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EVALUATING WATER SECURITY IN A CHALLENGING ENVIRONMENT: CASE STUDY OF OTI NORD SUB BASIN IN TOGO

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DECLARATION

I, Mawulolo YOMO, hereby declare that this thesis represents my personal work, realized to the best of my knowledge. I also declare that all information, material and results from other works presented here, have been fully cited and referenced in accordance with the academic rules and ethics.

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ABSTRACT

Water shortage across the globe has increased due to climate change among other factors with highly projected impacts expected at river basin level. Anticipating these impacts will help act on time to avoid future water crisis. As part of addressing future water shortage impacts on the Togolese community, this study aims at evaluating water security in the context of the global environmental change at river basin level taking the Oti Nord sub-basin as a case study.

Primary data were obtained through key informants' interviews while secondary data were gathered from relevant published and non-published papers and databases. Key informant interviews were done with staff from the governmental institutions, in addition to NGOs, community-based organisations and private operators. The Improved Fuzzy Comprehensive Evaluation Model (IFCEM) was used in assessing water security level in the sub-basin.

The results showed that the implementation of the adopted Integrated Water Resources Management approach was still at an early stage and not really evolving. To ensure water security in the Oti Nord sub-basin, the existing institutions, from different levels and domains of intervention contribute either directly (through water resources mobilisation, water resources management, control of pollution, protection of water bodies, development of water bodies, and the monitoring of drinking water quality) or indirectly (through juridical intervention, awareness raising and tree planting). Nevertheless, actions carried by these institutions are done in a dispersed way. As for the water security level, the study has shown that the overall water level is very insecure in the sub-basin for the assessed years (2010, 2015 and 2025) with the year 2025 being the worse. Water insecurity in the Oti Nord sub-basin is found to be the result of the combination of a decreasing water resources available (associated with the challenging environment such as population growth, climate change among others) and water quality deterioration. Finally, this insecurity is found to be the result of many factors including technical, institutional, juridical, environmental, socio-cultural, hydrogeological and demographical factors.

It was concluded that water security at basin level is subjected to changes in a challenging environment overtime (including climate change, population growth, GDP growth, land degradation among others). Nevertheless, factors such as water governance (including policies and regulations, management institutions and investments), nature (i.e. hydrogeological characteristics) and culture (i.e. taboos and buy laws) play key role in shaping the overall water security level. This study therefore recommends that government should prepare directives for the application of adopted water policies and regulations. The consideration of joined efforts in achieving water security by the existing institutions will be of great benefit. Sound waste management system should be established by the government along with awareness raising and educative activities to reduce the level of water pollution (especially surface waters) in the study area. Moreover, the improvement of the existing water information system (in terms of both data quality and quantity) is required. Finally, to overcome the hydrogeological constraint in the area, methods for water conservation and the use of non-traditional water resources, like rain water harvesting, should be considered and introduced.

Key words: Climate change, Fuzzy model, Oti Nord sub-basin, Water security, Water management strategies.

RESUME

La pénurie en eau à travers le monde a augmenté en raison des changements climatiques parmi d'autres facteurs, ceci avec de lourds impacts attendus au niveau des bassins versants. L'anticipation de ces impacts aidera à agir à temps enfin d'éviter toute crise d'eau dans le futur. Dans la perspective de faire face aux potentiels impacts de la pénurie en eau sur la communauté Togolaise, cette étude vise à évaluer la sécurité en eau dans le contexte des changements environnementaux globaux à l'échelle des bassins versant en prenant comme exemple le sous bassin de l'Oti Nord au Togo.

Les données primaires ont été obtenues au moyen d'interview de personnes ressources, tandis que les données secondaires ont été recueillies des documents et des bases de données pertinents publiés et non publiés. Les interviews de personnes ressources ont été réalisées avec le personnel des institutions gouvernementales, en plus des Organisations Non Gouvernementales, organisations communautaires et opérateurs privés. Le modèle amélioré d'évaluation globale floue (IFCEM) a été utilisé pour évaluer le niveau de la sécurité en eau dans le sous bassin.

Dans la perspective d'assurer la sécurité en eau dans le sous bassin de l'Oti Nord, les institutions existantes, de différents niveaux et domaines d'intervention contribuent directement (à travers la mobilisation des ressources en eau, la gestion des ressources en eau, la mise en valeur des plans d'eau, et la surveillance de la qualité de l'eau potable) ou indirectement (par une intervention juridique, la sensibilisation et la plantation d'arbres). Néanmoins, les actions entreprises sont faites de façon dispersée. L'étude a montré que le niveau global de l'eau dans le sous bassin est incertain pour les années évaluées (2010, 2015 et 2025) avec l'année 2025 étant la pire. Il a été trouvé que l'insécurité en eau dans le sous bassin de l'Oti Nord résulte de la combinaison de la réduction des ressources en eau disponibles (associée à la mutation environnementale tels que la croissance démographique, les changements climatiques, entre autres) et de la détérioration de la qualité de l'eau. Enfin, cette insécurité a été attribuée à de nombreux facteurs, notamment techniques, institutionnels, juridiques, environnementaux, socioculturels, hydrogéologiques et démographiques.

Il a été conclu que la sécurité en eau au niveau des bassins versant est sujet aux changements dans un environnement plein de défis (y compris les changements climatiques, la croissance démographique, la croissance du PIB, la dégradation des terres entre autres). Néanmoins, des facteurs tels que la gouvernance de l'eau (y compris les politiques et réglementations, les institutions de gestion et les investissements), la nature (caractéristiques hydrogéologiques) et la culture (tabous) jouent un rôle essentiel dans la définition du niveau global de sécurité en eau. Par conséquent, cette étude recommande donc que le gouvernement prépare des directives pour l'application des politiques et réglementations adoptées en matière de l'eau. La synergie des efforts dans la contribution à la sécurité en eau par les institutions existantes sera très bénéfique. Le gouvernement devrait mettre en place un système efficace de gestion des déchets, de même que des activités de sensibilisation et d'éducation pour réduire le niveau de pollution de l'eau (en particulier des eaux de surface) dans la zone d'étude. En outre, l'amélioration du système d'information sur l'eau existant (en termes de qualité et de quantité de données) est nécessaire. Enfin, pour surmonter la contrainte hydrogéologique dans la région, des méthodes de conservation de l'eau et d'utilisation des ressources en eau non-traditionnelles, telles que la collecte de l'eau de pluie, devraient être envisagées et introduites.

Mots clés : Changements climatiques, Modèle floue, Sous bassin de l'Oti Nord, Sécurité en eau, Stratégies de gestion des ressources en eaux.

DEDICATION

To the Living God Almighty who guided me in my entire life till this level and particularly for this course: All glory.

To My mother AMAYI Balamwe, my sister LANKE Yawa Kekeli, my uncle AMAYI Mesmein, aunties AMAYI Yvonne and AMAYI Veronique.

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ABBREVIATIONS AND ACRONYMS

ADB:	Asian Development Bank
AIDP:	African Institute for Development Policy
CDD:	Communication pour un Développement Durable
CWSI:	Canadian Water Sustainability Index
DE:	Direction de l'Environnement
DGEA:	Direction Générale de l'Eau et de l'Assainissement
DGMN	Direction Générale de la Météorologie Nationale
DGSCN:	Direction Générale des statistiques et de la comptabilité Nationale
DPEC:	Direction Planification, Etudes et Contrôle
DSID:	Direction des Statistiques de l'Informatique et de la Documentation
FAO:	Food and Agriculture Organizations
FORMENT:	FORmation à l'Entretien base sur l'animation rural
INSEED:	Institut National de la Statistique et des Etudes Economiques et Démographiques
IPCC:	Inter-governmental Panel on Climate Change
IWRM:	Integrated Water Resources Management
JARC:	Jeunes Adultes Ruraux Catholique
MAEH:	Ministère de l'Agriculture, l'Elevage et de l'Hydraulique
MEAHV:	Ministère de l'Eau, Assainissement et de l'hydraulique villageoise
MERF:	Ministère de l'Environnement et des Resources Forestières
MMEE:	Ministère des Mines, de l'Energie et de l'Eau
ORB:	Oti River Basin
PAI	Population Action International
PANGIRE:	Plan d'Action National pour la Gestion Intégré des Resources en Eau
SII-EAU:	Système Intégré d'Information sur l'EAU
SNMT:	Services National de la Météorologie Togolaise
SSA:	Sub-Saharan Africa
TCN	Troisième Communication Nationale
UN-DESA:	United Nations Department of Economic and Social Affaires
UNEP-GEF:	United Nations Environment Programme and the Global Environment Facility
UNESCO-IHP:	United Nations Educational, Scientific and Cultural Organisation-International Hydrological Program
VBA:	Volta Basin Authority
VBO:	Volta Basin Observatory
WR:	Water Resources
WS	Water Security
WSSI:	Water Security Status Indicators
WWAP:	World Water Assessment Programme
WWDR:	World Water Development Report

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CHAPTER ONE: INTRODUCTION

1.1 Background of the Study

Water scarcity is no more a tale across the world. Statistics have shown that up to 4.0 billion people (66 % of the world population) experience severe water scarcity, at least, a part of the year. While one billion people face severe water scarcity all year round (Mekonnen and Hoekstra, 2016). This situation has been attributed to some factors such as population explosion, urbanization, economic development, changes in living standard, increasing water pollution, over-abstraction of groundwater and climate change, which are considered as the driving forces to the global water insecurity (Engineering the Future, 2010; Wang et al. 2012a, b, c; Srinivasan et al., 2013). As a matter of fact, all these drivers are expected to continuously increase the level of water shortage due to the resulting increase in overall water demand (Vörösmarty and Sahagian, 2000; Srinivasan et al., 2013). The overall people expected to live in water-stressed areas by 2050 is reported to reach more than half the world's population (Schlosser et al., 2014; Schewe et al., 2014).

According to the International Panel on Climate Change (2012), vulnerability of freshwater resources will be associated with severe consequences for economic, social and ecological systems. Nevertheless, both vulnerability and consequences to be faced are reported to vary across the globe depending on factors such as the geographical location, water availability and utilization, demographic changes, existing management and allocation systems, legal frameworks for water management, existing governance structures and institutions, and the resilience of ecosystems.

