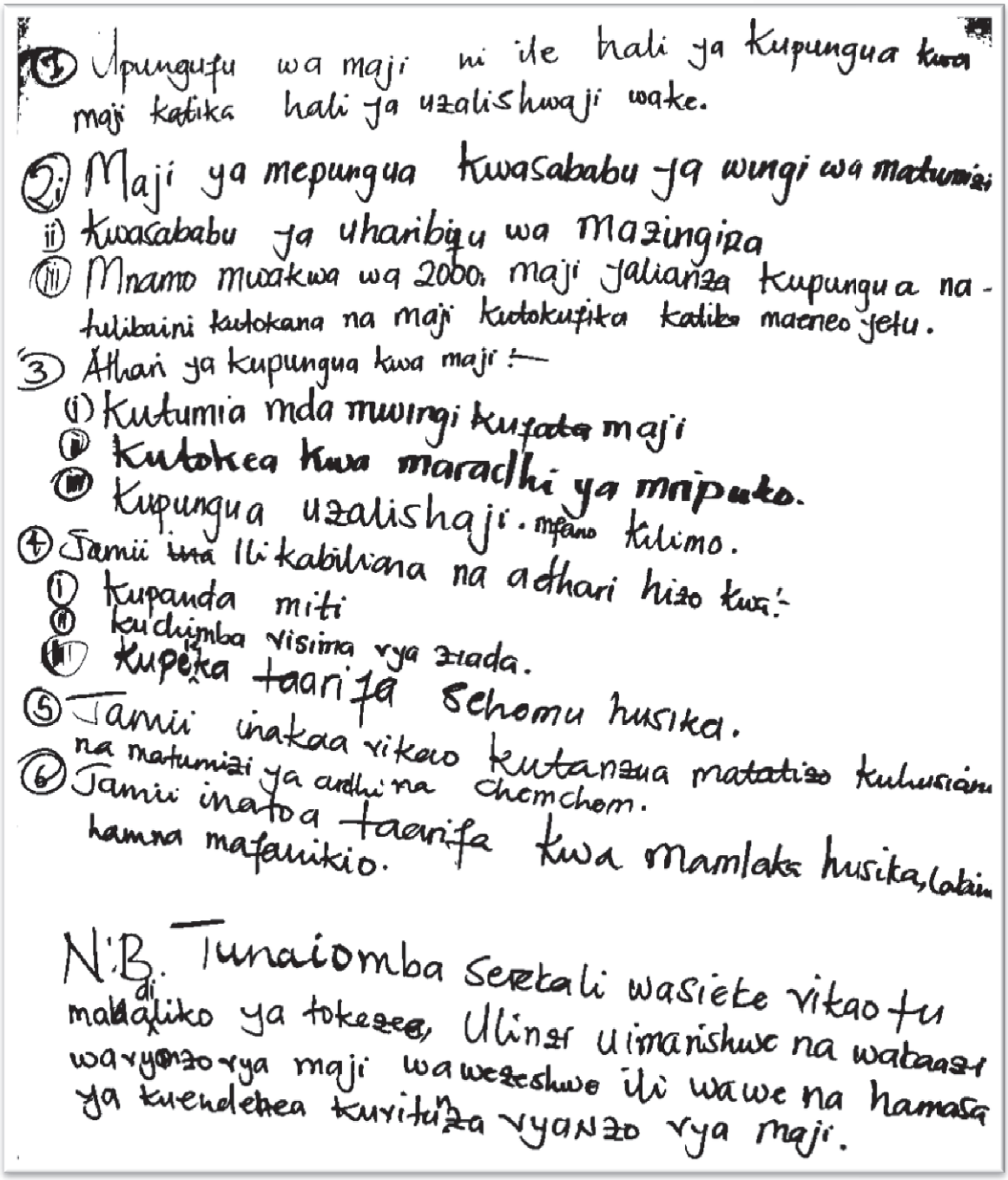
Plate 4-6: Women FGD Shehia of Mtoni - Oct, 2011

Plate 4-7: Men FGD Shehia of Mwanyanya - Oct, 2011

Plate 4-8: FGD Women Shehia of Mwanyanya-Oct, 2011

The discussions were relatively free and active with no intervention from outsiders however groups did ask some clarifications on the extent to be written or meanings of the discussion points. The typical discussion output is shown in fig 4-2 below and the translated outputs of the discussion are attached in annex 2 – FGD Proceedings

Figure 4-2: Typical Focus Group Discussion Out



iv) **Imagery Mapping:**

The Imagery mapping exercise was introduced to the FGD after the groups being familiar with mapping exercise and key topics of the discussions from the sketch mapping exercise and detailed group discussions. Clear descriptions were given by the facilitators to enhance the local people (FGD members) to map spatial development that took place in their locality in different periods of time according to their recalls. The intention was to get these spatial variations annually although on the local basis after their discussions they agreed that single year is not enough to show spatial variations in their localities. They agreed to put the variation in five years periods basing on the satellite image of 2006.

Community Imagery Mapping Exercise

Plate 4-9: Men FGD Shehia of Mtoni - Oct, 2011

Plate 4-10: Women FGD Shehia of Mtoni - Oct, 2011

Plate 4-11: Men FGD Shehia of Mwanyanya - Oct, 2011

Plate 4-12: Women FGD Shehia of Mwanyanya - Oct, 2011

v) **Key Informant Interview:**

This is the conversation between researcher and local respondents for the purpose of capturing in-depth knowledge of certain research issues such as spatial development history of the locality. Local elders, community leaders and local experts were resource persons for the study which provided valuable narrative historical development of settlements and other spatial development associated with groundwater depletion in the study area.

Key informant interviews were conducted one from each site for the determinations of finding in-depth knowledge of more experienced locals on groundwater situation in their areas. Consents for recording the conversation was sought from the respondent before taking any recordings of the conversations and this enables asking for detailed clarifications on the discussed issues.

The respondent in the site 1 (Mtoni) was selected due his familiarisation of the study area and understanding of land ownership and occupation matters. He has knowledge about land occupations, and conflict resolutions. He is also among the Masjid leaders who organised spring protection plan in-order to protect it from impurities and contaminations. The second respondent from site 2 (Mwanyanya) was identified during the FGD when the participants asked why he was not in the FGD. It was understood that he was a former employee of the Department of Water responsible for monitoring the Mwanyanya Spring. Both respondents were interviewed with open ended questions to give a wide range of describing their understands about groundwater decline, causes and effects as well as coping measures and capacity of the community on resource management. The translated scripts from the interview are attached in annex 3

vi) **Semi Structured Interview:**

The study used semi-structure interview to collect primary information from ZAWA officials which concerns with water resource and hydrological matters. The targeted was to acquire the information on hydrology situation and its influences in Zanzibar Island and specific understanding of groundwater re-charge in Zanzibar and the study area as well. The survey tried to extract scientific overview from the respondents by using guiding question from which respondents had a wider room of providing verbal details and evidences from documented reports. The selection of the respondent was done with the consultation of the Technical Director of ZAWA whereby two senior officers were selected from the Department of Water Resource.

One interview was conducted successful and the translated transcript is in annex 4 while the second interview was partially done and partially was put in written document that provides further information about the study issue. Other verbal descriptions were collected during the official visit to the spring areas and Saateni Water Works Station where water recharge is collected and measured.

4.3.5. Secondary Data Collection

The secondary data collection was collected from two major sources ZAWA and Metrology Department. Zanzibar hydrology, groundwater recharges data 1998-2011 and water resource documents were obtained from Water resource Department of ZAWA and the Annual total rainfall for Zanzibar 1975-2008, Zanzibar Monthly Rainfall (mm) and Mean rainfall 1995-2008 and 2010.

4.3.6. Weakly Feedback Meetings:

During the fieldwork every Friday evening (after office hours) the Zanzibar fieldwork team (Shareen, Wairimu and Said) had feedback presentations and discussions with Director of Urban and Regional Planning that briefed their fieldwork progress and way forward. The discussion helped to re-organise the fieldwork plans find solution for data collection challenges and recommendations for better progressing. The final meeting involved presentation of preliminary findings and farewell with team of expert of the Department of Urban Planning Zanzibar.

Officially the fieldwork and data collection exercise ended on 24th October, 2011 by departing from Zanzibar to Netherlands 25th October 2011.

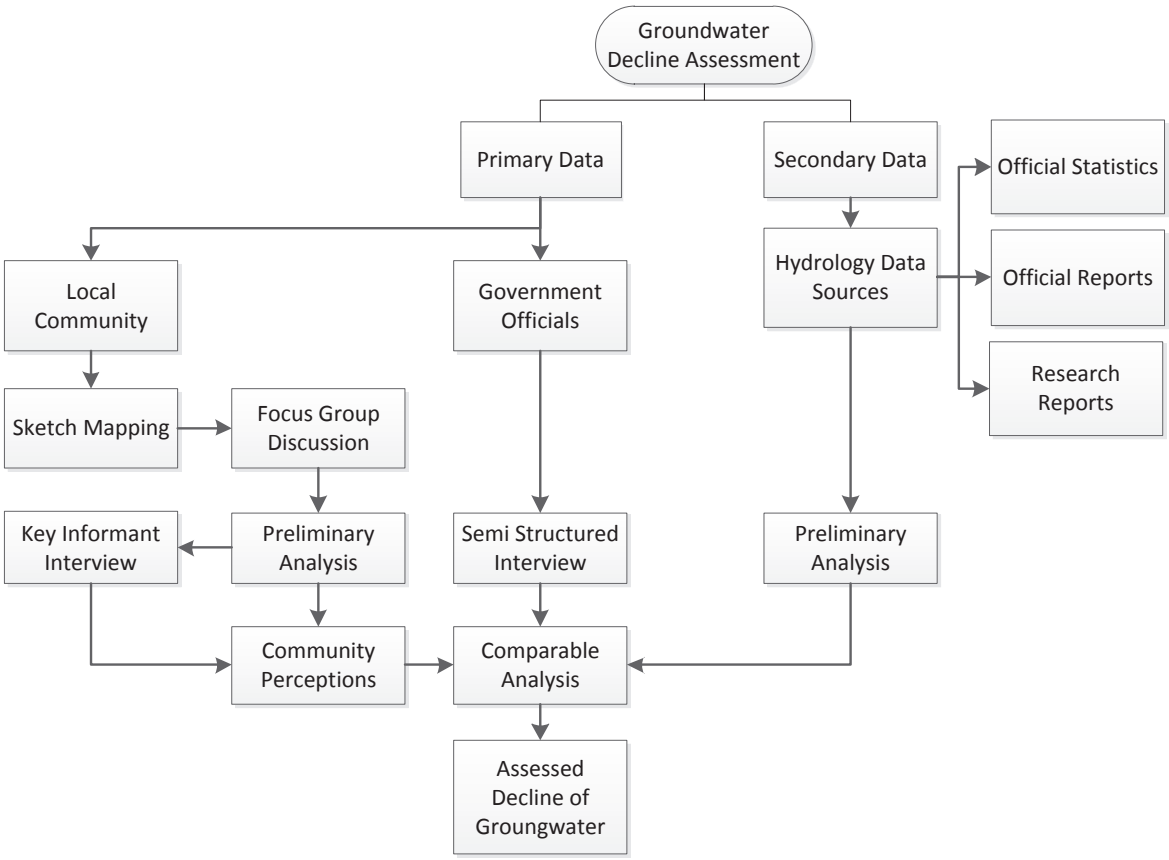
4.4. Data Processing and Analysis:

Several steps were required to ensure a rigours approach to processing and analysis. These include:

- Shortly after the FGD session the recorder and facilitator of the groups together reviewed the discussion outputs and notes taken during the discussion that helped to ensure maps/sketches are clear and meaningful to the research.
- Data from Sketch and Imagery mapping were sorted and compiled from every FGD separately so as to understand which output came from which group.
- After the FGD all recordings from the discussions were listened again to figure out key statements, ideas, and attitudes used to express causes, effects and coping measures of the groundwater decline and prepare FGD proceedings report in English language.
- Data sorting and report preparation was done based on genders information outputs.
- The report was used as a key tool for identifying contents of the research objectives and questions which enabled to answer research questions of objectives one and two.
- Sketch and Imagery maps were scanned, written group discussion were translated and documented for the used in research findings and discussions.
- Key-informant interviews that were recorder in audio format were listened and translated to English was sorted in causes, effects and coping measures of groundwater decline related categories.

- Semi-structured interview was recorded and translated to English, was used to identify information of groundwater issues from water resource expert view with regards to FGD's output.
- Generally, the qualitative data processed through coding and recording methods helped to group together alike data and filter the redundant ones during the qualitative analysis.
- Further analysis which was carried out to spatial data with the help of Excel, ArcGIS and ILWIS resulted to map and graphic outputs which was interpreted and used in research discussions to the final conclusion.
- The process to achieve the analysed output is shown in below:

Figure 4-3: Research Methodology



CHAPTER FIVE

5. LOCAL COMMUNITY ASSESSING GROUNDWATER DECLINE

5.1. Introduction:

In this chapter, the study findings are profoundly discussed basing on the local knowledge elicited from data collection process. The local community assessed the decline of groundwater under the following main topics.

5.2. Local Community Understanding of Groundwater Decline:

According to the field survey to assess the decline of groundwater a participatory mapping exercise was conducted from 26th September to 24th October 2011, local community of two study areas understand the ground water decline as:

Box 5-1: Focus Group Discussion - Understanding Groundwater Decline			
Shehia of Mtoni		Shehia of Mwanyanya	
Men	Women	Men	Women
The failure or lose of ability of a water source to produce the amount of water required to fulfil regular consumer's demand that normally they used to yield	The reduction in amount of water in springs from its original level to other lower level less than the original one	The decrease of water level in the springs or other groundwater sources	The situation where water sources lost its production capacity

The local community definitions were derived after extensively discussions in the FGD. All groups mentioned the question of water source to drop its original yield. About the question of determining the amount decreased, the groups bit differ although closely to similar meaning; for instance:

Box 5-2: Focus Group Discussion - Determining Groundwater Level Decline			
Mtoni		Mwanyanya	
Men	Women	Men	Women
We don't have proper measure to describe that the water was at a certain level/amount and now is in a certain amount but we use tree pole to check water depth	We discovered the water decline from the way we used to fetch water from the spring through the pipe (which is on top of the chamber) (see photo) but now we fetch water by bucket in the chamber	The water did not reach the level as it was used before. (See the photo)	The water scarcity

Plate 5-1Community member showing drop of water level

Plate 5-2 Community member fetching water

5.3. Causes of Groundwater Decline:

The local community mentioned several causes of groundwater decline which can be categorised into natural and manmade causes.