Climate models projected an increase in the aridity in the 21st century in most of the parts of the globe (including most of Africa, southern Europe and the Middle East, America, Australia, and Southeast Asia) (Dai, 2013). These changes were reported to be associated with an increased incidence of extremes that may increase risk of water supplies, risk of sea-level rise associated with sea water intrusion (IPCC, 2012). Moreover, IPCC projected that each degree of the warming, will expose approximately 7% of the global population to at least 20% decrease of renewable water resources (Döll et al., 2014; Schewe et al., 2014). Thus, an annual total of US$500 billion has been reported as the cost associated with water insecurity to the global economy (Sadoff et al., 2015). Besides all, the situation is reported to be subject of amplification at any point of the world (including SSA) with the increasing population, poverty as well as changes in the climate a (Oyebande, 2001; UN-Water/Africa, 2005; Boko et al., 2007; Christensen et al., 2007; FAO, 2012; United Nations, 2014).

As for river basins, predictions have showed that these units (especially international river basins) are likely to experience 'low water security' over the coming decades (Gain et al., 2016). Water shortage in also felt in West Africa. As a matter of fact, important basins such as the Volta River Basin and the Niger River Basin have been already reported to undergo freshwater shortage (Oyebande and Odunuga, 2010). This situation has been mainly attributed to climate change associated with changes in rainfall and increase in evapotranspiration (Roudier et al., 2014). As the result, an increase in the percentage of global population living in river basins with new or aggravated water scarcity is projected (Gerten et al., 2013).

Several water security assessments have been carried across the world (Falkenmark, 1989; Witter et al., 1999; Chen et al., 2004; De Loë et al., 2007; Yee et al., 2009; Engineering the future, 2010; Calow et al., 2010; Dunn et al., 2012; Shao et al., 2012; Hameeteman, 2013; Norman et al., 2013; ADB, 2013; Xiao-Jun et al., 2014; Jia et al., 2015; Yang et al., 2012; Liu et al., 2014; Liu et al., 2016; Gain et al., 2016; Srinivasan et al., 2017; Zende et al., 2018; Babel and Shinde, 2018 among others). Yet, most of these studies have been carried at national, regional and only few have been carried at river basin level and most of them are very recent (Yee et al., 2009; Liu et al., 2014; Jia et.al, 2015; Liu et al., 2016; Dang et al., 2017; Babel and Shinde, 2018). Thus, water security assessments at local scale such as basin level or sub-basin level become a requirement.

1.2 Problem Statement

Despite its contribution to the country's overall wellbeing, the Oti River Basin (Volta River Basin in Togo) has been reported to be subjected to great seasonal and or temporal variations under natural conditions (UNEP-GEF, 2010) as well as acute chemical and organic pollution of water resources (MEAHV, 2010). The situation is mainly attributed to the increase in population and water use (Gordon et al., 2013). The Volta River Basin and the Niger River Basin are generally considered to be the most affected basins by freshwater shortage (Oyebande and Odunuga, 2010) due to climate change, which will disproportionally impact water resources in the basin by affecting rainfall and evapotranspiration amounts over the basin (Roudier et al., 2014). As a matter of fact, the simulation tool SimCLIM2013 (considering the temperatures and the precipitation for the elaboration of climatic scenarios) has already shown 1°C increase in temperature against a decrease of 3-81 mm in precipitation associated with a decrease in the number of rainy days and an alteration in the rainfall distribution over the period of 1986- 2012 compared to the reference period of 1961-1985 in Togo (MERF/DE/TCN, 2015). As the result of the associated impacts on water resources, many reports have highlighted changes in surface water flow, loss of surface water, and the reduction in groundwater recharge (MEAHV, 2010). In the future, temperature is expected to rise between 1°C to 2.5 °C respectively at mean and long term in the overall Volta River Basin. As for precipitation, an average decrease of about 11% is expected with a consequent reduction in the river flow between 15% (2020) and 40% (2100). Moreover, frequent and rude extremes of drought and flood are also expected (VBA, 2014). Groundwater depletion observed in the overall country is also expected to completely exhaust by 2055 in the savannah region under the extreme scenario (MERF/DE/TCN, 2015). In brief, according to Vörösmarty et al. (2010), Togo is part of countries facing high threat to water security.

Problems like water shortage, water pollution and environmental deterioration in Togo may get worse and become a major impediment to the country socio-economic development. Nevertheless, existing studies have only looked at the potential impacts of climate change on ground water with a focus on administrative boundaries (MERF, 2015) and urban water supply (Ahiablame et al., 2012) with very few which have meticulously assessed water security in general and water security at hydrological basin level in particular (as the new water resource management unit). Based on the above, this study aims at evaluating water security level in the Oti River Basin in Togo in a challenging environment and over time using the case study of the Oti Nord sub-basin.

1.3 Research Questions

The underpinning research questions of this study are:

1. What are the water management strategies or approaches adopted in the in Oti Nord sub-basin?
2. What is the water security institutional arena in the sub-basin (Stakeholders, role in water security efforts)?
3. What is the water security level under the challenging environment and over time (current and future) in the sub-basin?
4. What are the potential barriers to water security in the sub-basin?

1.4 Objectives of the Study

1.4.1 General objective

The general objective of this study is to examine water security in the Oti River Basin, in the context of environmental change (including climate change, population growth and economic development) taking the Oti Nord sub-basin as a case study.

1.4.2 Specific objectives

To achieve the main objective, this study aims at:

1. Reviewing the existing water resources management strategies or approaches in Oti Nord sub-basin;
2. Investigating water security institutional arena in the sub-basin (Stakeholders, role in water security or water management efforts);
3. Assessing water security level over time in the sub-basin using the Improved Fuzzy Comprehensive Evaluation Model (under various socio-economic and physical water condition scenarios); and
4. Investigating potential barriers to water security in the sub- basin.

1.5 Significance of the Study

This study is meant to be a reference material for Togolese government and other stakeholders in terms of decision making regarding to ways of ensuring and sustaining water security at hydrological basin level under the challenging environment to mediate the current and coming conflicting water use demands, maximise water use and minimize the adverse impacts from land and water management practices, within the existing ecosystems. In addition, it has been recognized that the river basin approach is a comprehensive process for managing water resources in a more sustainable manner. Thus, the study seeks to evaluate water security over time in the context of the environmental changes, including climate change.

1.6 Organisation of the Study

This work is organized in five different chapters. The introductory chapter covers the background of the study, problem statement, research objectives, research questions, significance of the study and the organization of the study. The second chapter is the literature review which presents the existing definitions of water security concept, water security and its implications, and the theoretic and empirical background for water security assessment methods. The third chapter presents the methodology, including the study area, the research design, data collection methods and instruments, data processing and analysis, and ethical consideration. The fourth chapter presents the results of the analyses and discusses the results. The fifth chapter gives the conclusion and recommendations of the study.

CHAPTER TWO: LITERATURE REVIEW

2.0 Introduction

The study focused on water security and the environmental change (including climate change and socioeconomic development among others). The literature is reviewed according to the topic of the study and covers empirical and theoretical reviews. Key information and concepts were obtained from text books, journals, websites and documents from government institution as well as articles and papers.

2.1 Empirical and theoretical Review

2.1.1 Evolution of water security concept

The concept of water security has received an increasing attention over the past decades, in both political and academic debates. There is a series of definitions of this concept which are promoted by a range of international organisations as well as individual. The definitions are summarized in Table 2.1.

Table 2.1. Some definitions of water security

Definitions	***Sources***
Water security is seen as the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability	UNESCO-IHP (2012b: Resolution XX-5)
Water security broadly refers to Reliable access to water of sufficient quantity ‘and quality for basic human needs, small-scale ‘livelihoods and local ecosystem services, coupled ‘with a well-managed risk of water-related disasters.	WaterAid (2012)
Water security is defined as ‘the reliable availability of an acceptable quantity and quality of water for health, livelihoods, and production, coupled with an acceptable level of water-related risks.’	Grey and Sadoff (2007)
Water security as “a multi-dimensional concept that recognises that sufficient good quality water is needed for social, economic and cultural uses while, at the same time, adequate water is required to sustain and enhance important ecosystem functions”.	De Loë et al (2007)

Water security is defined to include access to safe water at affordable cost to enable healthy living and food production, while ensuring the water environment is protected and water-related disasters, such as droughts and floods, are prevented.	Cheng et al (2004)
Water security is simply an overarching goal where "every person has access to enough safe water at affordable cost to leave a clean, healthy and productive life, while ensuring the environment is protected and enhanced."	Global Water Partnership (2000)
Water security is a condition where there is a sufficient quantity of water at a quality necessary, at an affordable price, to meet both the short-term and long-term needs to protect the health, safety, welfare and productive capacity of position (households, communities, neighbourhoods or nation).	Witter and Whiteford (1999)

Despite some differences, these definitions have several common stands. The first stand is the focus on the adequate access to water in quality and quantity. The second one relates to the provision of water for human health through productive activities (whether agriculture or food production, industrial goods production or all of them) as specified in some definitions. The third stand is the focus on environmental conservation or protection. Finally, the fourth stands for the affordability of water and the prevention of water-related disasters.

2.1.2 Water security or scarcity in Sub-Saharan Africa: Drivers

It has been reported that up to 400 million people in 15 countries in Sub-Saharan Africa (SSA) currently suffer from water scarcity with an expected increase in the number to 800 million by 2050 (PAI and AIDP, 2012). Above all, the impact of water shortage is expected to be severe in arid and semiarid areas (representing 43% in SSA according to the World Food Program, 2008) with an expected decrease in precipitation of about 20% or more over the next century (Misra, 2014). Most of countries in SSA are reported to be under threat (ranging from low to high) to water security and biodiversity (Vörösmarty et al., 2010) with the situation known to be exacerbated at any point of the world (including SSA) with the increase in the population, poverty and the change in the climate associated with the increase in the temperature and changes in precipitation (Oyebande, 2001; UN-Water/Africa, 2005; Boko et al., 2007; Christensen et al., 2007; FAO, 2012; United Nations, 2014).

There is a common agreement in the scientific community of the current and future (in the near term, mid and end century) increase in the temperature in SSA as the result of climate change (O'Loughlin et al., 2014; Egeru et al., 2014). As for the rainfall, the region is expected to undergo varied performance in rainfall as well as in seasons (Shiferaw et al., 2014). It is also expected alterations in rainfall intensity (Songok et al., 2011) and intensification of extreme weather events, especially floods and droughts as the result of climate change (Egeru, 2014; Barasa et al., 2014). This situation is expected to consequently impact water resources in Africa by amplifying the existing stress on water availability and vulnerability level (Field et al., 2014; Phiiri et al., 2016). Moreover, the changing climate is expected to be associated with distortion of hydrological systems in SSA with additional instigation of water stress (Akiyode, 2011).

Population growth represents another key driver of water insecurity in sub-Saharan Africa. In SSA, the annual growth is estimated at 3 percent. This situation is expected to lead to a decrease in the amount of water available per capita in countries of the SSA by 2025 at the exception of Ethiopia (FA0, 1995), this, as the result of increased water demand under very limited managerial capacity (UN-Water, 2005). As the result, eleven countries throughout west, east and south Africa are expected to join the group of countries already suffering from freshwater scarcity. Moreover, population growth is associated with the deterioration of water quality (Calow et al., 2010; Mati et al., 2006) which will also induce water stress (Falkenmark et al., 2007).

SSA is characterised by a population growth exceeding the overall GDP growth (AfDB et al., 2007; IFM, 2017). Poverty in the region is expressed in terms lack or limited of access to resources (i.e. financial, human) (Oyebande, 2001; Ringler, 2013), which is linked to limited investment in water resources mobilization, relevant human capacity building and low storage capacity (Sadoff and Grey, 2002; UN-water, 2005; Ringler, 2013; Besada and Werner, 2015). Water scarcity in SSA has been recognized as an “economic water scarcity”, highlighting the lack of financial and human capital for adequate development of the existing water resources (Molden, 2007). Thus, poverty has been recognized as a threat to water security as to other securities especially when it forms a nexus with climate change (Akiyode, 2011). Nevertheless, it is judicious to highlight the other side of the interrelationship, where water insecurity can aggravate poverty.

Economic growth is associated with increase in water demand, whether, for agricultural development (case of most developing countries) or industrial purpose. As a matter of fact, the projection of water stress has shown an increasing pattern in 60% of the world, including large parts of Africa, this as the result of the increased water withdrawal for industrial and domestic purposes under ‘business as usual’ scenario (World Water Council, 2000).

2.1.3 Water security and its implications in Sub-Saharan Africa

Increasing water shortage is reported to be a major concern across the world as it has posed serious threats to food security and economic development in many parts of the globe (Butler and

Memon, 2006; Wang et al., 2012). In Sub-Saharan Africa (SSA), the threat facing water resources will have impacts whether indirectly or directly on health, food production, ecosystems and conflicts occurrence (WWAP, 2006; Boko et al., 2007; Schlenker and Lobell, 2010; Thornton et al., 2011; Nkem et al., 2011; Hannemann, 2015).

Several studies showed that food production in Africa, especially Sub-Saharan Africa (SSA) will be adversely affected (Boko et al., 2007; Schlenker and Lobell, 2010; Thornton et al., 2011) as the result of the rising incidence of water scarcity (Du Toit, 2011). As a matter of fact, it is reported that farming community (especially the smallholder) in Africa are already facing a series of robust negative impacts of climate variability and change on their production including crop and livestock losses among other consequences (AGRA, 2014). It is also expected changes in agro-biodiversity as the result of these changes (Niang et al., 2014). Consequently, this situation will be associated with an increase of nutrition challenges with West Africa expected to register the highest number of undernourished (+95% under an increase by 1.2 to 1.9 in the temperature) people in SSA (Munang and Andrews, 2014).

At another side, it has been reported that, although wars are most of the time related to political, economic and social factors, water shortage (in form of drought) represents a factor that add fuel to flames that are already burning especially in fragile places like SSA among others (Cimons, 2017). As a matter of fact, projection made show an increase in conflicts associated with water scarcity and stress (De Wit and Jack, 2006 cited in Gueye et. al. 2009).

Looking at the impacts associated with water scarcity in the world and SSA particularly as the great part that will be affected, there is a need to find ways to minimize these impacts as the environment (i.e. population, climate, etc) will keep changing.

2.1.4 Water security or scarcity in Sub-Saharan Africa: Case of River Basins

According to De Wit & Jack (2006), transboundary river basins in Africa, especially in SSA are expected to face increasing trend in water scarcity and stress pattern. As a matter of fact, in West Africa, Volta River Basin and the Niger River Basin have been already reported as the most affected basins by freshwater shortage (Oyebande and Odunuga, 2010). Thus, action need to be taken in order to avoid future water crisis.

2.1.5 Conceptual analysis: water security assessment

There is a variety of methods used to assess water security. It includes indices or indicators, frameworks and models. Some of the water security assessment models are described below.

2.1.5.1 Water Security Status Indicators (WSSI)

The WSSI assessment method is designed to 1) provide a framework to guide communities in selecting suitable or appropriate freshwater indicators; 2) integrate governance throughout the assessment process, first by incorporating stakeholders and second by incorporating the results of the assessment into water planning decisions and behaviour modifications; and 3) provide a path to integrate the assessment of both water quantity and water quality in terms of aquatic ecosystems and human health (Norman et al., 2013). Although this method is innovative and flexible based on its characteristics, it is not adaptable. In addition, the dissemination and timeliness of the data represent key issues in relation to effective assessment. Finally, the WSSI assessment method is limited to current water security assessment and does not include future risks (Dunn et al., 2012).

2.1.5.2 The Canadian Water Sustainability Index

The Canadian Water Sustainability Index (CWSI) is a method using numerical scores. It integrates a range of water-related data and information into a series of indicators (Policy Research Initiative, 2007a) where each of them assigned to a score ranging from 0 to 100, with a higher score meaning that the community is closer to the ideal conditions for the said indicator. A total of 15 indicators are considered and grouped into five component scores, where each component score comprises the average score for the three indicators. The five component scores are then averaged to calculate the final CWSI score. The index has been used across Canada in both first nation's communities and rural municipality. Although found to be adaptable with "some minor modifications" (Policy Research Initiative, 2007a), and receptive among communities (due to the reflection of its indicators of communities' reality) the method is usually limited by its huge requirement of data which are sometimes unavailable, creating data gap.

2.1.5.3 Asian Water Development Framework

The Asian Water Development Framework has been developed with the objective of establishing a mean of measuring water security. It focuses on the importance of measurements. The assessment is done through a set of key indicators which represent the inherent tensions among the different water uses as water resources are under increasing stress. These key indicators include household water security, economic water security, urban water security, environmental water security, resilience to water-related disasters. The framework is known for its capacity to indicate the adequate adaptation options (whether increasing investment, improving governance, or expanding capacity in the water sector). It is also known for its replicability and its ability to provide a robust, pragmatic, and readily understood assessment of water security. Nevertheless, the indicators are known to be very complex. In addition, this framework is limited to national and regional rather than individual basins level water security assessment. Furthermore, the framework provides only the baseline for analysing trends and the effects of policies and reforms that can be monitored and reported to stakeholders and offer a new way for leaders to look at the strengths and weaknesses of water resources management and service delivery.

2.1.5.4 Fuzzy comprehensive evaluation model

This method uses the catastrophe fuzzy membership functions and fuzzy numbers to determine respectively the dependency of water security on variables such as climate change, economic development and population growth, thus, evaluate water security. In addition, the method reduces the subjectivity in the evaluation process (associated with expert judgement during the weighting process) and provides more options compared to other classic theories (limited either as no or yes but not both) in terms of subjective criteria measurement under the fuzzy environment. Besides all, the Fuzzy Comprehensive Evaluation Model (FCEM) is recognized as effective in the way to formulate decision to problems in a fuzzy environment associated with uncertainties (Othman et al., 2008), thus, widely used to understand climate change impacts on water resources and identify adaptation measures (Prato, 2008; Armah et al., 2011).

2.2 Summary of the Review

In summary, there are many definitions of water security, however, most of them converge towards the adequate access to water in quality and quantity; the provision of water for human health through productive activities (whether agriculture, food, industrial goods or all of them); water for environmental conservation and water affordability. In addition, the challenges associated with the achievement of water security under the challenging environment (e.g. climate change, population growth) and its implications have been highlighted. Besides, water insecurity across the world and particularly in arid and semi-arid areas of SSA and its associated impacts have been highlighted. Finally, a lot of tools are used for water security assessment whether at national against local level in one hand and city against basin level. The overall summary of the advantages and limitations are depicted in the Table 2.2.

Table 2.2 Advantages and limitations of water security assessment tools

WS assessment tools	*Advantages*	*Limitations*
Water Security Status Indicators (WSSI)	Innovative and flexible	• Not adaptable • Does not include future risk
Canadian Water Sustainability Index (CWSI)	• Replicable with “some minor modifications” • Provides a robust, pragmatic, and readily understood assessment • Receptive among communities	Huge requirement of data.

Asian Water Development Framework	• Capacity to indicate the adequate adaptation options • Replicable • Provide a robust, pragmatic and readily understood assessment	• Do not assess individual basins level water security. • Baseline for analysing trends.
Fuzzy comprehensive evaluation model	• More options in terms of subjective criteria measurement under the fuzzy environment. • Effective in the way to formulate decision problems in a fuzzy environment associated with uncertainties • Do not involve human perception in decision making	• Recently introduced • Do not capture all the socio-economic indicators.
Improved Fuzzy comprehensive evaluation model	• More options in terms of subjective criteria measurement under the fuzzy environment. • Effective in the way to formulate decision problems in a fuzzy environment associated with uncertainties • Do not involve human perception in decision making • Additional fuzzy membership function • Score transformation formula.	Recently introduced Do not capture all the socio-economic indicators.

Source: Compiled from Policy Research Initiative (2007a), Othman et al. (2008), Dunn et al. (2012), Yang et al (2012), Xiao-Jun al. (2014), Xiao-jun (2014)

CHAPTER THREE: METHODOLOGY

3.0 Introduction

This chapter indicates how the data for the study is collected, analysed and interpreted to achieve the objectives of this study. It comprises the study area, research design, data collection and methods (including the measurement of variables), data analysis and ethical considerations.

3.1 Study Area

Togo is endowed with huge water resources made up of rainwater, renewable ground water and surface water These resources are unevenly distributed among the main hydrological basin and geological systems. Water resources in Togo are primarily mobilized for clean water provision and then for economic purposes including agriculture, livestock, aquaculture, industry, tourism and transport. The territory is divided in three hydrological basins named, « Oti River Basin», « Mono River Basin » and « Lake Togo River Basin ». The limits of these basins are fixed by a decree of the ministers' council.