5.3.1. Natural Causes

i) Changing of Weather Condition and Shortage of Rains

The local people indicated change in weather condition and shortage of rain as natural causes of groundwater decline. The Mtoni Men's FG differentiated between shortage of rains and change in weather by arguing that the change of weather may lead to shortage or excess of rains. Rainfalls depend on seasons; Most of the time intensity of rainfalls matches with cloves harvesting

Box 5-3: Focus Group Discussion Justifying Natural Cause of Groundwater Decline

- If Vuli rains come during clove season then rains become adequate and if there is no clove the rainfalls become poorly *(Men-FGD Mtoni, 2011).*
- Change of weather causes shortage of rains and rainfalls depend on whether condition *(Men-FGD Mwanyanya, 2011)*

But the Mwanyanya Men's group revealed that change of weather and shortage of rains are two different things.

Generally, three out of four FG mentioned change of weather as among the reasons for groundwater decline while two men's groups also mentioned specifically that shortage of rains is the reasons for groundwater decline and the women group of Mwanyanya mentioned no natural reason causes the decline.

5.3.2. Man-made Causes

- Hazard cutting down of trees and deforestation
- Housing construction
- Contamination of catchment areas and environmental degradation
- Increase in population and water demand
- Agriculture activities
- Sand excavation

i) Hazard Cutting of Trees and Deforestation:

All groups reveal that cutting of trees is among the major causes of groundwater decline. Many reasons have been mentioned that boost people to cut trees such as for energy consumption (fuel wood and charcoal), wood and tree poles for construction materials, site clearance for housing construction and sand excavations. In justifying the importance of trees in groundwater resource Key informants revealed that:

Box 5-4: Key Informants Clarifying Impacts of cutting of Trees on Groundwater Level

- Trees provide shade to groundwater and prevent it from descending while roots cover the water from going away (i.e. by evaporation process) (*key informant respondent Mwanyanya, 2011*).
- Forest clearance done in 1990s when people started to settle in the Shehia affected the streams and caused it to lost its water in *Kiangazi* (summer), which was never dried before

Moreover, the locals consider species of Bamboo tree reserve groundwater and when it is cut groundwater dry out. This notion was somehow accepted by the water resource expert although scientifically more review should be done to find out tree specious properties regarding with groundwater loving and hating (Ali, 2011)

Plate 5-3: Bamboo trees beside water source

Plate 5-4: Dropped Level of Surface water-Bububu Stream

ii) Housing Construction:

With exception of women FGD of Mwanyanya (site 2) all groups revealed that housing development in their areas contributed to the groundwater decline. The enormous housing development has taken place in 1980s and 1990s as many of the residents mentioned that they started to settle in the Shehia in 1980s where by groundwater situation was good but in 1990s they experience deficit of water and drying of streams in Kaskazi seasons. In justifying this reason, the Mtoni women group noted the lack of knowhow in housing development caused people to construct without any plan or guidelines and without thinking on the impact of what they were doing. Their priority at that moment was to have a place to live nearby urban area for cheap price. This was also mentioned by men's group of Mwanyanya where they mentioned even in low land areas (catchments) where rainwater used to log for long periods were also encroached and constructed.

Box 5-5: Water Experts Responding on Housing Construction Cause of Groundwater Decline

Housing construction in virgin lands affiliated with site clearance activities, cutting of trees logs (building materials) and exaction of soil and sand for construction material. All these are amounting to increase of stiffing of land surface that reduces its infiltration, reduce natural vegetation and increase of hard surface which increases water evaporation and runoff vegetation provides shades and reduces evaporations

iii) Contamination of Catchment Areas and Environmental Degradation

The community associated environmental degradation with the decline of groundwater. Two out of four FGD (one of women and other of men from different sites), mentioned solid wastes that were haphazardly disposed in streams water catchment degraded the watercourse and caused poor rainwater flow to the springs. The wastes caused the catchments to lose its retention capacity and increased runoff in streams which resulted to quick dry once after raining. The situation endangered streams-bank due to erosion which also caused sand to cover the water sources (springs). The men's group of Mtoni discussed the quality and quantity failure of Mtoni main spring in 1990s, as was resulted by groundwater contamination caused by residential houses which were construction nearby Mtopepo stream.

Box 5-6: Water Experts Responding on Environmental Degradation Impacts on Groundwater Decline

Contaminations of water catchments and environmental degradation are highly causing water quality problem of groundwater. The sludge solid particles from residential houses when dissolves and penetrate to the aquifer contaminate the water table and cause such problem. Most of the housed constructed along with Mtopepo stream and Masingini hills have poor pit sanitation which allows solid particles to penetrate and dissolve in ground streams to the water sources.

The conducted Water Resource Study with the support of FINNIDA in 1990 showed Mtoni Spring had high rate of coliforms and bleaching chemicals which was not only resulted from the informal

residential houses along the Mtopepo stream but also chemicals from Shoe and Textile Industries that was situated close to the source. The source was put in-operation again after housing demolition and closer of the industries.

iv) Increase in Population and Water Demand

Both women groups and the Mtoni men's group declared that increase in population has influenced the decline of groundwater level. Two arguments have been posted which are the increases of water consumption from which more water were fetched while groundwater does not increase. Also, increase in population resulted to the increase of human activities such as construction and cutting down of trees which affect streams and catchments.

According to the Director of Water Resources, both sites Mwanyanya and Mtoni were highly covered with vegetation and forest which then cleared slowly-slow by migrants who established their residence. The situation enforced the Water Department of that time to ask for cadastre survey and demarcation of their water stations in Mwanyanya and Mtoni so as to stop invasion form the people. On saying so, he was agreed on the point that increase of population density has an impact to water sources due to the increase of human activities. That was also supported by Water resource officer when she introduce among other reasons, the cause of the groundwater decline as a result of low recharge due to poor infiltration of rain water to the aquifer.

v) Agriculture Activities:

The men's group of site 2 (Mwanyanya) mentioned agriculture activities in their area and keeping of cattle contributed in the decline of groundwater, the activities are carried out in water catchments where land is wet throughout a year and good for agriculture production. The activities use water and degrade the catchments streams bank. Either they argued that sometime they had to clear land and cut permanent trees in-order to plant food-staff like cassava, yarns beans and other times they re-direct streams to get water for their plants and animals. They believe that contributed to the groundwater decline due to dry out of water ponds in most of areas which they used to cultivate and keep cattle such that they had to shift to other areas which still have some dampness nearby water sources.

Box 5-7: Water Experts Responding Connection Between Human Activities and Groundwater Recharge

There is a correlation between human activities and rainwater penetration in the ground. The more the virgin the land, the higher amounts of water penetration and higher the recharge of ground water while the more land/soil compaction, reduces absorbent or porous in soil texture that is lowers the rate of rainwater penetration and lower the groundwater recharge

vi) Sand Excavation

Both Shehias have been under pressured with illegal sand excavations. These activities that mostly are done by outsiders have been mentioned by men's groups in both sites as well as the key informant of site 2 who said that "sand excavation causes groundwater to go deep to the ground avoiding sunlight to approach a water table" he believes that sunlight pushes groundwater deeper while tree shades and vegetation cover protect directly hit of sunlight. The groups argued that, the excavation activities are done in catchment area and inner parts of the forest where trees are cut and streams which feed the catchments are disturbed and caused water to dry.

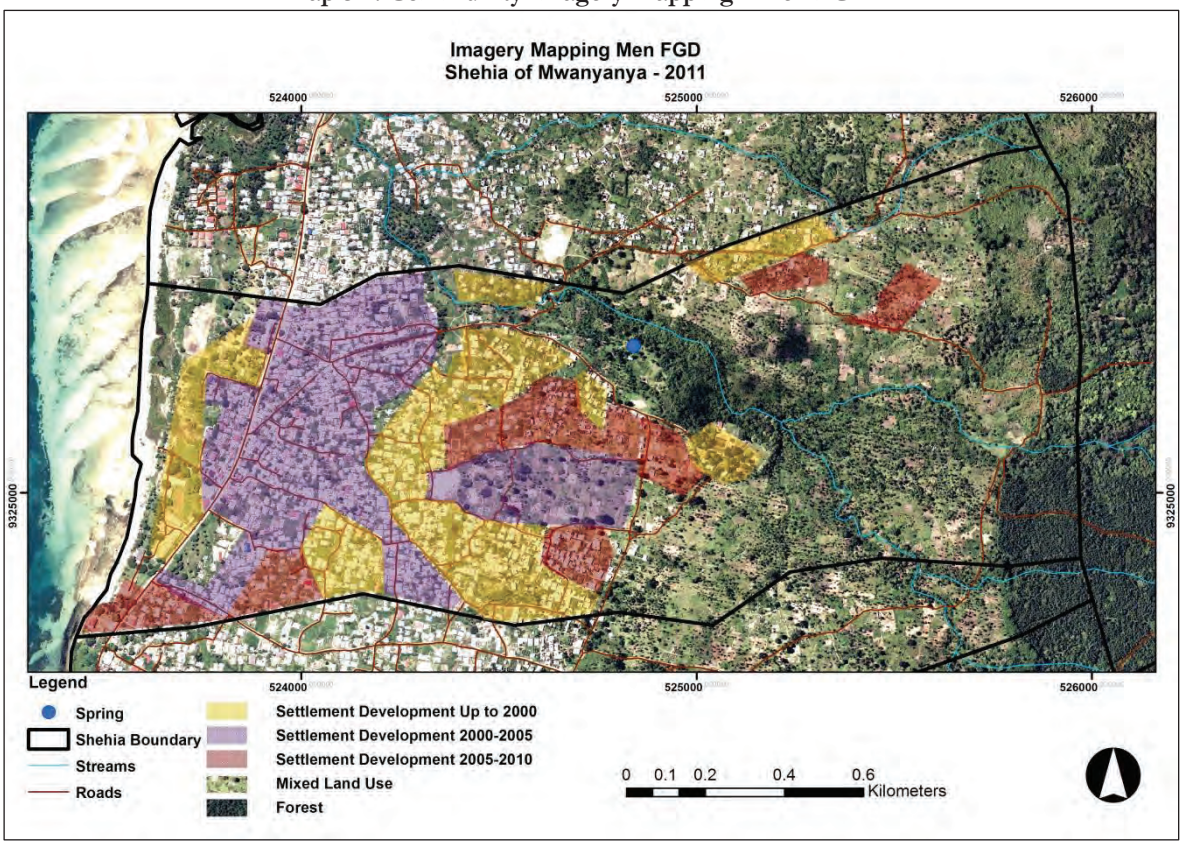
Responding to that, the water resource officer said there is no direct connection between the soil exaction and disappearing or immersing of water table. Geology of the area determines water table weather there is sunlight or not. But soil exaction activities under same principle of fresh land and disturbed land, has impact to groundwater recharge. Sand excavation involves human activities

including pic-up trucks in the site which caused soil compaction that reduces groundwater recharge rate. Either, the activities leaves bear lands and deep hollows which causes interruption with regular runoff that affects water sources.

5.4. Spatial and Temporal Assessment

General all groups in one way or another mentioned periods of time in assessing groundwater decline. For example men groups mentioned periods of before 1985 the groundwater situation were very good and started to notice some few changes from 1985 to 1988 and that was the period where areas started to grow from the main road to inner parts of the Shehias. In 1990 settlement development further grew towards the water sources and forest areas and left some patches that were occupied by first settlers not being developed yet. At that time those who were given agriculture land by the government started to sell to individuals illegally and caused more housing developments after 1990. The worse situation was observed in the last ten years where Government tried to control residential expansion towards the forest and government estates which caused land price to rise and enhanced those who reserved land to sell them in high prices. This situation exacerbated the groundwater decline after many open areas including playing grounds, agriculture plots, catchment areas and stream's bank encroached and constructed. Spatially locals showed this temporal spatial development in the Community Imagery Mapping map 5-1 below:

Map 5-1: Community Imagery Mapping - Men FGD



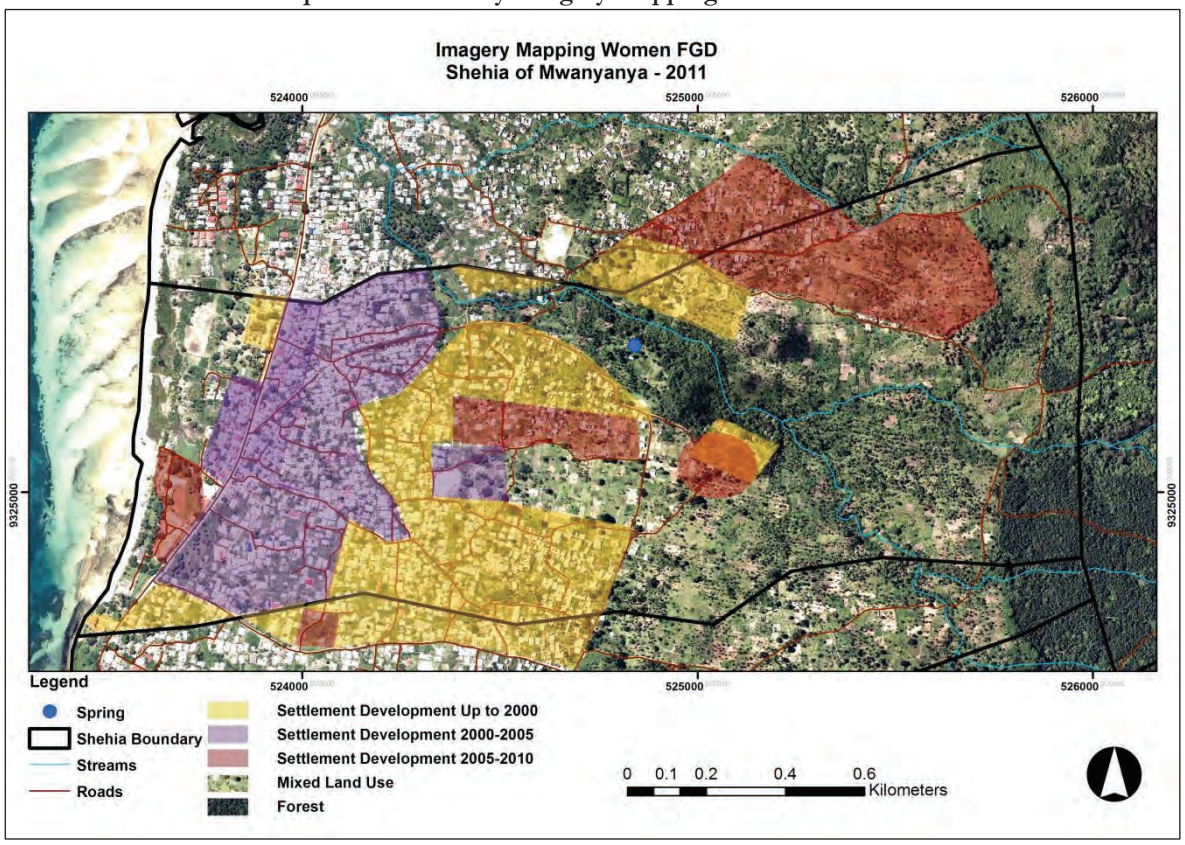
From the above community image, in the year 2000 concentration of settlements were highly found along the main road (linear development), about few metres toward the west of the road and about four hundred metres towards the eastern side of the road. The middle part of the area was covered with very few settlements in scattered clusters, cultivations, bushes and forest while the inner part was covered with mainly forest and cultivations.

In 2005 more housing developments took place towards the beach area west of the main road as well as west of the middle developed part towards the main road. The inner part of the area was covered

with few residential settlements, cultivations and forest. The forest was bit less dense from previous period of 2000.

The residential settlements in 2010 density at the partially developed areas particularly along the main road and merged with the middle part Shehia which also extended towards the main road. In inner part of the Shehia cultivation areas increased, forest decreased and few housing clusters extended to the northern east where was used to be forest and agriculture activities.

Map 5-2: Community Imagery Mapping - Women FGD



The Women Focus Group on the other hand, memorised periods of year 2000 and 2009 as the notable time for water decline. Spatial development and destruction of forest which took place in that period of time was mentioned as major reasons for the decline. In their imagery maps, women pointed out areas and some structures that existed before year 2000 and the new structure came after. They argue that new increased structures caused high concentration of developed areas along the main road except the Bububu School's area and southern part. Other areas had less concentration of settlements such as the middle part of the area which had much open grounds, grass land, bushes, forest, military camp site and farm lands. They also pointed out very few scattered single houses in the inner part of the area which highly concentrated with forest land and agricultural products.

The period of 2000 to 2005 the group showed as a period of much spatial development took place in the area including the construction of Bububu School, extension of the linear development towards the middle part of the area and build-up of many open terrains including play grounds, bushes and grass land. They also pointed out the land use change from forest to agriculture and agriculture to residential but all spatial changes that took place, forest land remained as the major land cover in the inner part of the area.

The period of 2005 to 2010 the group showed new settlement development to the south-west of the Shehia close to the beach area and to the northern east of the Shehia close to the Bububu Stream which also cross to the neighbouring Shehia. Other settlements developments are extension of the previous development in the middle part of the Shehia down-stream of the Mwanyanya Spring. The

group also showed-up some remarkable spatial development outside the Shehia boundary which to them has also impact to groundwater decline as shown in the above map 5-2 Community Imagery Mapping-Women FGD.

5.5. Local Based Coping Measures to Groundwater Decline

The effects of groundwater decline lead the community to sit and agreed together on measures to take for dealing with the consequences. These measures include establishing community committees and use existed religious committees to deals with individual people who appeared not to care on the issues. The committees also cooperated with Shehia Administrative Committees to educate people on water issues and resolve local disputes among the community members.

On the spatial issues, the committees used to protect water sources and catchments by directly deal with locals abused and miss used the sources or catchments by building houses, cutting trees, and excavating sand. They also organised water fetching program that firstly considered women and arranged special areas for washing and cattle feeding.

Shehia administrative committees on the other hand, are taking care of vertical correspondence between Shehia and external institutions like ZAWA on the question of water sources and water quality issues which helped one time to set buffer zone between residential houses and water source of Mwanyanya, and guided local people to protect local sources at Mtoni and seek support from the Red-cross-Zanzibar Branch.

The difficult area between the locals and the outside organisations is on land tenure and land use issues where by community itself failed to correspond with institutions responsible for land admiration and land use planning due to lack of security of tenure and land use development rights. In reflect to that the local community recalled the action that has been taken against them in 1990s when Regional Commission Office demolished number of residential houses because by the reasons of protecting the Mtoni water source. So they do never think of dealing with land use institutions to resolve spatial conflicts in their areas because of their safety and rights to occupy and develop their areas.

The coping measures that community has been taken to deal with the effects from groundwater decline can be related with the management natural resources in fields of communication and coordination among themselves and outside institution, planning and implementing their decisions as well raise awareness among themselves on the importance of managing water resource for their own benefit.

CHAPTER SIX

6. CONVENTIONAL ASSESSMENT OF GROUNDWATER DECLINE

6.1. Introduction

Scientific view on the groundwater decline is a chapter that introduces scientific aspect for assessing groundwater decline. References have been made from both case study area and globally to relate areas as was determined by the local community from the study area and the sub-objectives of the study.

6.2. Understanding of groundwater

The groundwater quantity from the scientific point of view needs to be determined from the amount of water in aquifer by using special instruments such as pressure sensors. In a normal circumstance, this amount there is a balance between volume or water amount recharge and discharge (Kranz et al., 1993) and if the amount discharge is higher than recharge by any reason, the groundwater level decline would be detected.

ZAWA uses to determine groundwater level from Mtoni and Bububu Springs by using "Barnes Formula". The formula as described in box 6-1 below enables them to measure amount discharged from the springs in daily bases. The results are used to draw trend flowchart showing sequences of groundwater amount for different period of times from the sources.

Box 6-1: ZAWA Determination on Groundwater Level Decline

$Q = 1.25H^{1.49}(L+2H) - 0.11$,

Where *Q = Quantity discharge,* *H = Head in feet and* *L = Length in feet*

Water from the sources (Mtoni and Bububu) flow in the gauge-chamber of weir length 36' and the Head is measured by water gauge in daily basis. The recorded Head is an input to the above formula which results into amount of ground water discharge (gallon per hour). The quantity is then converted into discharge cubic metre per hour and per day. The scale and chamber are shown in the photo below.

Plate 6-1Bububu and Mtoni Water Gages and Measuring Chamber at Saateni Water Work Station

6.3. Causes and Effects of Groundwater Decline

Basically local people of the study area (Mtoni and Mwanyanya) identified natural and man-made causes of groundwater decline. The key causes include change of weather, shortage of rainfalls, human activities, increase in population and increase in water demand due to the increase in consumption.

6.3.1. Natural Causes of Groundwater Decline

Among the reasons that community has mentioned on groundwater decline were Change of Weather and shortage of rainfalls. In scientific point of view, hydrological cycle describes constant movement of water which includes surface and groundwater, glacier, rainfalls and water vapour. The process of "condensation, evaporation and freezing of water occur in respond to the earth's climate conditions" (Kranz, et al., 1993). Global warming for instance causes raise in temperature which speed-up hydrological cycle and results into heavy rainfalls, high rates of evaporation and runoff, shorter periods of recharges and also drought. Moreover, melting of glacier leads to rising of sea levels which reduce amount of fresh groundwater through saline intrusion changes abstraction. Like other countries of Sub-Sahara, Zanzibar as a whole experiences rising of seawater level, increase in temperature and inconsistence rainfalls as shown in the Fig 6-1 below.

Globally, many studies have been conducted to analyse and model correlation of climate changes and its impacts on groundwater. To mention the few:

i) The study on the impact of climate change on groundwater recharge and runoff in a humid equatorial catchment sensitivity of projections to rainfall intensity conducted in South-western Uganda. It used historical rainfall data and delta factor to the semi-distributed soil moisture balance model to determine and predict changes in rainfall intensity. (Mileham et al., 2009)

ii) Modelling the effects of climate change and its uncertainty on UK Chalk groundwater resource from an ensemble of global climate model projections which projected the 2080 climate changes impacts to the groundwater with regard the uncertainties by using Global climate models (Jackson et al., 2011)

iii) The study on impact of climate change on groundwater in Australia: a sensitivity analysis of recharge which used sensitivity analysis of climate variables and WAVES modified version to determine changes in groundwater by considering various climate variables such as temperature, solar radiation and carbon dioxide concentration (McCallum et al., 2010).

iv) Effects of climate change on coastal fresh groundwater resources which is a study that evaluated the clime impacts on fresh groundwater by using Hadley Centre Climate Model in two high and low emission scenarios for 2000-2009 (Ranjan et al., 2006)

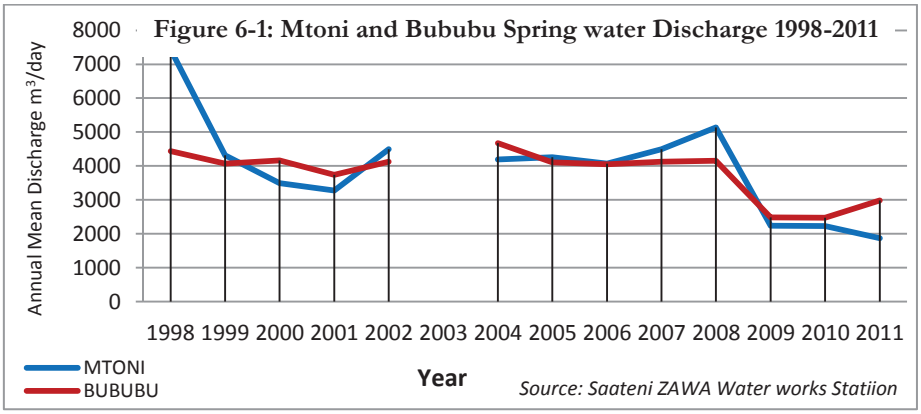
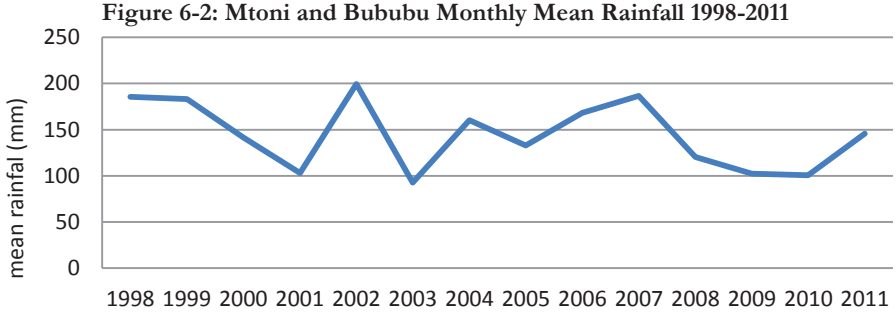


Figure 6-1: Mtoni and Bububu Spring water Discharge 1998-2011

All most all these studies conducted in various places of different environments with different methods and measurement criteria are revealing that climate change has impact on groundwater balance or and its sustainability. The studies pointed out the variation of results in relation to

respective region of studies and that, activities and land uses of specific catchments have much more influences on weather variables and groundwater stability as well.

Figure 6-2: Mtoni and Bububu Monthly Mean Rainfall 1998-2011



Source: Kizimbani Metrology Station

Kizimbani which is the closest Metrology Station to the study areas (Mtoni and Mwanyanya), reported the total annual mean rainfall of 1,734.66 mm for period of 1978-2005 with the minimum and maximum ranges of 761mm and 2,269mm of 1991 and 1994 respectively. This is bit higher in an average and minimum rainfalls but is lower than the maximum range of the National one of the same period, which was measured an average rainfall of 1,500mm with the rainfall range of 667mm-2,661mm.

The monthly mean rainfall which is shown in the above figure 6-2; gives a rainfall trend of 1998 to 2011 from which a significant drop of rainfall in years of 2001 and 2003 is observed as well as a significant increase of rainfall in year 2002. In generally there is uniformity of rainfalls at this zone and Zanzibar rainfall pattern as a whole.

Relatively, the Saateni Water Works Station that used to collect water from Mtoni and Mwanyanya sources recorded water flow from the sources and by assessing the flow data from year 1998 to 2011, is found the lowest amount discharged was below an average of 1,500m^3 per month in 2003 for Mtoni and Mwanyanya was less than an average of 2,000m^3 per month. The highest amount recorded was 1998 and 2008 for Mtoni spring which produced an average of 7,431m^3 and 537m^3 per month respectively while for Mwanyanya spring the highest amount was recorded in 2004 and 1998 which reached an average 4,671 and 4,439m^3 per month respectively. Due to this trend as shown in the above figure 6-1, both sources lose their capacities and that the highest amount produced in previous year are very rare to be reached again in following years.