Oti River Basin (ORB) represents the Togolese part of the Volta River Basin (which stretches from approximately latitude 5^o 30' N in Ghana to 14^o 30' N in Mali). The Oti River Basin covers an area of 26 700 km^2 (about 47.3% of the country) and lies between 6°10' and 11°10 latitude north and between 0°and 1° 25' longitude east. It covers the five economic regions such as the western part of Central, Plateaux and Maritime regions and almost the whole Kara and Savannah regions. In total, more than twenty-tree districts (from the 39 existing districts, as of 2016) are fully or partially concerned by the management of the ORB, revealing its importance (UNEP-GEF, 2010). Oti River and its tributaries divide the basin into seven sub-basins, namely, the Koulougona, Oti Nord, Koumongou, Kara, Oti Sud, Mo and Plateaux du Sud sub-basins. Oti River Basin is known to play a key role in the economy of the country through it contribution to the overall GDP (37.7 % of the national GDP in 2006) (DGSCN, 2010). In addition, the basin is known for its contribution to the country food security as it provides fruits, staple foods (millet, sorghum, coco yams, maize, groundnut, beans and yams, cassava), non-timber products (like Shea) as well as meat and aquatic products (UNEP-GEF, 2010).

3.1.1 Location

The study was conducted in Oti Nord sub-basin, one of the ORB sub-basins. The sub-basin covers a total area of 6000 km^2 and lies between longitude 0° 10' W and 1° 0′ E and between latitudes 10°10′N and 12° 0′ N (Figure 3.1). The sub-basin covers the entire Kpendjal district and small portions of Tandjoare, Tone and Oti districts.

The choice of the study area was done with regards to the socio-economic, environmental, physical and agroecological characteristics. The Oti Nord sub-basin is part of the savannah region characterised by high poverty level (the highest in the country) (65% of the population in 2017) (INSEED, 2018), food insecurity (53.3 % of the population in 2010) (PAM-Togo, 2010), high population growth rate and an agroecology subject to water shortage and stress (dry savannah). In addition, the study area is also known for its acute land degradation (Barry et al., 2005), high exposure to flood events. Furthermore, the area represents the largest sub-basin in the Oti River Basin (with a total area of 6000 km^2). Besides all, the availability of the required data has played a key role in the choice of the area of study. The water used in the sub-basin is mainly from ground water sources. Currently, there is no waste water treatment schemes, resulting in high pollution of water sources (especially surface water).

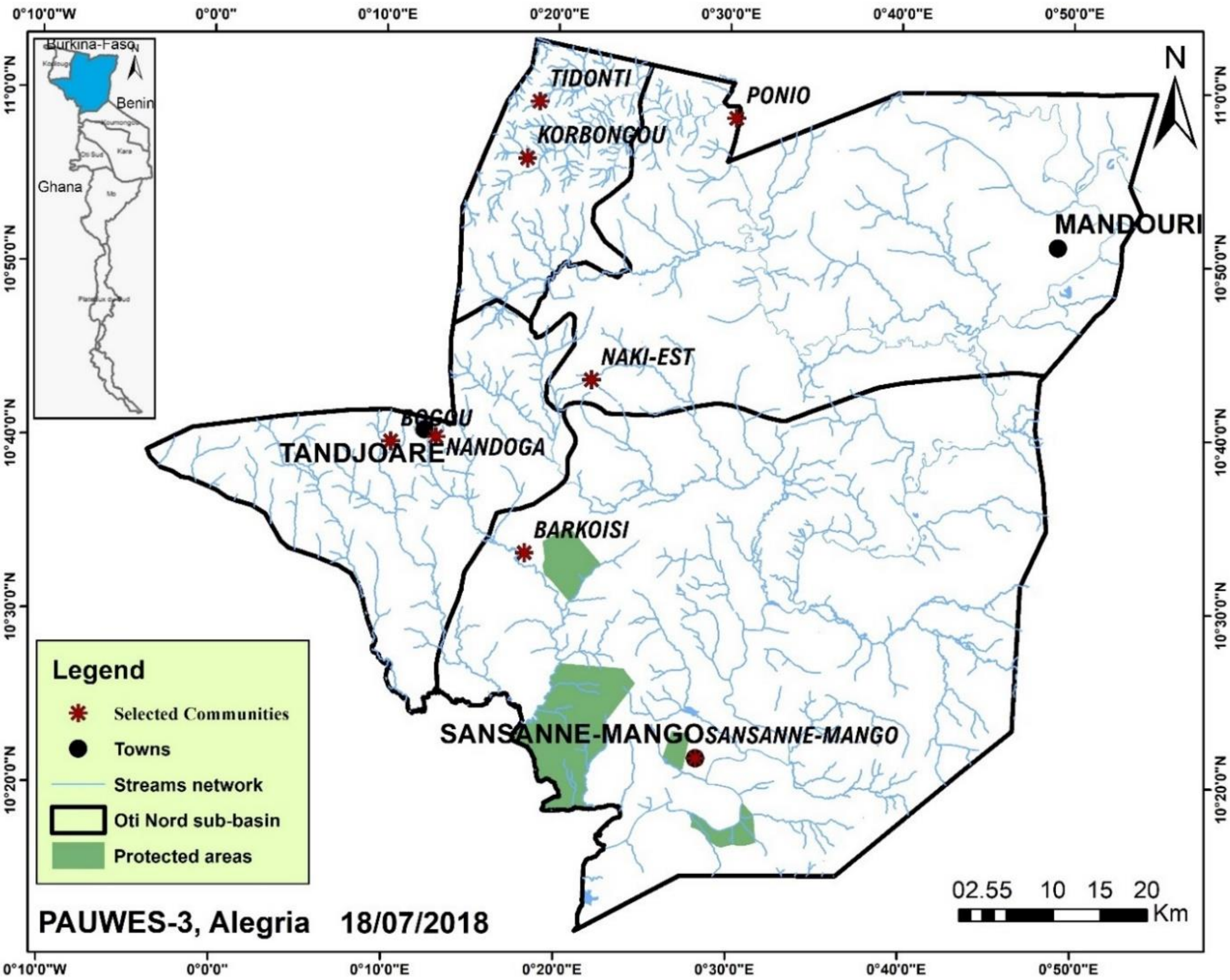

Fig 3.1. Map of the Oti River Basin and Oti Nord sub-basin

Source: Yomo (2018)

3.1.2 Demographic and socioeconomic characteristics

The key demographic and socio-economic characteristics of the Oti Nord sub-basin are summarized in Table 3.1

Table 3.1 Key demographic and socioeconomic characteristics of the Oti Nord sub basin

Characteristics	***Oti Nord sub-basin***
Population (inhabitants)	612720 (as of 2015)
Ethnic population	Majority Moba-Gurma
Main livelihood	Crop farming and livestock
Main crops	Millet, sorghum, maize and rice
Climate	Mean Tropical
Agro-ecological zone	Dry Savannah Zone
Soil type	Gleyic luvisols, fluvisols, ferric luvisols and chromic vertisol
Rainfall patterns	Uni-modal
Major rainfall period	April/May - Sept/Oct
Mean annual rainfall	1000-1200 mm
Annual temperature	Min 27.1 º C, Max 29.5 º C

Source: Data compiled from FAO/UNESCO (1995), DSID (2006), PNUD/FEM/MERF (2007), DGSCN (2010), INSEED (2015) and Gadédjisso-Tossou (2015)

From a hydrological point of view, the sub-basin is drained by the Oti River and its tributaries characterised by a simple seasonal variation with high waters level being between August and October. The River is characterized by an important annual flow which varies between 100 and 300 m^3 per second and an irregularity coefficient K3 ranging between 2,6 and 3 (MMEE/DGEA/UN-DESA, 2009). The annual recharge capacity in sub-basin is about 177 mm (as of the one in Mango).

3.2 Methods

A mixture of methods (including ordinal tools and model) has been used to achieve the set objectives.

3.2.1 Sampling design

To achieve the objectives of this study, a multistage sampling technique was employed. Firstly, all the districts in the sub-basin (including Tone, Oti, Kpendjal and Tandjoare) have been considered. In the second stage, the counties were purposively selected based the availability of community-based organizations (including Water Users Associations, water committee, water related association). As the result, 8 counties were selected, namely, Sansanne-Mango, Ponio, Tidonti, Korbongou, Barkoisi, Naki Est, Bogou and Nandoga. Finally, 12 community-based organizations out of the selected counties were available and accessible during the period of data collection (April-July 2018).

3.2.2 Data collection

Both primary and secondary data were collected to address the objectives of this study. Therefore, key methods have been used for each specific objective. The objectives of this study and the method used for each objective is summarized in Figure 3.2.

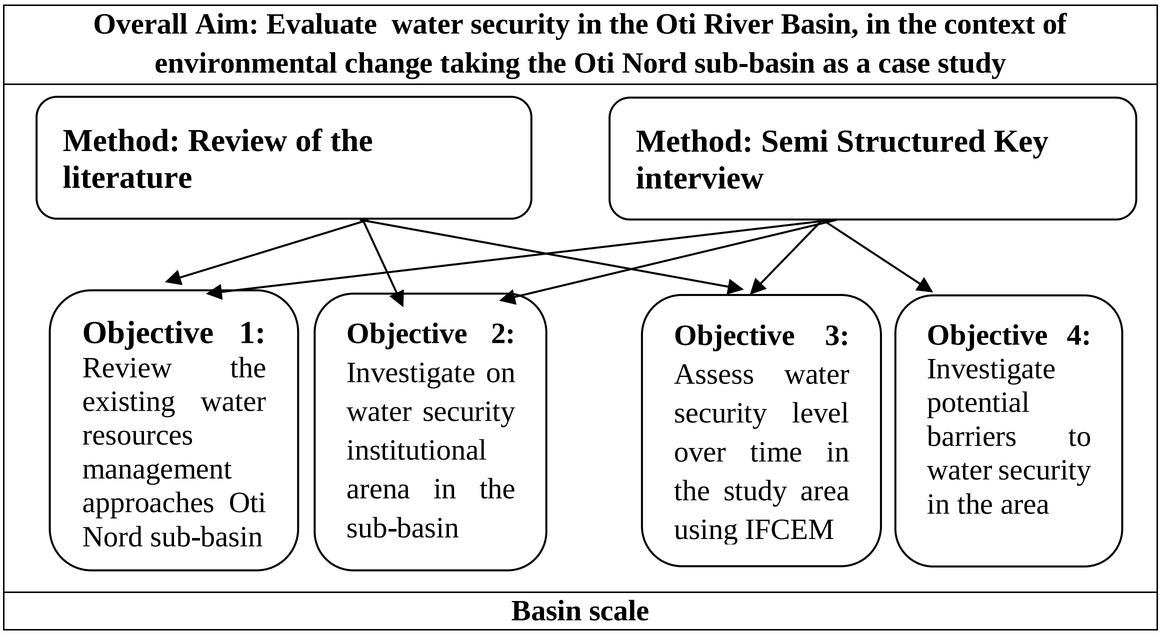

Fig 3.2. A summary of research design and links between different methods used and the research objectives

3.2.2.1 Primary data

Primary data were collected using semi-structured interview. Data on the water resources management during the precolonial period, water resources management institutions efforts or role in achieving water security and potential barriers in achieving or sustaining water security were collected. Selected key representatives (e.g., director, monitoring or evaluation officer, project manager or leader, president) of stakeholder institutions in water resources management and water resources management related domains in the sub-basin (government institution in water and water related sectors, private operators, civil society, water user associations) were interviewed. This step was taken to achieve the objectives 3 and 4. The interview conducted are shown in Figure 3.3.

Fig 3.3. Interview with key informants in Ponio (a) and Mango (b) counties (Photo credit: Lare)

3.2.2.2 Secondary data

Secondary data were obtained from existing literatures relevant to the research topic (published and non-published papers and reports) and databases. These data include the existing water management strategies or approaches in the sub-basin (as well as in the country) but also climate-based parameters, socio-economic parameters (population growth, GDP growth), physical characteristics of water resource, societal water usage (water demand, and water supply) and other parameters such as sanitation. Thus, a documentary review was deemed appropriate.

The overall data collection is summarised in Table 3.2.

Table 3.2 Summary of primary and secondary data used

Type	*Data*	*Method and Sources*
Primary data	Water resources management approaches; Role of institutions in sub-basin water security; Potential barriers to water security.	Semi structured interview
Secondary data	Existing water management strategies or approaches in the sub-basin; Climate-based parameters (T°); Socio-economic parameters (population growth, GDP growth); Physical characteristics of water resource and the society pattern in terms of water usage (water demand, and water supply) and other parameters such as sanitation level.	Published and non-published papers; Documents and database from the National Meteorological agency; Ministry of planning, development and communal development; Ministry of Water and Rural Water Systems; Regional directorate of hygiene.

3.2.3 Data processing and analysis

Data obtained were analysed in four ways:

- The review of water resources management strategies in the basin was done through a content analysis;
- Data on potential barriers to water security and the roles of existing institutions in ensuring water security were analysed using simple descriptive statistics of the SPSS software version 16.0 and Excel (to draw graphical patterns and trends);
- Data on water resource and its interaction with the environment and society were analysed in multiple steps wise approach (based on the improved fuzzy comprehensive evaluation model) to assess the water security level. For water security assessment, manual calculation and simulation are the methods used; and
- Finally, Arc GIS Software version 10.2.2 was used for mapping the study site.

3.2.4 Fuzzy comprehensive evaluation model

The improved fuzzy comprehensive evaluation model which has been developed based of the traditional catastrophe evaluation method was used to evaluate water security level in the sub-basin.

3.2.4.1 Catastrophe theory and traditional catastrophe evaluation method

The fuzzy comprehensive evaluation model is based on the catastrophe theory that is initially designed to deal with discontinuous dynamic systems, especially those governed by a potential energy-like functions (Wang et al., 2011a). The theory is associated with basic assumptions with results having their application in other domains. Assuming a dynamic system M with a set of input variables (control variables) and output variables (response variable). The potential function V of the said system can be expressed as V (x, u) with x and u representing respectively the response variable and the control variables.

According to Loehle (1989), the control variables can be assumed to be slowly dynamic compared to the state variables. The value of all control variables known as "catastrophe progression" ranges between 0 and 1 in the normalization formula and can be obtained from the initial membership function, this through recursive algorithms subject to the normalization formula. The summary of all the traditional catastrophe models is given in Table 3.3.

Table 3.3. Summary of the traditional catastrophe models

Category of Model	Dimension of control variables	Potential function	Bifurcation set
Fold	1	$V(x) = x^3 + ax$	$a = -3x^2$
Cusp	2	$V(x) = x^4 + ax^2 + bx$	$a = -6x^2, b = 8x^3$
Dovetail	3	$V(x) = x^5 + ax^3 + bx^2 + cx$	$a = -6x^2, b = 8x^3, c = 3x^4$
Butterfly	4	$V(x) = x^6 + ax^4 + bx^3 + cx^2 + dx$	$a = -10x^2, b = 20x^3, c = 15x^4, d = 4x^5$

Source: Su et al (2011)

The traditional catastrophe evaluation method is based on the catastrophe theory. It focuses on catastrophe fuzzy membership, which is obtained using analytic hierarchy, utility function and fuzzy evaluation. In summary, the multi-criteria evaluation method consists of : 1) dividing the system into sub-systems, parameters and then indicators (organized in each sub-system based on the their inner logic relationships and their importance) (Wang et al., 2011a); 2) normalising the initial data obtained using catastrophe theory and fuzzy mathematics (based on the adequate catastrophe model) (Su et al., 2011); 3) finalizing the value of each subsystem based on the principle of minimum value or the principle of mean value (depending on whether the indicators are complementary to each other or interchangeable within one system) (Wang et.al, 2011a). The catastrophe evaluation method is known for helping in evaluating the criterion of water security without involving human perception in decision making, which can create bias and make the overall result less reliable (Xiao-Jun al., 2014).

3.2.4.2 Improved catastrophe evaluation method

The catastrophe evaluation method was improved by Yang et.al (2012) with the purpose of accommodating sub-systems having high level indicators (more than four) and incorporating the gradations of evaluations samples. The improvement of the traditional catastrophe evaluation method was done through the introduction of an additional fuzzy membership function and a score transformation formula. The improved catastrophe evaluation method follows a series of seven steps depicted below:

Step-1: Establishment of indicator system

Water security represents the result of interaction between water as a natural resource, the environment and the society (involving economic activities) among other factors. As the result, factors such as climate change, population growth and economic development among others may have some impacts on water security as they are under continuous change. Although these factors are independent, they may interact and restrain one another within the system, thus, affecting water security.

While combining the concepts of entity and association model, water security system based on the study context and the available literature (Falkenmark, 1989; Babel and Wahid, 2008; ADB, 2013; Wang et al., 2015 among others) is divided into five sub-systems in the present study and includes external environment security, water resources security, water-society security, water economic security and water-environment security. “Water resources security” depicts the characteristics of water as a resource in the sub-basin, especially its physical availability to sustain all kind of human activity (including, domestic, agricultural, commercial, recreational and others). It throws light on how much water is available. “Water-society security” subsystem is the reflection of the interaction between water and society. It expresses society utilization pattern of the physical water resources. “Water-economic security” subsystem focuses on the value of water allocated for all economic activities in the sub-basin. It brings together agriculture, industry and other economic activities. “Water-environment security” subsystem mainly addresses the health of surface and ground waters in the area of study but also the existing sanitation level. It considers the quality and quantity of water in the ecosystem. Finally, the “External environment security” subsystem refers to factors which are not directly part of the water system, but which interact and affect the system. For each sub-system, key parameters have been selected. Finally, the overall indicators have been defined based on the parameters selected, the literature as well as the context of the study.

Some aspects of water security such as water management or governance has not been considered in this study as it does not represent an end to water security but a mean to achieve water security (Lautze et al., 2011). Nevertheless, this aspect is acknowledged as key in shaping water security. In addition, the existence or absence of treaties (which represents also a governance/management aspect) is not considered in this study as Togo rely less on external waters (only 3.2 billion m3 per year against 11.5 billion m3 per year produced internally) (FAO, 2016). The overall system for the assessment of water security in the context of Oti River basin is as shown in the Figure 3.4.

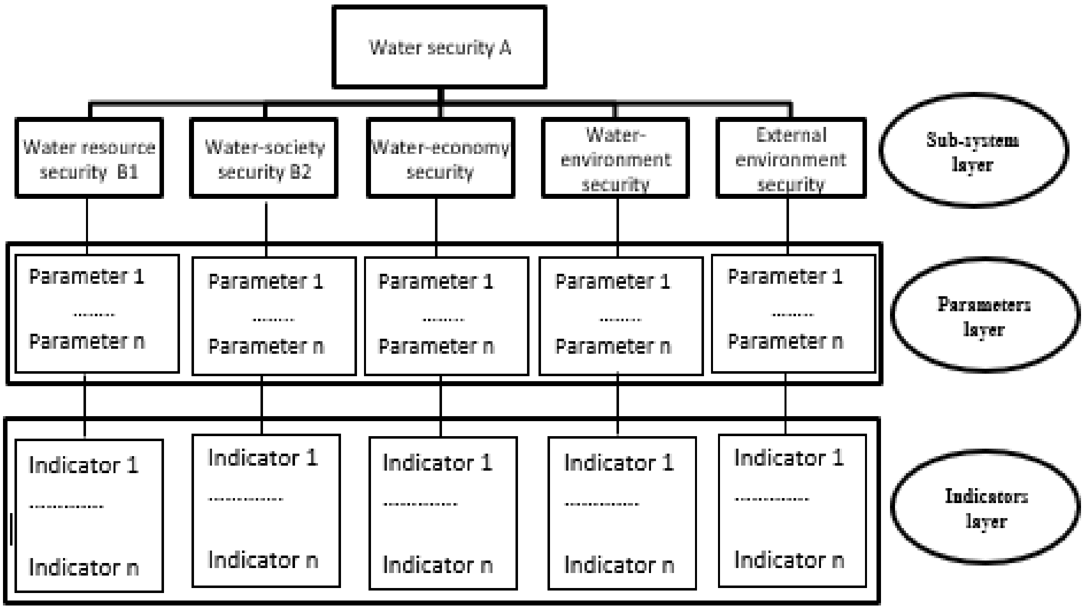

Fig 3.4. Indicators system of water security assessment model in a challenging environment
Source: Adapted from (Xiao-Jun al., 2014)

A total of 23 indicators were considered for the assessment and sorted by their inner logic relationships and their importance (Table 3.4).