6.3.2. Man-made Causes of Groundwater Decline:

i) Increase in Population and Water Demand:

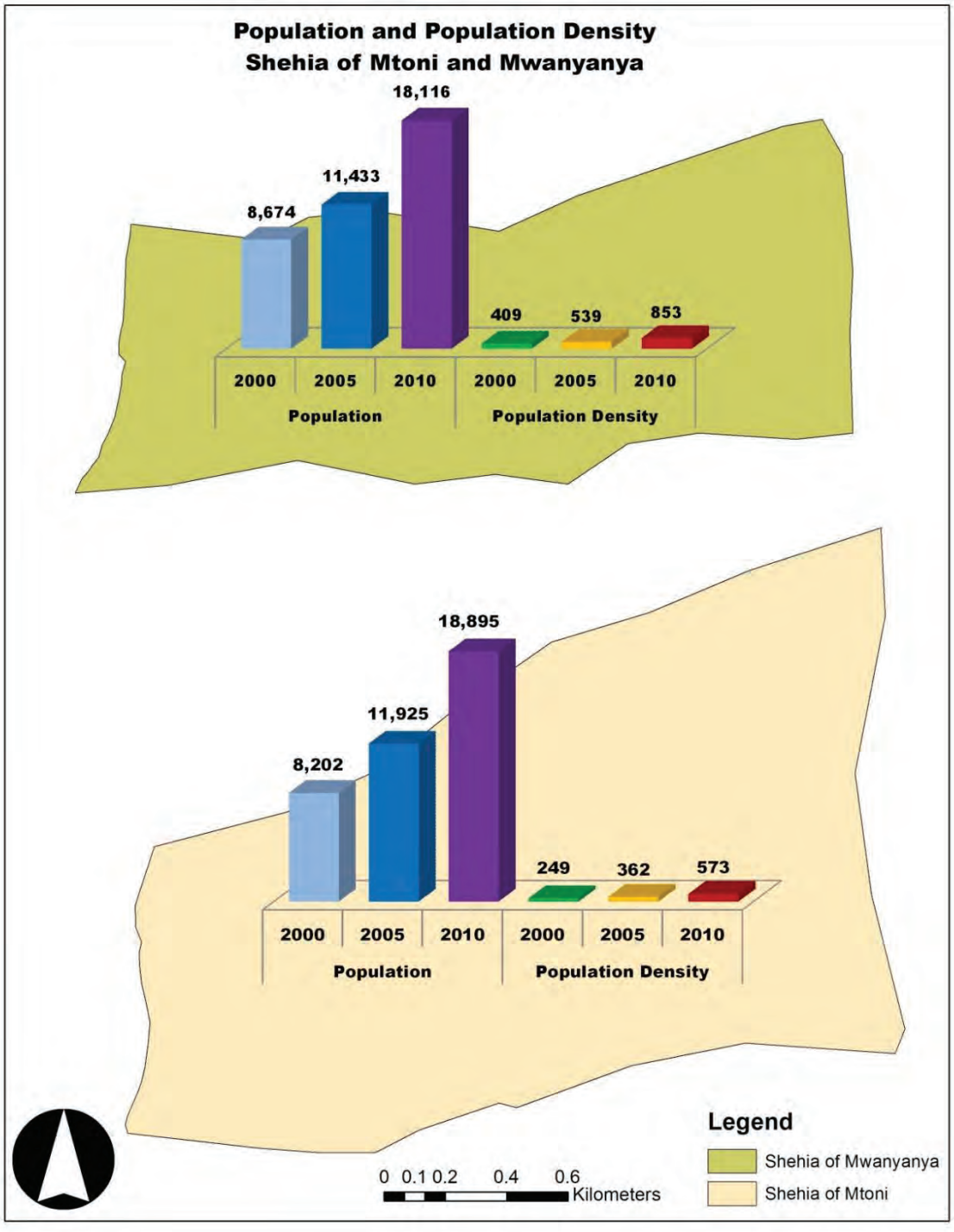
According to the National Population Statistics both Shehias have dramatically increase in population. The population growth rate rose from 4.9% to 9.2% per annum in 1988-2002 (HBS, 2002) which is higher than the regional annual growth rate of 3.9% to 4.5% of the same period. In both cases, the population density rose from 274 to 629 people per km^2 and from 409 to 936 people per km^2 in 2002-2011 for Mtoni and Mwanyanya Shehias respectively.

Regarding to the analytical period of this research, population of the Mtoni Shehia rose from 8,202 to 18,895 in a period of ten years 2000-2010 which is more than 130%. The same situation applies for the Shehia of Mwanyanya which its population increased for 109% in a period of ten years as shown in the figure 6-3.

In respect to that, water demand has also increased to the same extent as it was revealed in the MKUZA II, 2011 which estimated the demand basing on the 2002 population growth rate projection (MKUZA II, 2011). The water demand for the Urban-West Region was reported to increase from 41,973,585 to 46,553,648m^3 per day in 2005-2009 (Zanzibar Water Authority, 2009), which is equal

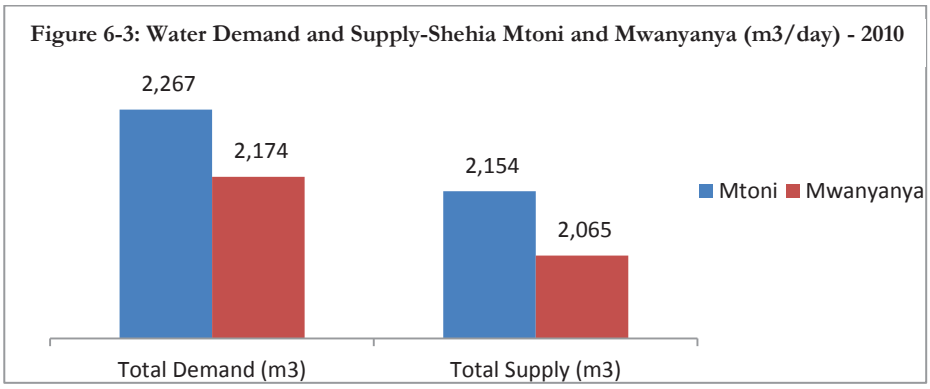
to 11% increase for the Urban West Region in a period of five years. Relatively, the actual demand is estimated for the study areas as 120 litres per capita per day while the actual supply from the mains is an average of 114 litres per capita per day; meaning that there is a deficit in water supply of 5 % per capita per day. The total amount demand and supply of the case study area is shown in Fig 6-3 below.

Map 6-1: Population and Population Density 2000-2010 - Shehia of Mwanyanya and Mtoni



Alternatively, the community obtains the rest amount of water from other sources like spring, wells and stream. This amount is estimated to be 113m^3 per day for the Shehia of Mtoni and 109m^3 per day for the Shehia of Mwanyanya.

The extraction of groundwater through boreholes/well particularly in up-streams as shown in map 6-2 and 6-3 below also reveals an impact to the groundwater of Mtoni and Mwanyanya springs which are in downstream.



ii) Development Density:

The question of housing construction can be associated with the effect of urbanisation on storm water runoff as was shown in map 6-4 that based on rational method of hydraulic design which is used to estimate runoff by regarding gradient, land cover and settlement characteristics. The theory of relating development density to estimate extent of runoff has been also observed by this research. It proved that population density, has correlation with the level of urbanisation and increase in inhabitants per specific area causes decrease in permeability of such area (Butler & Davies, 2004); in other words, the higher the population density, the higher the rate of surface water evaporation and runoff and the lower groundwater recharge. In addition to that, map 6-1 above show both Mtoni and Mwanyanya have high increased rate of population density for the last ten years such as Mtoni, the density increased from 249-573 (i.e. 130% increase) and Mwanyanya density increased from 409-853 which is an increase of 109%. Justifiably, the percentage of recharge reduced from 35 to 10%, runoff increased from 50-85% and evaporation reduced from 15-5% for the last ten years.

iii) Human Activities:

Sand excavation, contaminations of catchment areas and environmental degradation, agriculture activities and deforestation are here regarded as human activities. From the Government of Zanzibar point of view, increase of human activities in and around water catchments areas threaten the Government strategy of achieving the MDG that requires countries by the year 2015 to halve proportional people living without sustainable access to safe drinking water (MKUZA II 2010).

Basically, there is no strong evidence to show impacts of environmental degradation to the quantity of groundwater due to sand excavation, solid and liquid waste disposals, chemicals, and organic metals contaminations. Instead the Environmental Impact Assessment Study conducted by FINNIDA in early 1990s for the whole Zanzibar Island revealed impurity of Zanzibar urban water supply has its roots from the sources like Mtoni and Bububu-Mwanyanya. It also pinpointed the Forestry Nursery of Mwanyanya as a threat to Mwanyanya spring due to pesticides and chemical fertilizer. Mtoni Spring on the other hand, was found with industrial chemicals from shoe factory and Co. textile industry. Moreover the report put clear that agricultural activity particularly irrigation scheme and other development activities such as tourism may in the near future have significant impact to the sustainability of groundwater. People's bad behaviour of dumping trashes in streams and storm water drains (natural and constructed) causing water stagnant that seeps in ground and contaminate both the groundwater and seawater. Areas like Northern-west (Ras-Shangani to Kinazini) sea-channel of Zanzibar town was detected to contain high concentration of faecal and coliform (70066 E. Coli per ml) in 1990 (EIA FINNINDA). The stagnated waste water on the other hand can be justified as reduction of water permeability to the ground which reduces the rate of recharge.

6.3.3. Spatial and Temporal Assessment on Causes of Groundwater Decline

In this study, spatial terrain is taken as the assessment factor to determine effect of spatial developemnt to the groundwater level. The elevation of a source in this case spring need to be associated with the spatial development. Normally "goudwater moves from high water surface elevation to low water surface elevation" (Kranz, et al., 1993) while spring sources are the result of groundwater discharge of up-streams groundwater. Activities at up-stream always have impact to downtream.

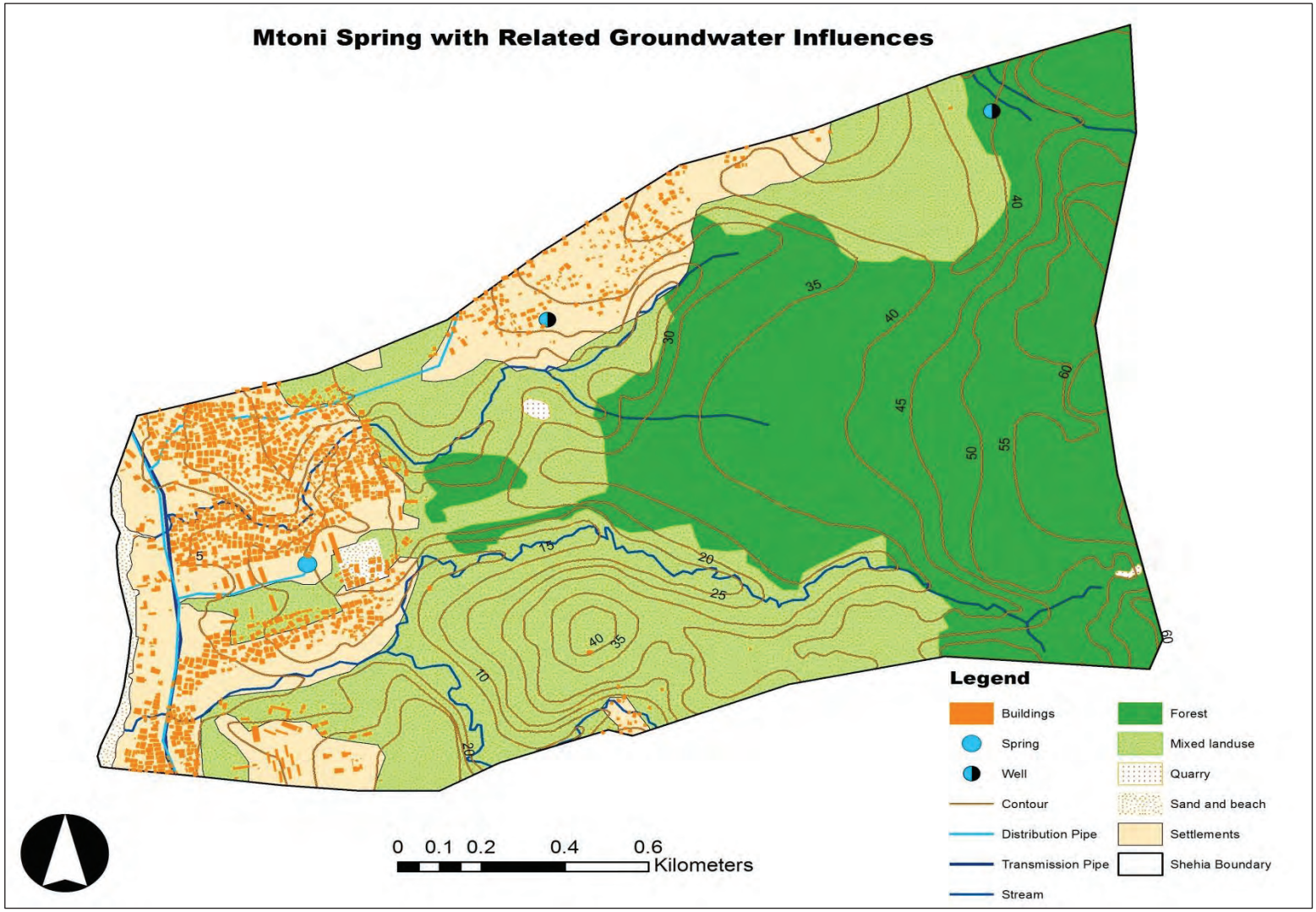
From the map 6-2 and 6-3 below, clearly shows that, the spatial development particularly settlements have influence to the groundwater stability of both sources. In the first case, the Mtoni spring which is in elevation of 15 metres above the mean sea level it is almost surrounded by settlements from all directions the upstream and downstream with some small patches of mixed land uses of bushes, agricultural and also settlements. The spring has its root from upstream groundwater of Masingini hill (120m elevation). The hill which is covered by conserved forest is a source of Mtopepo Stream which also contributes to the source catchment. This stream now is seemed to be covered with mixed land use including agriculture and settlements which both have impact to groundwater recharge.