Step 2: Normalisation of the indicators values

The original value of each indicator is attached with a range and unit. The normalisation is a process which consisting of converting indicators original values into dimensionless values to make their use easier (as they become free from their units). The normalisation is done base on the functional relationship (positive or negative) of each indicator. In this case, values of indicators were transformed into numbers ranging between 0 and 1 through the following equations:

$$Xi' = \frac{Xi - Ximin}{Ximax - Ximin} \qquad (1)$$

$$0 \leq Xi \leq Ximax;$$

$$Ximin < Xi < Ximax; \quad Xi \geq Ximax$$

The variables express better condition when their values are large, thus known as "larger is better" (positive); otherwise "smaller is better" (negative) formula was used:

$$Xi' = 1 - \frac{Xi - Ximin}{Ximax - Ximin} \qquad (2)$$

$$0 \leq Xi \leq Ximax;$$

$$Ximin < Xi < Ximax\ ;\ Xi \geq Ximax$$

Where i is the indicator, Xi the original value of i, $Ximin$ and $Ximax$ are respectively the minimum and maximum value of the indicator i.

Step-3: Establishment of the fuzzy membership function

This step follows the normalization step and consists of establishing the catastrophe fuzzy membership function for each indicator selected through catastrophe models (function of the number of low level indicators contained in a high-level index which are sub-systems). The fuzzy membership function for high level index containing one or two or three or four lower level indicators (Su et al., 2011) or five lower level indicators (Yang et al., 2012) are respectively the following:

The cusp catastrophe: $Xa = a^{1/2}$ and $Xb = b^{1/3}$ (3)

The swallowtail catastrophe: $Xa = a^{1/2}$; $Xb = b^{1/3}$ and $Xc = c^{1/4}$ (4)

The butterfly catastrophe: $Xa = a^{1/2}$; $Xb = b^{1/3}$; $Xc = c^{1/4}$ and $Xd = d^{1/5}$ (5)

The Wigwam catastrophe: $Xa = a^{1/2}$; $Xb = b^{1/3}$; $Xc = c^{1/4}$; $Xd = d^{1/5}$ $Xe = e^{1/6}$ (6)

Step-4: Calculation of sub-systems/indexes

The calculation of the sub-systems and the overall water security system follows the un-comparative/minimum value, or the comparative or mean value principles as described below:

(a) Un-comparative or minimum value principle

The function of the control variables cannot be replaced with each other within the sub-system. Therefore, the minimum value of the control variables (a, b, c, d....n) can be used for the sub-system.

$$B = \min\{Xa, Xb, Xc, Xd \ldots \ldots Xn\} \quad (7)$$

(b) Comparative or mean value principle

The control variables can fill up the deficiency of each other. Therefore, their mean value can be used for the system as depicted below:

$$B = \frac{Xa + Xb + Xc + Xd + \cdots Xn}{n} \quad (8)$$

Step-5: Calculation of water security

Water security is then obtained through successive calculations in accordance with the priority of the levels. In this case, water security (which represents in this case the high-level index) contains five low level indices (SS1, SS2, SS3, SS4, SS5), making it to fit the Wigwam catastrophe model depicted as follow:

$$WS = f\ [XB1 = (B1)^{1/2};\ XB2 = (B2)^{1/3};\ XB3 = (B3)^{1/4};\ XB4 = (B4)^{1/5} \text{ and } XB5 = (B5)^{1/6}] \quad (9)$$

As all the sub-systems are complementary in achieving the overall water security, the comparative or mean value principle was applied. The formula as follow:

$$WS = \frac{XB1 + XB2 + XB3 + XB4 + XB5}{5} \ (10)$$

Step-6: Score transformation

It consists of determining the gradations of the evaluation samples as these gradations are difficult to be established directly through the catastrophe evaluation method (Yang et.al, 2012). It helps to transform the high values obtained from the catastrophe evaluation method, difficult to be compared (Poston and Ian, 1978) into more commonly used synthetic values. While supposing that the relative membership degree for all indices equal to xi $(WS1, WS2, \ldots.WSn)$ where xi is determined by the number of grade. Based on the suitable catastrophe model and the theory of Cramer's Rule and Vander monde determinant (Kurosh, 1975), the modified values of the water security (Y) can be obtained using the following formula:

$$y = 9.144WS - 35.665WS^2 + 66.378WS^3 - 58.18WS^4 + 19.32WS^5 \ (11)$$

Step-7: Water security gradation

In this study, the gradation system adopted is the one proposed by Yang et.al (2012). The water security level is divided into five grades: 0.2 (very insecure), 0.4 (insecure), 0.6 (basic security), 0.8 (secure) and 1.0 (very secure).

3.3 Ethical Consideration

The major ethical problem to this study were the difficulties in accessing regional planning reports and institutions database for privacy. The problem was overcome through a clear explanation of the objective and relevance of the study which benefited of a coverage from the Ministry of Water and Rural Water Systems, the Regional Water and Rural Water System directorate and the Savannah region hall to access the needed data and carry out the interviews.

Table 3.4. Indicators for water security assessment in the Oti Nord sub-basin

Sub-system	Parameters	Parameters description or logic	Indicators	Unit	Functional relationship	Source
Water-Resources Security (WRS) (B1)	Modulus of surface water	It reflects the amount of surface water resources in each part of the Basin. It can be calculated as the ratio between the total renewable surface water resources amount and the evaluation area	Modulus of surface water (C1)	10^6 m^3 km^{-2}	Positive	Liu et al., 2014 ; Jia et al., 2015
	Modulus of ground water	It reflects the amount of groundwater resources in the basin. It can be calculated as the ratio between the total renewable groundwater resources amount and evaluation area.	Modulus of ground water (C2)	10^6 m^3 km^{-2}	Positive	Liu et al., 2014 ; Jia et al., 2015
	Stream flow	It gives an idea on moisture level of a year. It can be calculated through as ration between the annual discharge in a locality and the interannual discharge over a period.	Stream flow index (C3)	-	Positive	VBA, 2013
	Ground water recharge	It gives an idea of the state of ground water as well as its evolution.	Ground water recharge capacity (C4)	mm/ year	Positive	VBA, 2013
	Water availability	It reflects the amount of water resources is available. It is calculated through total amount of water resources (or surface runoff)/total population.	Per capital water resources availability (C5)	m^3/ capita/ year	Positive	Falkenmark, 1989; Shao et al., 2012
Water-Society Security (WSS) (B2)	Water consumption	It gives an idea on the total amount of water withdrawn, and which is no longer available to be used. It is calculated through the total amount of water resources withdrawn (concerns only the domestic water withdrawn) /total population It can change	Per capital water consumption (C6)	m^3/ person /year	Negative	Wang et al., 2012 ; Xiao-Jun al., 2014

		under external factors and increased economic activities.				
	Drinking water conditions	It gives an idea of the urban population having access to up to standard drinking water. It can be calculated using the ratio between the urban population having access to up to standard drinking water and the total urban population.	Urban population with access to improved water (C7)	%	Positive	Jia et al., 2015
		It gives an idea of the rural and semi-urban population having access to up to standard drinking water. It can be calculated using the ratio between the rural and semi-urban population having access to up to standard drinking water and the total rural and semi-urban population.	Rural and semi-urban population with access to improved water (C8)	%	Positive	Jia et al., 2015
	Drinking water exposure	It gives an idea on the quality of surface water in the study area. It can be calculated as the ratio between the site-specific thermotolerant coliforms (30°C) and the permissible limits of these germs.	Surface water quality factor (C9)	-	Negative	ADB, 2013; Babel and Shinde, 2018
Water-Economic Security (WES) (B3)	Water consumption	It expresses the total amount of water withdrawn for economic purpose (Agricultural, livestock and industrial). It can be calculated as the ratio between the total amount of water withdrawn for economic activities and the total water* 100	Economic water consumption rate (C10)	%	Positive	ADB, 2013
	Economic water value	It gives an idea on the revenue generated by commercial/ industrial sector water use (CFA/m^3). It can be measure through the ratio between the non-agricultural GPP and the non-agricultural water use in the basin.	Commercial/industrial revenue per m^3 of water (C11)	FCFA/ m3	Positive	ADB, 2013

		It gives an idea on the revenue generated by livestock sector water use. It can be estimated through the ratio between livestock GPP and the amount of water used for the purpose.	Livestock revenue per m^3 of water (C12)	FCFA/ m3	Positive	ADB, 2013
	Water allocation	The parameter gives an idea on how water is allocated in the sub-basin but also the price attached to the allocation depending on the activity. The price may vary from one activity to the other.	Non-agricultural water price (C13)	FCFA/ m3	Negative	Wang et al., 2012
			Agricultural water price (C14)	FCFA/ m3	Negative	Wang et al., 2012
Water-Environment Security (WEES) (B4)	Pollution level / Health of water bodies (Surface and ground water)	It depicts the pollution level of water, particularly in the rivers of the sub-basin whether directly or indirectly contaminated. It can be calculated as the ratio between the dissolved oxygen and the permissible limit. EU and OMS standards have been considered in this case.	Surface water quality factor (C15)	-	Negative	ADB, 2013; Babel and Shinde, 2018
		It gives an idea on the quality of ground water in the study area. It can be calculated as the ratio between the site-specific pollutants (nitrates in this case) and the permissible limits of these pollutants. EU and OMS standards have been considered in this case.	Ground water quality factor (C16)	-	Negative	ADB, 2013 Babel and Shinde, 2018
		The pollution level can be defined by the population having access to improved sanitation.	Population with access to improved sanitation (C17)	%	Positive	
		The reuse of waste water gives also an idea on the level of pollution in the sub-basin. It can be calculated as a ratio between the amount of water (industrial or domestic) re-used and the total water consumed	Water reuse rate (C18)	%	Positive	Babel, 2016

	Water resources utilisation	This parameter can be captured using a ratio between the total amount of water supplied or used (for any purpose) and the total amount of water resources available. It concerns both surface and ground water and captures the level of human pressure on water resources	Water resources utilisation rate (C19)	%	Negative	FAO-AQUASTA, 2012 ; Wang et al., 2012 Jia et al., 2015
External-Environment Security (EES) (B5)	Population growth	Increase in population may be associated with increase in the water demand	Population growth rate (C20)	%	Negative	VBA, 2013
	Land degradation	This parameter expresses soil condition which play key role in water recharge rate but also the quality of surface water. It can be calculated as the ratio between the land degradation area (only the land with degradation indices 4 and 5 are considered) and the evaluation area.	Land degradation rate C21)	%	Negative	Pérez-Foguet and Giné, 2011; VBA, 2013
	GDP growth	Change in the GDP reflect water use for economic purpose. It increases may be associated with the increase in water demand.	GDP growth rate (C22)	%	Negative	Wang et al., 2012 ; Xiao-Jun al., 2014
	Temperature	Changes in temperature are associated with changes in the evapotranspiration which may have impact the amount of water available. In this case, the average temperature has been considered.	Temperature (C23)	°C	Negative	Wang et al., 2012 ; Xiao-Jun al., 2014

CHAPTER FOUR: RESULTS AND DISCUSSION

This chapter presents the results of the analyses and discusses the results. The results are presented based on the set objectives.

4.1 Water Resources Management Strategies or Approaches in the Oti Nord sub-basin

Despite the adoption of the water resources management at the hydrological basin level; the management is still done currently on administrative unit. Therefore, water resources management in the Oti Nord sub-basin, an entity of the whole country is quite the same as at the national level. This part includes the evolution of water resources management approaches or strategies in Togo over time, the implementation of the Integrated Water Resources Management (IWRM) and the implication of this approach.

4.1.1 Evolution of water resources management in Togo

Water resources management has undergone a series of regime from the pre-colonial time till to date in Togo.

During the pre-colonial period water resources management approach was quite embryonic or non-existing mainly ensured through customary measures such as taboos and buy laws. These customary laws and practices covered water conservation, pollution control, protection of the catchments or rivers among others. At that period water is considered as “something sacred which need to be protected”. In addition, water (whether coming from rivers, ponds or waterfalls) was considered as belonging to everyone as a gift from gods, thus, not for sell (Interview, 2018). As an example, in one community in the study area, elements such as shoes are not allowed at water points and any human activities where not carried around the points, as it is considered as a sacred ground. This has helped to keep the quality of water even during those old days (Interview, 2018).

Later, the national sectoral approach for water resources management raised up. This approach was established automatically after the independence of the country associated with the setting up of the ministries. The national sectoral approach gave the primacy to the public administration of the state and was characterised with a multiplicity of actors whether in terms of its management or its protection. The key legal enactments and laws related to water resources management and development in Togo since the independence (1960) (before the adoption of the IWRM) are shown in the Table below (Table 4.1).

Table 4.1 Water related legal enactments and laws (1960-2000)

Year	Law/Decree Passed	Outcomes and Institution Responsible
1974	Order N° 12 of the 6 February 1974	The article 14 and 15 of the Land and property legislation defines the public domain of the state being made up of the public maritime domain (ocean banks and tributaries bank) and the public fluvial domain (rivers, lakes, lagoons and ponds).
1980	Decree N°806250/PR of 21th October 1980	Regulation of water regime (Ministry of Water Resources)
1988	Law N° 88-14 of the 3th November 1988	The section IV and VI of environment code emphasis on reject in water and other ecosystems (atmosphere and soil) and the authorisation conditions for any infrastructure or planning with potential impacts on ecosystems, regulation of water abstraction for any use (Ministry of environment).
1995	Decree N° 956061 /PR of the 9th October 1995	Regulation of water regime (Ministry of Water Resources)
1996	Law N° 96-004 of 26th February 1996 of the mining code	The mining code in its articles 41-43 highlight the requirement to regulate the prospection, the exploitation and the marketing of water

In 2002, water resources management in Togo has shifted to focus on the integrated approach. This choice had been attributed to both the existing conditions in water sector at the national level and the international environment in terms of water resources management especially the Dublin (1992), Rio (1992), Paris (1998), New York (2000) and Johannesburg (2002) conferences, the second word forum of water (2000) and then the West African Integrated Water Resources Management issued with the declaration of Ouagadougou in March 1998 (MEAHV, 2010).

4.1.2 Features of Integrated Water Resources Management in Togo

The Integrated Water Resources Management (IWRM) in Togo (being the same in the Oti Nord sub-basin) is considered as a new way of thinking about water that considers a shared responsibility of all actors of water resources management including the state and different water users.

The approach has been chosen in line with the strategy of complete poverty reduction of the government, which has detected access to clean water as one of the main causes of the existing poverty in the country (MEAHV, 2010). The approach was adopted in the Water Code as a key approach defining the principles and fundamental rules to which the allocation, the usage, the protection and the management of water resources will be subject to (MEAHV, 2010).

Togo interprets IWRM to mean: (a) Ensuring fundamental changes regarding to policies, strategies and actual juridical framework, institutional mechanism and management practices, (b) taking into consideration and bringing together various usages and functions (including physiological, socio-cultural, economic, environmental of water), (c) managing water as a collective good and (d) making it integral part of people life (MEAHV, 2010).

Water resource is defined to encompass under the article 6 of the Law N° 2010-004 on water code " all waters flowing in rivers; water in wells or ground, reservoirs, natural or artificial lakes, ponds, atmosphere, treatment and purification plants, any hydraulic installation for public use as well as installation of land (depending on water or territorial sea which protection and management are done with respect to international agreement)" (MEAHV, 2010). To ensure a better management of water resources, basic principles (adopted from the IWRM principles) have been defined in the article 3 of Law N° 2010-004 on water code (MEAHV, 2010). The overall principles are shown in the Table 4.2.

Table 4.2. IWRM principles adopted in Togo

IWRM PRINCIPLES	WHAT IT INVOLVES
EQUITY	It consists of equitable treatment of the population regarding to WR (equal allocation of water to the population, right to access, equal distribution for various purpose, this, considering efforts made for water conservation and protection).
SUBSIDIARITY	It involves the mobilization of WR, the participation of water users and the decentralized water management decision making.
INFORMATION	It includes the right for all to be informed about the state of WR as well as the right to participate to all consultations and decision-making procedures which may impact adversely WR.
PLANNING AND PARTICPATION	It considers the adhesion of water users and partners to the overall process of water planning and management, the transparency in decision making and a better application of decision taken by key actors.
SUSTAINABLE DEVELOPMENT	Water development and management responding to sustainable development principles.
MANAGEMENT OF WATER BY HYDROLOGICAL BASIN	Considers hydrological basins as planning unit. Includes the participation, management or protection of WR, integration of water cycle components as well all the users in a coherent way.
COOPERATION	Cooperation of all institutions working in areas related to water at all level for the management and protection of WR.

PRECAUTION	Preventive measures are taken to avoid or reduce any risk of WR pollution or any danger associated with the planning or the implementation of activities which are susceptible to affect WR, the environment as well as the population which depends on it.
POLLUTER-PAY	The polluter pays expenses associated to the fight against pollution, but also preventive measures engaged by public powers.
USER-PAY	Setting of water utilisation pricing based on the nature of usages, the quality of water and the quantity used.
RESPONSIBILITY	It defines how society and individuals assume their power and responsibilities regarding to water resources. This responsibility should be done in a way to not harm the resource (either by current or future water users).

4.1.3 Integrated Water Resources Management practices

The success of IWRM approach has been reported to include the political will (one-way engagement of political authorities and adoption of the water law, conformation of sectorial and sub-sectorial policies and strategies to the national water policy, integration of policies and strategies with potential impact on water resources management such as policies on taxing, privatisation, pricing, market rules etc), a good institutional framework (limited to defined roles), adhesion to the IWRM concept and the participation of almost all the actors and stakeholders (mechanism of representation, participation and information), qualified and competent human resources to implement the process, the existence of a data observatory (collect of data and continuous monitoring of the evolution of water resources). As a matter of fact, water should be recognized by political authorities as an important element in socio-economic development of the country.

The adoption in 2010 of the water law as well as the national water policy considered as the reference for IWRM is highlighted as an expression of political will regarding to the management of water resources in an integrated way. This aspect is backed up by the defined institutional framework expressing clearly the roles of each actors to be involved in the process (the state, the National Water Council, central water administration (Ministry of Water), the national water agency, public institutions) with a potential to reduce the continuous conflict of competences between actors.

A financial instrument has been elaborated and adopted, directed by the principle of user-pay and polluter-pay as regulations elements. A system of royalty fee, subsidies and taxes of "water" regarding water abstraction for users (excluding domestic users) and polluter institutions (established according to the article 16, 20, 39, 95, 143, and chapter 1 of the funding system title) (Law N° 2010-004 on water code, 2010). This system is elaborated to feed the IWRM fund established by the water law to support initiatives and efforts of IWRM at national level and to deter abusive abstraction and rejections but also to orientate water demand and consumption and encourage beneficial and useful water usage. Nevertheless, this instrument is yet to be operationalized.

To ensure adhesion of water users and partners to the overall process of water planning and management of inter-sectorial committees as well as the management of water infrastructures at all level (national, regional and local), an institutional platform (supported with a program of capacity building) of concertation is established. The concertation on the question of water are planned to be carried on regular basis. However, this platform has failed to achieve its vision.

An Integrated System for Information on Water (SII-EAU) was established since 2015 as an observation network to collect key data (especially water resource itself, abstraction, usages, mobilization infrastructures and water stage and harvesting), ensure their treatment, storage and dissemination (as directory, bulletin, synthesis documents) as well as the monitoring of parameters over time and over space (done on monthly basis). So far, the network ensures the collect, treatment and storage of hydrometric and hydrogeological data (surface, ground water, quality and quantity). The resulting data bank is availed for free for water management and any related actions. In addition, a monitoring system is also set and updated on monthly or daily basis (depending on the data). With the bank of data available, actors will be informed and will be able participate in key activities such as the development of basins blueprints and sketches of planning and water management, basins synthesis and monographs.

IWRM in Togo takes in consideration the transboundary basins and aquifers shared with other countries of the region. This explained the participation of the country along with other riparian countries in the process of elaboration of the upcoming Volta River Basin charter.

Although a set of sectors depend heavily on water for their activities (including agriculture, fisheries, livestock, energy, environment among others), only the domestic water supply considers the management of water resources in an integrated way.

IWRM in domestic water supply

Water supply directorate in its vision of improving clean water supply to rural, semi-urban and urban populations, considers key IWRM principles such as the responsibility, cooperation and subsidiarity principles at some extend. Clean water in rural and semi-urban is supplied respectively through water points and mini-adduction.