On the second case, Mwanyanya spring is seemed not to be affected very much by land use development such as settlements and mixed land use. It still surrounded with forest and mixed land use in upstream and downstream respectively. Settlements are also seemed to get into the mixed land, forest and closer to the Bububu stream. These settlements are bit in high elevation of 5 to 10 metres (as shown in map 6-3 bellow) than the spring which means they may have impact to the recharge of the spring at downstream.

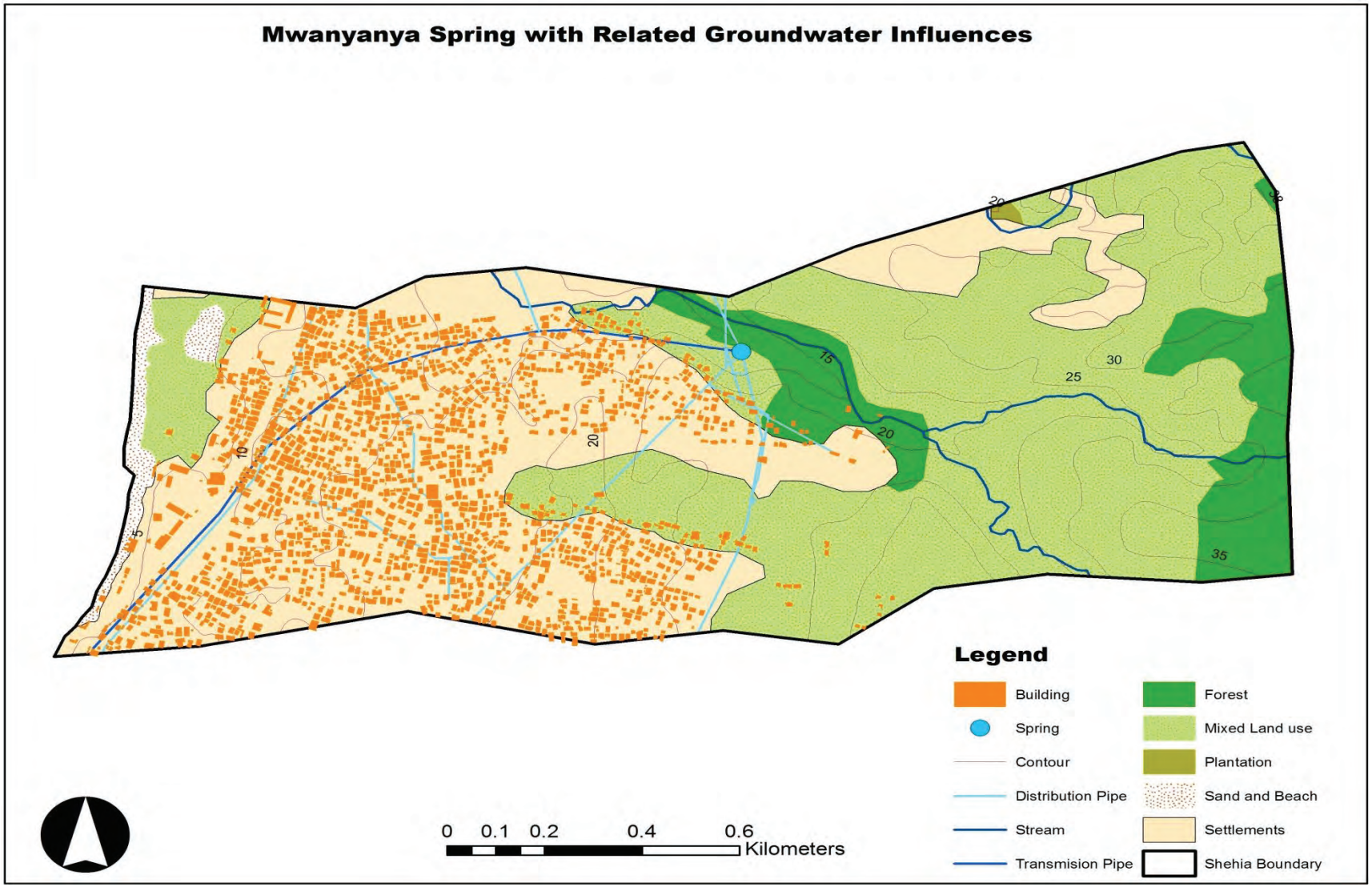
NB:

The visualised below maps (6-2 and 6-3) were produces from different datasets such as building layer from the GIS-SMOLE Mapping dataset of 2009 and land use layer from 1993 Unguja Land use dataset while water related features were retrieved from GIS-ZAWA-water network dataset of 2009. Hence the overlay of these layers might have some inaccuracy due to overlapping or mismatch of geo-referencing.

Map 6-2: Map Groundwater Related Influences – Shehia of Mtoni



Map 6-3: Map Groundwater Related Influences – Shehia of Mwanyanya



In further analysis, the study inspects characteristic of runoff with regards to land use and gradients in-order reflect the development density in regard with land slope and runoff. The aim is to assess the elicited LSK which revealed that increase in settlement in their areas contributed to the decline of the groundwater. Three major land uses have been selected for this discussion, which are forest, settlements and mixed land use. The characteristic of each land is described in table 6-1 below.

Table 6-1 Land use and Slope Characteristic

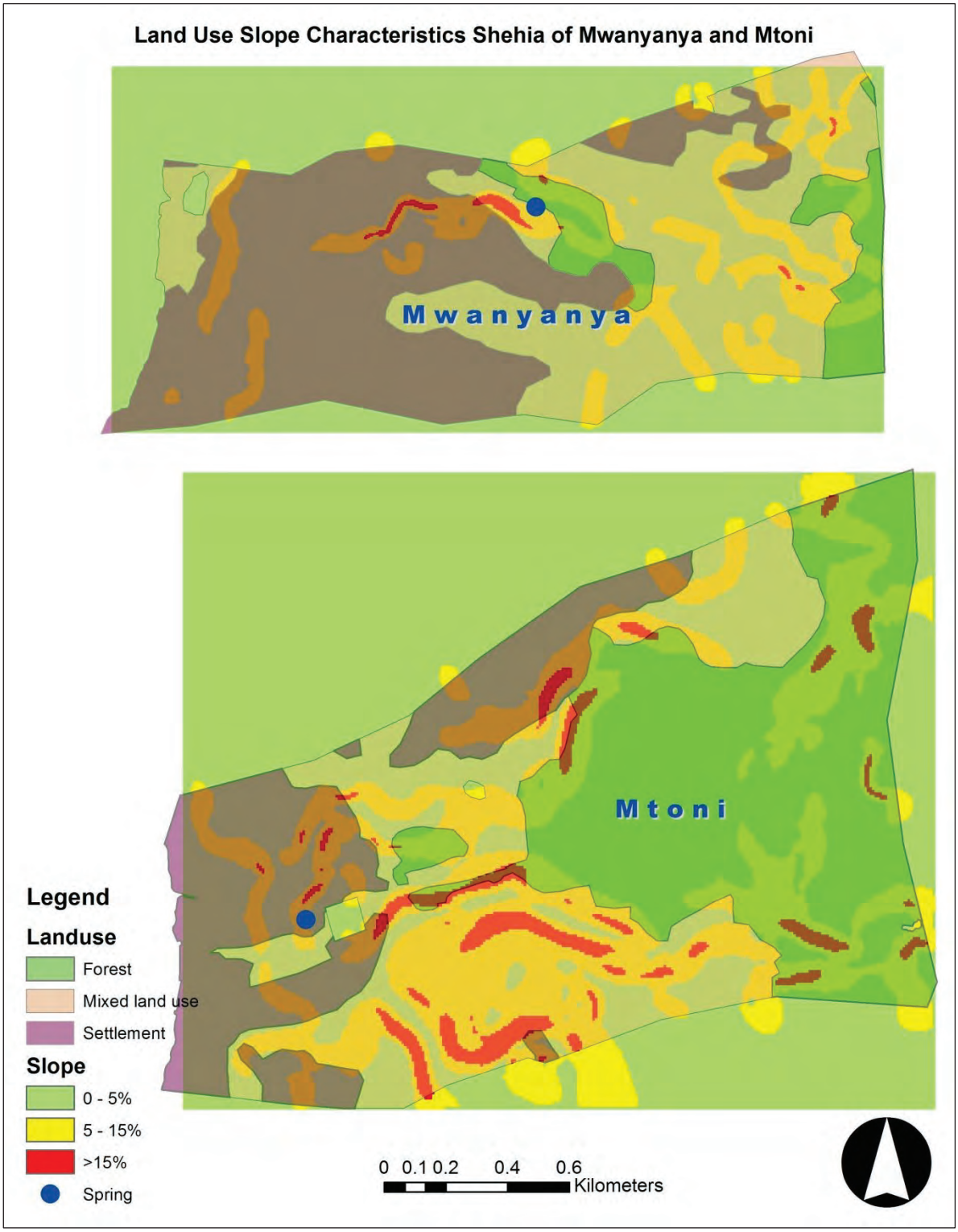
Land use	Description	Adapted Coefficient of Runoff and Slope Characteristics		
		Flat (0-5%)	Rolling (5-15%)	Hilly (>15%)
Residential	Dense built-up area	0.10	0.15	0.20
Forest	Dense woodland	0.70	0.75	0.80
Mixed land use	Cultivation, lawn, scattered built-up, sand and trees	0.40	0.45	0.50
Source: Hydraulic Manual Rational Method (Oregon Department of Transport Highway Division (ODTD), 2005)				

From map 6-4 below shows result output of where runoff is critical according to land use slope characteristic for both Mwanyanya and Mtoni.

- Mwanyanya on one hand, the slope in forest land is moderate or rolling that its runoff is normal
- The mixed land use has few patches of steep slope (hilly) that includes small are closer upstream to the source that its runoff is high however is to the advantage of the source due to its elevation and gradient characterizes which is flat.
- Settlements are generally in flat gradients with some patches of moderate slope and very few patches of steep slopes. Runoff highly is influenced with built-up density rather than slope due high density of informal development on the dominant flat gradient of the area. The runoff is taking place at downstream from the source so that it has no advantage to the sources instead it increases water loss to the sea.
- On the other hand, Mtoni forest land cover is characterized with all gradients characteristics. The edges of the forest formed with rolling slopes and flat areas at the middle. Hilly is observed in peaks of the moderate slope areas. The forest land shows a strategic natural form of tapping runoff and enhancing groundwater recharge due to flat slopes surrounded with elevated gradients.
- Mixed land is mainly consists of rolling slopes with hilly on its peaks and flat land in its bottom. Runoff in this area is bit high and influenced with land form rather than land development that are scattered in the areas.
- The build-up is characterised by mainly flat lands with belts of normal gradients. There are some few hilly patches on rolling belt and the spring is found in this area. Both built-up density and gradients have influence to the runoff whereby spring is surrounded with density settlements and undulations closer to the source which release it water to both the source and loss to the sea.

Generally, the recharge of the Mwanyanya spring is normal with the advantage of being in the downstream at flat gradient and surrounded with forest and mixed land cover which allows full recharge and storage to the groundwater. In the case of Mtoni spring, discharge is influenced with land form and development density. The spring is in normal slope that its runoff is higher than low slope areas closer to the source. Thus allows groundwater movement to the downstream. Settlement development has taken place in both downstream and upstream that reduced recharge to the source.

Map 6-4: Reflection of the Land use Slope and Runoff



CHAPTER SEVEN

7. USEFULNESS OF PARTICIPATORY MAPPING IN ASSESSING NATURAL RESOURCES

7.1. Introduction

This chapter discusses findings on groundwater decline according to community perception and from the scientific view regarding the research questions objectives and questions.

7.2. Participatory Mapping in Assessing Natural Resources

Participatory Mapping is a primary tool used in this study to assess natural resources. It was used to elicit primary knowledge from local people by using Participatory Mapping tools such as Community Sketch Mapping to identify general over view of the resource in terms of location and importance in relation with other physical features; Community Imagery Mapping to determine spatial developments in relation to spring and the decline of groundwater; Focus Group Discussion to qualitatively justify reasons behind the decline of the groundwater and key informant interview to qualify temporal information about the groundwater and related features.

Assessing groundwater needs data that are obtained from primary sources so as to identify availability and extent of the resource. It also needs knowledge on geology and hydrology of the specific area which highly determines the state of the groundwater and its storage. In both cases historical information is helpful to understand the extent variation and reasons behind. Observations or monitoring and investigations are pathways to the proper conclusions on what factor is exactly causing groundwater quantity variation and to what extent it contributes.

The information which has been obtained through participatory mapping regarding the groundwater decline are potential input to the fully assessment of the resource. It gives basic evidence of the groundwater decline that include historical information of the assessed water sources and causes of the decline. Moreover, the knowledge tries to measure the extent of the decline by showing water-marks (Plate 5-1 and 5-4) observed in different time periods. Causes that have been obtained from LSK reflect with the scientific reasons on groundwater decline; natural cause on one side mentioned climate change and inconsistence of rainfalls. It went further by associating it with other dependable factors like rainfalls and cloves yields. On the other hand man-made causes were described in different manner such as settlements development, agriculture activities and disposal of solid wastes in water catchments. Besides, some knowledge that could not automatically be elicited from pure scientific researches was obtained in this research such as detection of groundwater by using smog and tree species.

On the question of the local people readiness to exchange knowledge, this study found on one side that community is keen to learn and understand the groundwater issues, to tackle groundwater decline related issues and on the other side the community is ready to share knowledge they have for studying the situation and find its solution.

On the question of mapping, the LSK came up with sketch and imagery maps describing local environment in relation to the groundwater decline. The produced graphics were somehow clear, mapping elements such as north arrow from mapping orientation, legends, symbols and titles were sketched; yet the community had no cartographic knowhow.

Lastly, participatory mapping collected LSK as community base views rather than individual's views. The view is subjective information that can be quantified to strengthen people perceptions in assessment of

resources studies and can be used as an evidence to represent their stands on the management of such resources. Obviously, this cannot be obtained in the purely scientific resource assessment studies which its results are only between instruments and the researchers.

Despites the above achievements that provide information attributed to the decline of the groundwater, the information could not quantify amount of the decline in any period. Also there was no knowledge obtained that informs about land gradients with respect to groundwater recharge and runoff which is vital in assessing groundwater movements and recharge. The community mapping outputs is not competitive to standard maps due to lack of mapping skill and time limitation of mapping exercise.

7.3. Genders Based LSK

The ability of providing spatial knowledge highly depends on familiarisation of a person to the study area and time of his/her living. This study found outdoors activities has something to do with familiarisation of the locality. In this study, difference in providing spatial knowledge between men and women was found in two major areas, the discussions among the genders and scale of mapping features in maps.

Discussion on one hand, women discussion groups took more time to discuss issues before they put in mapping or writing. They preferred to be more precise in providing information so that they took time to discuss and make understood by themselves first before deciding to put it in writing. Men's group, used to take short times to discuss issues and reach to conclusion. In both cases, men and women groups provided closely similar quality of information that could be used together and exchangeable. Thus, proves both men and women to have typical ability of organising themselves, discussing, arguing and make decisions as well as producing quality information as was shown in (Box 5-1and 5-2 above).

On the other hand, women skill on mapping spatial features that they know is higher than men. They mapped features in large scale (details) although it was only to small areas while men's groups mapped feature in small scale but in large areas. It was found that majority of men's FGDs were more familiar with the whole study areas while women were only concentrated to small interested areas. See also map 4-1 and 4-2 above.

7.4. Relevance of the Local Knowledge in Assessing Groundwater Sources

In line with this study the significance of the local knowledge in assessing the groundwater sources firstly understands the question of the groundwater decline which can be differentiated from availability of groundwater or water resources.

The local community have their means to detect the decline of groundwater by observing on earth surface smog or humidity condition, depth of discharged groundwater, and speed of spring discharge. Both cases, community associate the existence of groundwater by looking for special tree species like bamboo and vegetation covers which they define as the sign for groundwater availability. This knowledge is therefore, is useful for detecting and monitoring of changes in groundwater availability.

On the other hand local community is associating cloves yields with rainfall intensity; and that good clove harvesting seasons result to intensive rainfalls season and vice-vasa. Likewise, poor recharge is expected if clove plantation will continue to decrease. If that will be approved, this fact will be useful to predict rainfall intensity and encouraging plantation of such tree plantation for better and sustainable recharge.

The obtained local knowledge from this study revealed the ability of local community in undertaking natural resources management with technical and financial support from respective organisations. That meant to declare Local Knowledge is a tool for identifying capacity of the community in resource management and a tool for analysing capacity building needs to empower the community.

7.5. Potentials and Shortfalls of Using P-GIS in Assessing Groundwater Sources

7.5.1. Potentials

In this study, Participatory Mapping is found to be as flexible and negotiable approach that can be moderated according to the community situation before, during and after data collection process.

Before data collections, apart from the data collection time schedule which was prepared in advance, the researcher conducted preliminary survey to the study area and made discussion with local leaders to negotiate appropriate time for data collection conveniently with the community. This also gave opportunity to the community to prepare themselves and dedicate adequate time for the research. Concurrently, gives the researcher time to get general overview of water sources and their related spatial features before data collection exercise.

During data collections The approach provides adequate room to make follow-up of information that needed clarifications or justifications such as reasons of groundwater decline, to make observations such as to see water marks that show levels of water decline, and even to review methods, tools or guiding questions when the pre-ones fails to come-up with the expected out-put such as use of audio and video recording instead of manual recording which probably could cause loss of information.

After data collection from FGD, it was possible to validate imagery mappings from the community themselves by asking meanings of some features which they put in maps and also to identify appropriate resource person for the in-depth interview on the decline of the groundwater sources.

On the context of the data collection, generally the assessment of the groundwater decline study found out that, Participatory Mapping is a means to an end; which means that, it explores non-documented potential knowledge of local people to the documented and understandable manner.

Furthermore, the approach provides room for two-way knowledge transfer between community and researcher. The researcher transferred research knowledge to the community through recruitment of the research team (FGD facilitators and recorders) and through briefing of the study's aim and data collection methodology from which the role of community in FGDs was introduced in the FGDs. The community on the other hand provided adequately knowledge on the studying issue which could be used by the researcher to fulfil the studies objectives. This knowledge is then transferred back to the community in-order to realise its usefulness in a fruitful manner.

7.5.2. Shortfalls

The Participatory Mapping is a time consuming approach, particularly when researcher is strictly bond with P-GIS ethics, which always gives community high respect and that, community owns the data and data collection process. Hence the researcher has to wait and be patient to facilitate the process even if it will cost him/her more time and fund.

On the question of accuracy and data validation is bit challenge in the sense that some information acquired from the community perspective are questionable and sometimes such information cannot be verified from other sources. For example when the community justified that cloves yield influences rainfall intensity; then no data source can validate about that information. Hence further researches are needed to clear such dilemma.

7.6. Similarities and Contrasts of Local Knowledge Dataset and Secondary Dataset introduction

7.6.1. Similarities

Both datasets comprise of spatial and non-spatial data. For example, on one hand the locations of physical features as shown in community sketch and imagery mapping (map 4-1, 4-2 and 5-1, 5-2) and causes and

effects of groundwater decline non-spatial data obtained from FGDs. On the other hand, location and land use map (map 1-1 and 6-2) and statistical data of rainfall and springs yields from secondary dataset.

Both have temporal data aspect. E.g., spatial development of 2000-2010 as plotted in the community imagery mapping and historical narratives provided by the key-informants while from secondary dataset we found data like 1998-2011 rainfall data and 1998-2011spring discharge data.

7.6.2. Contrast

The major different between the dataset is seen in area of data management (i.e. data acquisition, organising, processing, storage updating and editing). Unlike secondary dataset, local knowledge dataset is scattered between and among local individuals. It is not organised, processed or documented. Updating and editing of data is done in a traditional or cultural manner, say elders train young generations on only important things such as protection of bamboo tree for preservations of groundwater.

7.7. Qualities Assessment of Local Knowledge and Secondary Data Sources

Basing on this study that used participatory mapping tools to assess groundwater decline, the quality of local knowledge data source is determined by familiarisation of data provider to the study area and the study field. If the provider is well familiar with area that resources is found, the quality of information from such source is expected to be valid. This was revealed in this study which used familiarisation as one among the criteria of selecting resource persons for data collection. The result showed that the locals who long lived in the case study area closer to the water sources are more knowledgably about water sources condition and its surrounding environment. Besides, the quality of the secondary data can be assessed in aspects of validation and data source reliability.

CHAPTER EIGHT

8. CONCLUSION AND RECOMENDATION

8.1. General Conclusion:

In principal, the study of Participatory Mapping to Assess Groundwater Decline measured the decline of water level in groundwater sources of Mtoni and Mwanyanya Spring basing on local people knowledge living in the spring's neighbourhoods. This assessment was qualified using scientific data and assessment methods. The results proved that participatory mapping assessed decline of the groundwater through using community perspective and qualified through conventional assessment. Furthermore, the LSK is useful in assessing natural resources particularly groundwater. Rationally, the assessment is concluding as follows:

8.1.1. Local Spatial Knowledge on Causes and Effects of Groundwater level Decline

According to the local community, groundwater decline on one hand is a result of human activities in the catchment areas particularly up-stream. These activities include agriculture, deforestation, and settlement development as well as extraction of groundwater through pumping from wells. On the other hand it is a result of natural consequences of weather condition which affects hydrological circle and cause shortage and unstable rainfalls. This certainly causes poor recharge of the groundwater.

The decline of groundwater level affects the local community in economy, socially and healthy.

- Local people extra spend their time and money to fetch water, which they could use to attain other socio-economic activities. They spend much money to pay for extra water costs for water purchasing from.
- The Society experience social disputes rose because of water fetching, controlling sources and condemning misuse and abuse of water sources.
- Local people risked their healthy due to using of un-safe alternatives water sources including from water venders who do not care about water quality as they care about income.

8.1.2. Coping Measures to Counter the Effects of Groundwater Level Decline

The study identified coping measures to counter the effects of the groundwater level decline in the study area. Among these measures are:

- The local community identified the groundwater decline related problems, organised themselves and set measures to deal with them.
- They developed strategies that included awareness raising, cleaning of steams, drilling wells and making water fetching schedules that helped them to control social conflicts.
- High involvement of community members in dealing with water issues, which resulted to proper flow surface water in the streams, meeting of their water demand and avoiding un-necessary disputes among the community member because of water.
- Through using local leaders and religious committees, community managed to solve their spatial related problems such as to deal with people constructing in water catchment of disposing solid wastes in streams.
- Through using the Shehia committees, the community corresponded and collaborated with external institutions for dealing with water related issues and land use conflicts. It also facilitates attaining of external support to the community.

8.1.3. Usefulness of Participatory GIS in Assessing Natural Resources Particularly Water Sources

Regarding to the comparative assessment of the Participatory Mapping and Scientific approaches, Participatory Mapping is useful in assessing natural resources such as groundwater sources. Even though it cannot be used alone due to its limitations to fully assess natural resources. Basing on that, the following areas are justifying its usefulness and weaknesses:

- The obtained quality of LSK in assessing groundwater was influence by familiarisation of local people to the study area and study issue rather than capability of gender in providing information. Both genders (men and women) groups have competence of generating LSK..
- Relevance of the local knowledge in assessing groundwater sources revealed that the elicited knowledge for assessing groundwater was only preliminary knowledge which consists of some new study areas such as prediction of rain intensity by using clove yields. Still further studies are needed to be combined to strengthen the assessment.
- On potentials and shortfalls of using P-GIS in assessing groundwater sources concludes that Participatory Mapping shortfalls are few to compare with advantages that makes it to be useful in assessing resources. Yet validation of doubtable data from reliable sources cannot be ignored.
- Unlike secondary dataset, local knowledge dataset is still poor and un-organised, which results to miss trust some local data sources due to information variation with respect to local data sources. The researcher is obliged to rely on the more valid data sources among the available datasets.
- Similarities of the local knowledge dataset and secondary dataset are substantial detected on type of data features while contrasts are mainly detected in data set properties and management from which the local datasets are mostly un-organised and weak.
- Finally, the qualities of local knowledge and secondary data sources can be assessed by regarding first local knowledge data collection methodology, selection criteria of the study area and resource persons or respondents regarding their familiarisation of the study area and knowhow of the study issue. Then, quality of the secondary data can be assessed regarding the reliability of the sources and validation of the data.

Hence, this study added value to the participatory mapping approach in assessing natural resources from not only to identify, planning and managing of on-ground resources but also underground resources such as water and the likes.

8.2. Study's Limitations:

- Time scheduled for data collection particularly mapping exercises was not enough. Sketch mapping exercise for example took about 30 minutes instead of 15 minutes due to intensive discussions on what to sketch where and how. Similarly in imagery mapping, groups took more than 50 minutes instead of 30 due to memorising features development in a particular time. Groups kept on arguing what was developed and when.
- Apart from the attempted conventional assessment on groundwater decline, the study had limited data and approaches distinctive to the elicited LSK for justifying every local based data and fact. Literatures were used to develop some justifications although they were not seemed to fit very well due to different circumstances of the study area.

8.3. Recommendations for Further Researches:

Taking into account the discussed study's findings and limitations, this study recommends the following on further researches on participatory mapping methodology and the usefulness of the LSK.

8.3.1. Participatory Mapping Methodology

The study's findings identified that more could be elicited from the community if the assessment was able to identify and map not only springs and surface streams but also underground water such as water table and groundwater storages. That process would require groundwater identifier (sensor) and measuring instrument. Thus, this research recommends the use of such tool that will be incorporated in participatory mapping for ground resource assessments. The tool should be able to be used with or by the local community themselves so that they will be able to identify and map their own resources with little technical support from outside. Probably the community would be enabled to monitoring groundwater resource for effective and sustainable management.

8.3.2. Usefulness of the Local Spatial Knowledge

The notion that community are unwilling to provide and share knowledge on matters that they are accused for misuse and abuse has been reversed in this study. Thus, the LSK on groundwater sources and catchment management that was discovered in this study is highly recommended to be adapted in conducting natural resources researches that communities have interest in their daily life.

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9. ANNEXES

Annexes 1: Research Matrix

Questions	Relevance	Data Collection Method and Output
Objective One: *To come up with Local Spatial Knowledge (LSK) states causes and effects of groundwater level decline in their locality*		
What causes decline of water level in groundwater sources in the study area?	Elicit qualitative LSK of decline causes in groundwater sources	• Sketch mapping shows spatial features that causes the decline • FGD comes up agreed causes for the decline
How the water decline affects local people in the study area?	Elicit qualitative LSK of decline effects groundwater sources	• Sketch mapping shows spatial features that reveals effects from the decline • FGD agree on effects of the decline
Objective Two: *To elicit local based coping measures to counter the effects of groundwater level decline*		
What coping measures are taken by local people in the study area to deal with water decline?	Comprehend coping strategies of LK on water decline effects/ impacts	FGD comes up with most important ways /measures they use to deal with decline of groundwater level in the society
How local people resolve spatial problems among themselves	Measure local people ability in determining coping measures among themselves	FGD outlines hints and strategies for compromise and management of their spatial resources
How local people resolve spatial problems with official institutions.	Measure local people ability in determining coping measures with institutions	FGD outlines strategies for compromise with institution for and managing resources
Objective Three: *To find usefulness of Participatory GIS in assessing natural resources particularly water sources*		
Is there significant different between genders LSK in assessing groundwater decline?	Understand knowledge capacity between men and women groups	Data sorting in gender group basis for research topic findings and discussion
What is the relevance of the local knowledge in assessing groundwater sources?	Value LSK in assessing groundwater decline from official data records	Review water quantity records of groundwater sources specifically of Mtoni and Mwanyanya Springs from office archive
What are potentials and shortfalls of using P-GIS in assessing groundwater sources?	Evaluate the usefulness of the PGIS in assessing groundwater resource	Analysis and judgment on usefulness of PGIS in assessing water resource particularly (the decline of groundwater sources)
What are the similarities and contrasts of the local knowledge data set and secondary data set?	Compare datasets and see their relationship	Identify similarities and contrasts between the datasets for observation of usefulness of the local knowledge
How the qualities of local knowledge and secondary data sources can be assessed?	Qualify the value of the LSK basing on its data source	Analysed data sources for discussing the usefulness of LSK in resources assessments

Annexes 2: Focus Group Discussion Proceedings

Focus Group Discussion Activities

Activity 1: Opening FGD

The local leaders (Shehas of the study areas) opened the meeting by introducing the researcher to the community and brief the intention of the meeting (i.e. To grasp the local knowledge on the question of groundwater decline).

NB:

- The introduction was made before splitting of the groups into two, men and women.
- Meeting participants were all adults and lived in the area for more than five year.
- The intended number of participants was 12 to 13 per group but actually an average of 18 people participated per group.
- The opening speech was not discussed and the leader welcomed the facilitators start discussion programme

Number of participants

Shehia of Mtoni		**Shehia of Mwanyanya**	
Men	Women	Men	Women
17	18	19	17

Activity 2: Introducing the FG the Groundwater Decline Concept and Discussion Ground Rules

Facilitator briefed on the general concept of groundwater and its threats world-wide

The group agreed on discussions ground rules which included switching phones in silent mode and making the discussion free and opening to every participant.

The group was split into two basing on gender.

Activity 3: Sketch Mapping

Facilitators of each group asked the group members to draw map of the Shehia on flipcharts with significant spatial features

Shehia of Mtoni		**Shehia of Mwanyanya**	
Men	Women	Men	Women
• The group used short discussions and quick consensus • It generalized features in small scale for mapping • Selected central feature to start mapping • Access roads, river and paths were the input features to the central one • Water source and Masjid (worship house) were among the important land mark of the Shehia • Legend and North Arrow was provided to define some features with symbols like houses, roads and river and orientation of the map	• The group made long discussions to agreements • Detailed features in large scale mapping • Water source was the key point of the map • Access roads, river and paths were the map framework • Houses and other features like bamboo trees, army camps and schools was input feature to the layout. • Uses of shape, symbols and labels to describe features - in the map.	• Strong discussions and supportive contributions • Large coverage with many features in a small scale • Broad knowledge of the study area • Key map features include main road across the Shehia from urban to country side, sea shore and forest • Access road, common structures like Masjid, water source, and schools were key land mark for other feature organisation in the map • Important features were also labelled • Use of map elements like legend and North Arrow Direction.	• Took long time to discuss and agree each other • Small coverage with few detailed features • Uncertainty knowledge of areas beyond their livelihood • More emphasis put on central access road which connects various places in the area. The road has also direction arrows • Shapes, symbols and labels were used to represent features in the map. • North Arrow Direction was used to orient the map.

Activity 4: Group Discussion on the meaning of the groundwater decline, causes, effects and coping measures

The facilitator initiated the discussions by asking the group members to discuss and come-up with agreed groundwater decline causes, effects and coping measure. He also introduces the opportunity for the group to use time-line scale to state the situation. On the other hand the groups were asked to discuss and come-up with ways they used to resolve their water sources and land related disputes among themselves and between the community and outsiders.

The main discussion topics are:

- What is the groundwater decline?
- How groundwater decline happened and why?
- How people are affected by groundwater decline?
- How people are managing their land related conflicts?
- How people are dealing with groundwater decline?

Causes of the groundwater decline:			
Mtoni		Mwanyanya	
Men	Women	Men	Women
• The group defined the groundwater decline as failure or lose of ability of a water source to produce the amount of water required to fulfil regular consumer's demand that normally they used to yield	• The group came-up with the meaning of groundwater decline as the reduction in amount of water in springs from its original level to other lower level less than the original one	• The group define the groundwater decline as the decrease of water level in the springs or other groundwater sources	The group defined the groundwater decline as the situation where water sources lost its production capacity.
• The group declared that they do not have proper measure to tell that the water was at a certain level/amount and now is in a certain amount. • The major causes for ground water decline include: o Shortage of rains o Haphazard cutting-down of trees o Housing construction o Sand excavation o Changes in weather condition o Contamination in catchments such as throwing of solid wastes • The group used to introduce an issue say meaning of water decline or to mention the cause then the point was widely discussed. Then agreement was put in the flipchart. The writer had to read what he wrote and asked if is right or not. • In some cases, the group realised that what they were putting in the discussion was their fault that contributed to water resource problem such as contaminations and haphazard construction • They also insisted on keeping on discussion rather than one to write down everything for them.	• They discover the water decline from the way they used to fetch water from the spring through the pipe which was set on top of the constructed chamber of the spring (see photo) but now they use water bucket in the chamber to get the water. (Meaning that the water went down) and even the springing speed is reduced and cannot be seen clearly as they experienced to see it before. • In their area, the water started to decline suddenly due to the weather condition. • In 2009 the water declined because of o Cutting down of bamboo trees o Increase of residents in the area o Construction without know-how • The group memorised the time of decline as it was water scarcity time such that they used to wake-up in late nights to fetch water.	Causes of groundwater decline are: • Deforestation in spring catchment areas. • Sand excavation in the catchment areas • Housing construction in catchments & conserved areas • Changing of weather condition which causes lack of rains • In a period of 1985-1988 - 1990 major change of water level was observed which caused by: o Cutting trees especially bamboo trees o Invading of catchment areas for agriculture and housing construction o Small-scale agriculture activities in the springs (sources) areas • From 1991 to date (2011) groundwater decline keep-on increasing due to: o Housing construction in the nearby water sources, forest and rivers o Increase in population o Sand excavation in water catchments o Increase in water consumption o Haphazard deforestation o Changing of weather condition	Water declined because of: • increase in water consumption due to the increase of users • environmental degradation • in 2000 the water declined and they realised from the discharged water failed to reach to places they normally experience to reach
Effects of the groundwater decline:			
Effects of the groundwater decline include: • Insufficient water resource to satisfy daily consumption • Crowding and long queues in fetching points • Health risks for consumers • High costs in time and money	• Strife among people (children and women) • Contamination of the environment	Before putting down the declining of groundwater effects, the group first discussed the meaning of effect that could be positive or negative but for the group agreed water decline has only negative effects.	Among the observed effects are: • To use much more time to fetch water from far places and long queues • Emergence of infectious diseases • Decreased of productions such as agricultural products

		• Scarcity in water availability • Spending more time for water fetching. • To go long distances to look for water • Loss of some animal species that live in water such as lizard • Drop of economy and domestic production due to the use of much time and money for fetching water.	
Coping measures taken from groundwater decline:			
• Construction of concrete chamber in the source in-order to prevent water loss (runoff) and contaminations (supported by Red-cross) • Community organised itself and cooperate with the Department of Water • Conducted cleaning operations of sources (spring and river) and the nearby catchment areas. The operation scheduled 2 to 3 times a month depend on the condition of the sources • Other measures included o To seek support from for drilling boreholes or protected wells and construction of water reservoir for water storage. o To seek support of putting water guard in-order to prevent waterborne disease o To seek support for continue developing the construction of retaining-wall around the source and river sides to control soil erosion and contaminations o To raise awareness among the community members on the impact or effects of the increased decline	• The community called meetings and discussions which lead to the digging of the community well to help to reduce inconveniences as a result of water scarcity.	• The community had community awareness raising sessions to educate each other on the actual situation and discuss the way out like: o To dig more local wells o To establish conservation projects for water sources/ catchment and lands o To issue punishment to those who are against community resolutions which include taking them to the court of law or government institutions	The community organised itself and started to: • Plant trees (particularly bamboo) • To drill extra wells • To contact with various respective organisations for the intention of getting support of improving the water situation in the area
Conflict/dispute resolution among the community			
• When dispute arises they call the community meeting to resolve it • To set special arrangement to enhance proper utilisation of water during the scarcity. Women are given priority in water fetching • Raising community awareness on the importance of protecting water sources and its impact if it is not well attended	• Announcements were displayed to the whole society to caution on any kind of destruction or contamination of the sources, action will be taken against the opposing people. Community organised meetings to discuss and find solutions • The community used Masjid Committee to resolve their disputes	• The community committee disciplined those misbehave on the agreed community issues on groundwater conservation. Among the punishment set were to plant number of trees or could be taken to the court of law and to educate those who found ignorant • The group referred to causes and effects of groundwater decline and cautioned	• The community has sits to discuss and resolve their disputes related to land uses and water sources • They use to inform responsible institutions but they got no effective respond

	related to water resource, source and land and land use related conflicts.	themselves not to avoid the truth that some of causes are their own fault.	
Conflict/dispute resolution between community and outside organisations			
The group did also give its opinion on improving the sources hygienic condition and water storage. They meant to say it would be more appropriate if there will be sorted a specific places for washing clothes, construct water storage tank to stop water lost and re-use the water during the water deficit	The Masjid Committee cooperates with Shehia committee to deal with community issues in Government and non-government offices and organisations	• For water resource issues the community through its development committee contacted with ZAWA to find solutions. Also it meets with other related organisations to discuss particular issue like conservation of forest • Either, there is a good cooperation between the community and other institution in looking for appropriate way of resolving disputes and planning for community development	The community through their representatives (committee) went to government organisations such as Department of Water and Lands and tried to reconcile on Mwanyanya main water source area, its buffer zone and catchments area. Governments overruled by prohibiting any human activities in buffer zone of 150 metre from the source but outsiders are still invade and excavate sand in catchments and cut-down trees. **NB:** Besides, the group give their opinions by asking the government not to sit and discuss about water sources and catchments without making follow-ups or involve the community living in such areas. People have big roles to play in conserving and safeguarding the sources and its catchments. What they need is to be empowered and mobilised to play their roles
Activity 5: Imagery Mapping			
Mtoni		Mwanyanya	
Men	Women	Men	Women
The facilitators introduced the imagery mapping exercise by asking the groups to draw on transparent sheets affixed on satellite image. The group asked to draw many maps as they want that could show spatial development took place over certain period of time according to their memories.			
The group came-up with spatial development took place in periods of five years interval started from 2000, 2005, and 2010 More emphasis was put in showing construction of residential houses and expansion of the settlement areas towards the source and catchment Representation of the development in map was showed in cluster form and not as single house or feature	The KVZ area in 2000 was the SUKITA project area. It was used for poultry keeping and vegetable garden. The area nearby was only open ground and forestry. The school at the time being had few classes and the health care centre was not constructed yet. The spring area was closed by tree's canopies and the spring was open (not protected). Coming to 2005 period, the SUKITA area was changed to the KVZ camp which was fenced with solid wall, school was developed and Masjid nearby the spring was constructed. Houses also were developed nearby telecommunication tower and	The group decided on the spatial developments in four periods, before 2000, 2000, 2005 and 2010. But the developed map showed only three period with the same meaning i.e. Development up to 2000, development from 2000-2005, and from 2005-2010. Major argument was on health care centre which was constructed (before 2000 or 2005 but Bububu school was already constructed before 2000 (difficult in memorising things particularly the non-commonly features. Argument on new residential houses, some of group-	The group put emphasis on change of use of open spaces such as playing grounds, non-governmental forests. Residential houses were developed and increased vividly. The development took place between 2005-2010 increased housing density to the already housing settlements while outside the settlements the encroachment of the public lands and forest continues till to today. The group was much discussing and so slow in drawing that took about one hour to complete one map.

	nearby forest areas and open spaces like playing ground pitches. Other playing ground pitch was developed in forest areas and the numbers of houses in developed areas were increased. In 2010 the forest decreased and at nearby spring it was cleared. Numbers of residential houses were doubled in some areas but army camp was not touched. There is also new gas station at the main road.	members wanted to mention and show in map houses (and owners) one by one while others disagreed due to unrealistic; because there are so many houses but some of them were afraid of something bad may happen if it will be mentioned. The group agreed to generalise the features in a cluster form.	

Activity 6: Wrap-up the Focus Group Discussion

The Recorder summarised the activities took place in the focus group discussions and highlighted common discussion points and discussion main outputs as they were drawn by the groups. Key points were mention by comparing between groups and see if were there any disagreements from the group members and to see if any major point was left out during wring in the flipcharts.

All most all groups had no objections on the readout points and had nothing to add except the Men group of Shehia of Mtoni who insisted to ask for the support from any interested organisation to support them on improving the condition of their water sources.

Activity 7: Closing the Focus Group Discussions

The local leaders on behalf of the Focus Group Discussion team thanked the participants for their attendance and active participation as well as contributions which were open and remarkable not only for researching purposes but also for the leadership of the locality and government as a whole.

Almost all discussions took about three hours except the women's group of Mwanyanya took about 4 hours to complete.

Annexes 3: Key Informant Interviews

Respondent: Mr Abdalla Machano Idrissa of Shehia of Mwanyanya

Age: 74

Time of living in the study area: 43 years.

Special entity: He has long experience in water resource aspect particularly Mwanyanya main spring. Before he became a permanent resident in the Shehia, he used to work and do socio-economic activities in the Shehia for more than twenty years.

Occupation: Retired watch-man of the forma Department of Water-Zanzibar (now ZAWA) responsible for Mwanyanya water station.

He got his basic experience on water resource from Chinese volunteers who used to work in Water Department as water engineers in 1960s. He was attached to the team for some times (about 2 years) before he was officially employed by the Department of Water in 20th January, 1968.

Discussion:

What is your understanding of groundwater decline?

The water from the Mwanyanya spring was so huge. It did not have seasons or months or days. It flow-out all the times. Water was spilled out the reservoir chamber throughout a year and for many years. The big pipe that takes water to Saateni water station was all covered by water from the spring for long time but today it can be seen clearly except during heavy rains.

In water-shed or reservoir where main pipes send water to town installed, you find water marks of different times. It can be seen differences of water levels of that time, which was so much that the whole chamber was covered by water; unlike now where only can be seen down the chamber.

In the spring, it is difficult to see its level or measure its amount but in the chamber because it is a shed you can see marks where water used to reach that can be used to distinguish its level in different times.

Which specific year you remembered that water was in such situation (huge, and you can't differentiate its level between seasons such as dry and rain seasons)?

Actually, I cannot remember about years but it was before the ruling of President Salmin Amour when water situation was very good and after that the water started to decline year-by-year, month after month day after day till to the situation we have today. It started to decline in season's periods that a certain water level could not reach until Masika rains or Vuli rains, then it went down till even the previous season could not reach to next season and now it seems to decrease to a large extent and I don't think it will go back to previous amount.

You know at those days all these areas were covered by trees but today trees are only cover the spring area and the rest there is nothing.

Do you want to say trees contribute to that situation?

Tree attracts rain, so if there are no trees problem will raise even to barrier wind blowing which drive-out water.

Are there any other reasons that causes decline of groundwater?

May be but this is what I can say for now.

You have said that after the ruling of the Dr Salmin Amour water started to decline, how can you differentiate the decline before that time, during, and after that time, or any other time after?

Especially, during less rains in a year, water decline increases. It takes long time before it rains till land becomes dry so that groundwater decreasingly down because of lack of rains or insufficient rains. Long time ago I remember during Pupwe time (the coldest season of the year) you would find areas like this

(water catchment) is all covered by smog during morning times, the sign of groundwater presences but now no Pupwe that could come and causes such situation you will find is just like dry windy.

What is the essence of the smog, does it has anything to do with the groundwater?

Actually, if ground has water, it shows as vapour on the ground. It also happened in water ponds areas where water evaporates during morning times. You cannot see it in dry lands. This means that fog or vapour on lands is a sign of groundwater presence nearby upper surface or whenever you see such thing, understand that amount of water underground is high and when groundwater amount is low the smog disappear as well.

Is there any other indicators shows the sign of presence or decrease of groundwater?

No, I don't know other indicators.

Apart for the water mark in the reservoir or water coverage of main water-pipe in the reservoir/chamber what other measure you used to identify the increase or decrease of groundwater level?

Long time ago we used a tree pole which has numbers. We used to measure water level every day in mornings and keep records. Also in the chamber door there was an iron plate on which water passes. We used to measure water on that plate and know how much it rose. Also the water sound when it poured in the chamber we could identify if the water is much or less due to its speed from the spring now the sound is so small. But I don't know how now they measure the water amount.

When we come into local norms is there any believes concerning the increase or decrease of groundwater?

He hesitated to talk about that although he revealed that in a long time ago, the spring area was also place for Satan who used to protect the spring against violations or people who came for washings or destruct the source. He himself has never seen that apart from hearing from other local people. But once a number of people increased in the area that notion disappeared and nothing is going-on. Guards are taking care of the source and still water is decreasing days after days.

Due to your experience that you have observed the water situation day after day, year after year, what is your expectation of the water situation in the next coming years (say five to ten)?

He said he cannot guess, totally it depends on God. Groundwater depends on rain. If rain comes water will be available but if not we should expect more decline.

What is done to improve the groundwater situation?

All area around the source including the upper hill areas was planted trees but people have cut the trees for construction and some people cut trees and excavate sand in catchment areas. Main pipes which were below the earth surface are now open due to the sand exaction. The hilled areas above the source have affected by sand excavation and housing construction. You know if you dig a hole of about one to two metres; the sun will heat the area and causes the water to go further down. That is sun light pushes the groundwater down. As far you dig and water immerses down. It doesn't stand to see the sun light. So trees proved shade. If it will rain the moist or dampness remains for a month or two but the cleared land water is not retaining in the ground.

The uphill areas help to collect water from the forest and flow into the river. Some water from the river is contributing to the spring and the rest is discharged to the sea. Long time ago the area that you are seeing it today as spring was like a big pond. Water from the ground streamed out and formed a natural pound that was used by people to swim, wash and do many things (it was during the Colonial period in 1880s where the Sultanate of Zanzibar excavated the area and construct a big concrete chamber for controlling runoff to the reservoir chamber. From that chamber water flowed by gravity to Saateni Water Works Station and to the Zanzibar Harbour for ships came to Zanzibar at that time for their business and other

came specifically for taking water due to its quality which was purely natural and very clean. This is to say the spring was not only one but many and its accumulation made spring chamber that can be seen today.

What is the secret of bamboo trees with groundwater?

These trees provide good shade for storing groundwater. Most places that have groundwater bamboo are growing.

So, why it is like that?

They thrive and surviving by groundwater. That is why they grow in water catchment areas. In this area bamboo were planted and spread along the river. They provide shade to the river and spring and help to keep groundwater. People are cutting bamboo because they are good construction materials.

Summary: the discussion by the researcher and respondent was asked if he is willing to be mentioned his name in this research. He agreed to be mentioned his name.

Respondent Number Two: Shehia of Mtoni

Name: Abdul-Karim Rashid.

Age: 47:

Time of living in the Shehia (study area): 26 years.

Special entity: Long experience in land administration matters and social disputes resolutions. He is also a senior member of the Masjid Committee in the Shehia.

Discussion:

In generally, there is a water deficit in ground sources due to decrease in amount of water recharge and that was caused by many reasons such as:

- Cutting down of tree for agriculture activities, housing materials and construction
- Expansion of residential settlements in forest, streams and close to water sources
- Increase in population and human activities in water catchments
- Sand/soil erosion as a result of land clearance. Soil is washed to water catchments and spring which then causing less rainwater penetration to the ground and the spring as well.

During the water decline people suffered from water deficit such that they only get little freshwater from sources in early mornings then becomes dirty and un-cleared which is not safe for drinking.

In 1970s the whole area was covered by thick forest and water at the time was very well. The situation continued to be well until in 1980s where small changes were noticed in population and agricultural activities but water was still fine.

In 1990s, people started to settle nearby water sources and water started to decline. The situation became worse in the 1992-94 where people constructed their houses closer to the Mtopepo which caused the Urban-West Commissioner of that time to demolish houses near by the spring and Mtopepo river bank. Settlement expansion continued corresponding with the increase of groundwater decline till the spring is surrounded with settlements and obviously, the spring will dry.

All water sources are under the government supervision to ensure that they are okay. The government is dealing with only sources and not catchments that are the life of the spring; for example Mtoni spring is believed that its source is an underground stream from Masingini Hill. Still people were not stopped to cut trees and construct houses in Masingini. In fact, some of residential plots are officially surveyed. Then what should we expect if not more drying of water sources.

In 2000 the water overflow from the spring has totally stopped and between Novembers and Marches (dry season) the water levels now show to drop in the spring itself. Among the indicators which show that water decline is dry-out of the stream runoff to the sea. The river was not seasonal like it is seemed today.

Effectiveness of community cannot directly be seen in the management of water sources. The government does not recognise community efforts on conserving the sources or involve them in the management. Every part is doing on its own. The community have environmental projects that dealing with tree plantations and Masjid committees that deal with protection of water sources and disputes resolutions while government is doing in its own similar things but most of the time is against the community with the notion that they are the major source of the water decline and environmental degradation. But that is not true because we are the one who are affected when water is not available. We know outsiders are the one doing these illegal things.

Some of residents are cutting trees for energy consumption and very few are making charcoal for business and some of them are using the tree and sand/soil as building materials.

On the land management part is that, many areas of the Shehia are owned by the people themselves. Individuals land lords are capable of controlling their lands against illegal cutting of trees or sand excavation. They are managing themselves. The only problem is on land sub-division and selling to other people which then turned them into residential settlements. And this is a challenge for the Government because they cannot stop them from selling their properties.

Buffer zone is safeguarding of water quality against human activities and protecting sources from being perished. Director of Water Department declared 150 metres buffer zone from the springs to settlements and the community accepted that but I don't think if it is enough because spring has sources that could be surface and ground rivers which also need to be protected, by introducing laws that will control development in upstream rivers and hills which bring water to the springs.

Generally, during dry season (December to Mach), rains are very few although sometimes *Vuli* rains that comes in August -November can be very heavy and helps to keep moist for sometimes up the beginning of *Kiangazi*. *Masika* starts 21st March to June and connects with *Pupwe* (winter) season in June to August. *Pupwe* has light rains and cold winds that keep lands moist. We believe that wind dries the groundwater, so if it blows too much the amount of water loss will be much. October-December is uncertainty period because if *Vuli* rains are poor then land becomes dry and hard for agriculture while underground water is diminishing.

In finalising the discussion, the researcher highlighted some of key points of the discussed in-order to see if the respondent has anything to add or correct or to discard. The respondent agreed to be mentioned his name in the research.

Annexes 4: Semi Structured Interview

Guiding questions include:

- How do you assess the hydrological situation of Zanzibar in the five past years?
- According to the organisation (ZAWA) what is the expected situation of groundwater of Zanzibar and the study area sources?
- What do you think could be the reasons behind such situation and why do you think so?
- Which parts of the Island are more affected and why?
- What the organisation (ZAWA) is doing to manage the situation (groundwater decline)?
- Is there any consideration of involving local people in groundwater resource management? If yes, how should they be involved?

Name of the respondent: Rukia Masheko Ali

Title: Water Resource Officer - ZAWA

Discussion:

Hydrological circle has large extent from the drop of rain get into the earth surface and travel to the ground to the atmosphere up to rainfall again. The catchment is the whole area which stores rain and surface water and feed or charge the groundwater. From that point of view community is ha a major concern in managing catchment areas. The issue is do the community aware of that or not or if they have any knowledge on the way managing the catchments or not. The human activities that take place in catchments have direct impact to water sources; for example as:

- Water catchment areas do not need human activities. Human activities cause land compaction that reducing rate of soil permeability. By compare virgin land or farm that its soil is loose and residential settlements land, the farm land capacity to rainwater penetration in higher than the residential land which its soil porous are compacted. Theoretically the total amount of rainfalls distributed to runoff to rivers, lakes and marine. Other amount is immersing into ground to aquifer and after under gone with respiration process water from the ground and earth surface evaporates to the atmosphere which then gone under condensation process before falling down as rainfall.
- Rate of re-charge depends on soil coverage. If the soil is covered by hard materials means the ability of drop of rain to penetrate to the ground is low and if the soil is not covered by trees or grasses the rate of evaporation becomes high and reduces the amount of water to be retained in the ground. That entire situation requires communities live in the catchment areas (as the main stakeholder) to understand hydrological circle and ensure water circulation favours the groundwater recharge. If we have water dams for instant, it will favour water retention to the ground which is good for us who rely on groundwater. Hence, it is important to analyse factors influencing groundwater re-charge by looking catchment areas and how people cutting trees, paving, keep animals and cultivating.
- On the case of soil/sand excavations also it has impact on groundwater recharge because it leads to having water ponds. Technically, tropical countries like Zanzibar rate of evaporation are high in ponds or open water bodies to compare with bare or un-compacted lands or hills. Also in quarries sites, they associated with so many activities like truck movements that causing land compaction which reduces the capacity of land to absorb rain water hence results to low recharge
- Trees species have influence on groundwater. There are water loving and water hating species. The water loving species have a tendency of retaining water in the ground such as Mitondoo or Mitomondo and water hating species like caliptus (Mvumo) tend to absorb water from the ground or uses much water in respiration processes. Generally other trees growing in water sources like bamboo have roots that keep water and control evaporations. But this subject needs tree species specialists and environmentalist to talk in deep about it. For our case of water resources and

hydrology expert, tree species help us to detect groundwater availability rather than understanding species causing water to decline if they will be cut or to increase if they will be planted. Besides, trees in general have influence in hydrological circle. The characteristic of water hating trees is that they observe water from the ground and you can find moisture on earth surface in mornings which later-on evaporates.

- About fog or water vapour in Pupwe seasons during morning times, there is no evidence to show if it indicates the presence of groundwater or water table is high or whatever. But frost or dew formed in morning times is what is so called condensation and respiration process of hydrological circle. May be further research is needed to find out if there is any relation between smog/fog and presence of groundwater. The important thing is to find out where fog-water comes from. If it is from the atmosphere that means is a condensation process and if from the ground or trees it is a respiration.

Name of the Respondent: Said Saleh Abdul-Rahman

Title: Senior Water Resource Officer – ZAWA Zanzibar

Title of the Document: "*Kutohifadhiwa kwa Mlima Masingini Kunapelekea Kukauka kwa Chemchem za Mwanyanya na Mtopepo"*

Theme of the document: To describe reasons for depletion of Mwanyanya and Mtopepo Springs

Major alarms of the document:

- Brief history of the urban water supply of Zanzibar town from 1880 where the Zanzibar Ruler King Sayyid Barghash bin Said established the system from the sources to stone-town by using local drains.
- Improvement of water collection system from the sources to Saateni reservoir before distribution to the supply system in 1923. The improvement also included the use of metal transmission pipes instead of local stone drains.
- Increase of urban water supply due the increase of demand in 1960s by adding boreholes of Kianga and Mwembe-mchomeke.
- Starting of environmental degradation of Masingini hills in 1980s due to deforestation and housing construction.
- Impact of settlements in Masingini Hill/forest that caused rainwater to run away to streams and reduces groundwater recharge.
- Suspension of Mtopepo Spring in 1994 due to environmental study's results which found unacceptable amount of solid particles in water.
- Government interventions in 1996 which include demolition of settlement in Mtoni area to combat with the contamination of the sources from human activities but nothing has been done to increased settlements development in Masingini area.
- Statistical information of decrease in water discharge of Mtopepo and Mwanyanya in ten years period from 1998 to 2000

Year	Water discharge to Saateni (Billon Litre/year)	Year	Water discharge to Saateni (Billon Litre/year)	Difference in periods of 10 yrs.
1998	3.31	2008	1.95	3.21 – 1.95 = 1.26
1999	3.02	2009	1.70	3.02 – 1.70 = 1.32