In rural areas as well as in semi-urban areas, based on the National Water Policy on clean water and sanitation services delivery, adopted in 2006, water resources are supplied based on the FORMENT strategy. The DIEPA (Décennie Internationale pour l'Eau Potable et l'Assainissement) strategy known as FORMENT (FORmation à l'ENTretien basée sur l'animation rural) strategy, adopted in 1986 and made applicable since 2012 (DGEA, 2012) consists of providing water or water infrastructures while ensuring the sustainable management of those infrastructures and the accountability of the beneficiary communities. The strategy is based on the communities' demand and participation to water delivery services (one of the tenets of IWRM) approaches. Communities' participation to water delivery services is mainly done by the maintenance of water infrastructures. To ensure the effectiveness of the task, networks of 3 actors (including the water committee, repairmen and spare parts marketers) were created with each actor endowed with a role. The water points (being borehole in most of the cases) are managed (technical and financial view) by the water committees (in which the concept of gender is strong) (one of the tenets of IWRM). The repair of the water points is ensured by craft repairers who are private operators. Finally, the material retailers supply to the community the required materials for the repair. All these actors work in collaboration to ensure the sustainability of the water points. The overall process is supervised by a FORMENT agent who ensures the animation with communities and serves as link between communities and the authorities of hydraulic services (DGEA, 2012).

In urban context, although there is not yet a sectorial policy related to clean water supply and sanitation, the existing policy prone that the public service of water delivery be managed by the state or the territorial communities or any valuable private institutions. In the case of Togo, urban and some semi-urban areas are supplied with water by the Togolaise des Eaux (TdE), a para-public institution to which has been assigned the exploitation of the public service of water delivery and public service of collective sanitation by the law n°2010-006 since November 2014 through a lease and concession contract. The overall management of the Togolese water heritage has been given to a public organization known as "Société Patrimoine-Eau (SP-Eau)", created under the decree n°2011-130/PR of 3rd August 2011 with the mandate of ensuring water resources management through: (i) the management and development of the state heritage in water and domestic waste water sanitation in urban and semi-urban area and (ii) the refund of debts resulting from loans contracted by the sub-sector (MAEH, 2015).

4.1.4 Limitations of IWRM practices for water management in Togo

Above all the achievements such as the introduction of IWRM key principles in plans, programmes and some sector related policies, the implementation of IWRM faces key challenges. The IWRM basically defined to be carried at hydrological basin level as a planning and management unit

(Article 135 of the Law N° 2010-004 on water code) is still not operational. In addition, at the institutional point of view, the management of water resources in the basins is still hanging on the shoulders of the Ministry of water, sanitation and rural water systems (national/central level) as the established organs for the management (i.e. National Water Council) are not operational and key management organs (basin agencies, basin committee, and national water agency) planned for are yet to be established even after the decree 2012-004/PR of the 29th February 2012 (article 1 of the section IV) giving the mandate for the operationalization of organs and institutions established in the water code was issued. Besides, water resources management transition in Togo is suffering from lack of funds to boost this initiative adopted. As an example, the round table organized in June 2011was without financial outcomes (MAEH, 2015). In addition, the limited understanding of the concept by the key actors, the institutional instability and limited collaboration between actors of water related sectors have been pointed out as key hindrances toward the full implementation of IWRM in Togo (Interview, 2018).

In summary, water related texts as well as regulations show that Togo as well as any of its basins or sub-basins rely on Integrated Water Resources Management approach for the management of its water resources. Nevertheless, the implementation processes and implemented actions show that the IWRM in Togo is still at its early stage and not really evolving. Thus, the question remains to know if the partial implementation of IWRM approach was beneficial, was the approach able to solve the existing problems or source of additional problem since it adoption and is the approach achievable in the context of Togo as in other countries?

4.2 Water Resources Management Arena in the Oti Nord sub-basin

4.2.1 Water resources management institutions

Although represented at district level, water resources in the Oti Nord sub-basin are currently managed by institutions from different levels (i.e. international, sub-regional, national, regional, district and village) and domains of intervention (i.e. government institutions, NGOs, community-based organisation and private operators).

The main regional institution in charge of managing and regulating the development of water resources in the Oti Nord sub-basin (as part of the Volta River basin) is the Volta Basin Authority (VBA), created in 2006 with the mandate of promoting permanent consultation, tools among the parties for the development of the basin, implementing the IWRM and authorizing the development of infrastructures and projects associated with substantial impact on the water resources of the whole basin (Volta- HYCOS, 2006). The authority works at regional level.

Based on the Law N° 2010-004 on water code and the National Water Policy of August 2010 (MEAHV, 2010), water resources in the Oti Nord sub-basin as integral part of the country resources is supposed to be managed by two entities such as the National Water Council (created by the decree n° 70-161/PR of the 14th September 1970) and the Oti River Basin institutions in a joint action. Nevertheless, because of the non-operationalisation of the National Water Council and the absence of basin institutions, the Oti Nord sub-basin is managed by the institution representing the Oti River Basin (Water Resources Directorate of the Ministry of Water and Rural Water Systems). This Directorate works in collaboration with other directorates of the ministry (water supply directorate; planning, evaluation and monitoring directorate; sanitation directorate, Savanah regional water and rural water systems directorate) but also water related ministries, technical/scientific/educational organizations (such as the Universities) and public institutions (i.e., the national Institute of Hygiene, National meteorological services). Water resources directorate oversees the elaboration of water policies and regulations, preparation of orientations regarding to the standardization and regulation of water resources management, different water usage and the establishment of water quality measurement instruments; hydrological and hydrogeological studies; evaluation of water resources and potential needs essential for water development; the implementation and monitoring of water related programmes; the application of measures towards water resources development and protection. Moreover, the directorate is also mandated to ensure regional and international water resources management cooperation, animate and coordinate national water use planning institutions as well as to coordinate the management of transboundary basins.

At regional, district and village level the overall management is ensured by the regional directorate of water and rural water systems in collaboration with other water related regional directorates; civil society including Non-governmental organizations (e.g. Rafia, CDD, Togolese Red Cross Savannah), water users associations, water related community-based associations and water committees and public institutions (such as the regional meteorological services). The key local management institutions are water committees (in rural and urban areas) and clean water users and sanitation associations (only in rural and semi-urban areas).

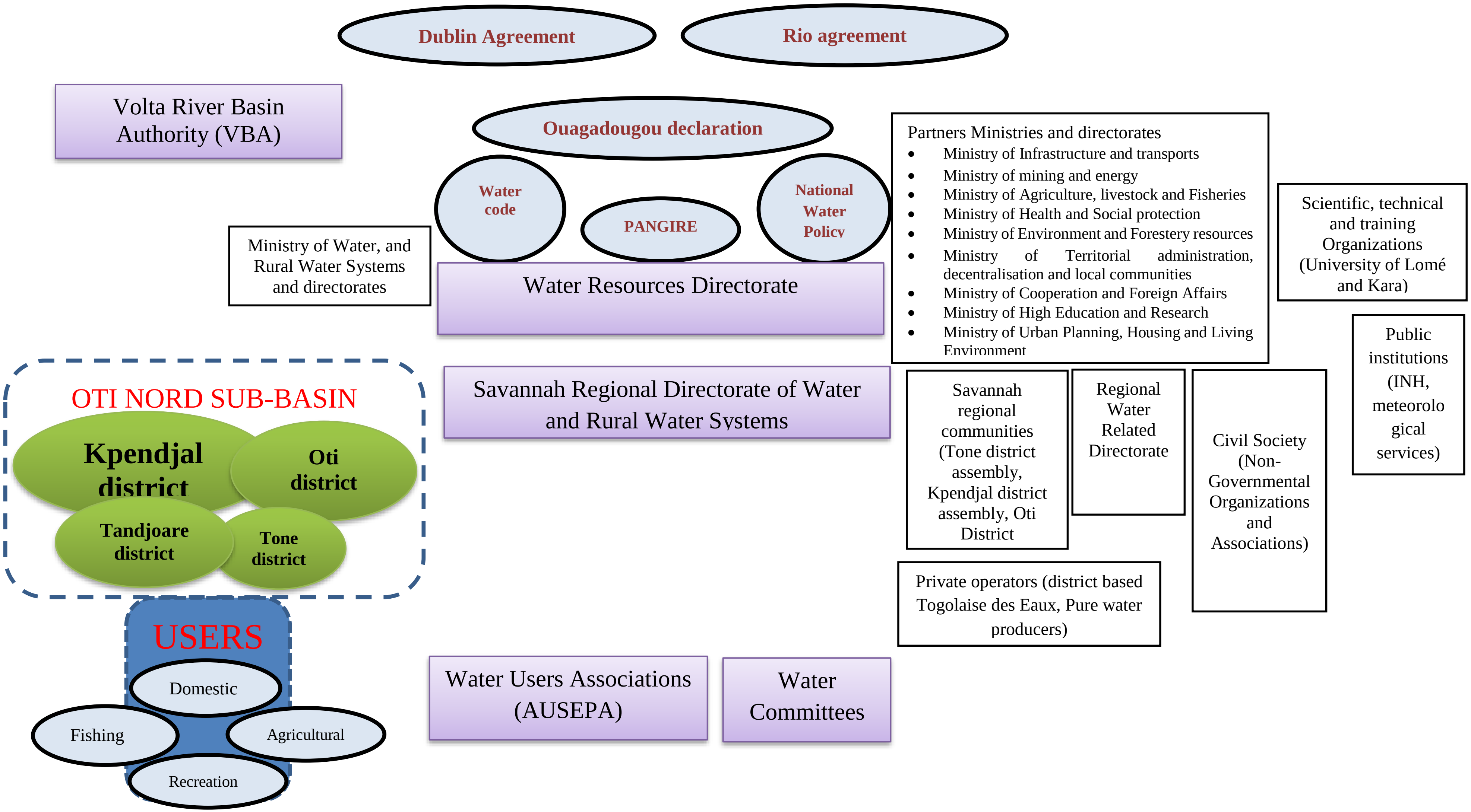

Fig 4.1. Institutions and interrelationships conceptual map in the Oti Nord Sub-basin
Move rectangles represent the described entities constituting the institutional framework of water management in the sub-basin. The Low left blue dotted box highlights the various water users in the sub-basin. The upper left dotted box with green ovals are the various district part of the sub-basin with their representative proportion. The rest of ovals are example of adjacent entities. Finally, the ovals with brown texts are key documents used for the overall water management in the whole country.
Source: Authors' construction

4.2.2 Roles of institutions in water security in the Oti Nord sub-basin

Institutions intervene to ensure that water demands are covered in adequate quality and quantity domestic uses, economic activities in the Oti Nord sub-basin. Institutions intervening in the effort to ensure water in adequate quality and quantity for the population health, economic activities as well as ecosystems protection in the Oti Nord sub-basin are of various types. A total of 32 respondents have been assessed, out of which 41% are from government institutions, 37% from community-based organizations, 19% from NGOs and 3% from the private sector (Figure 4.2).

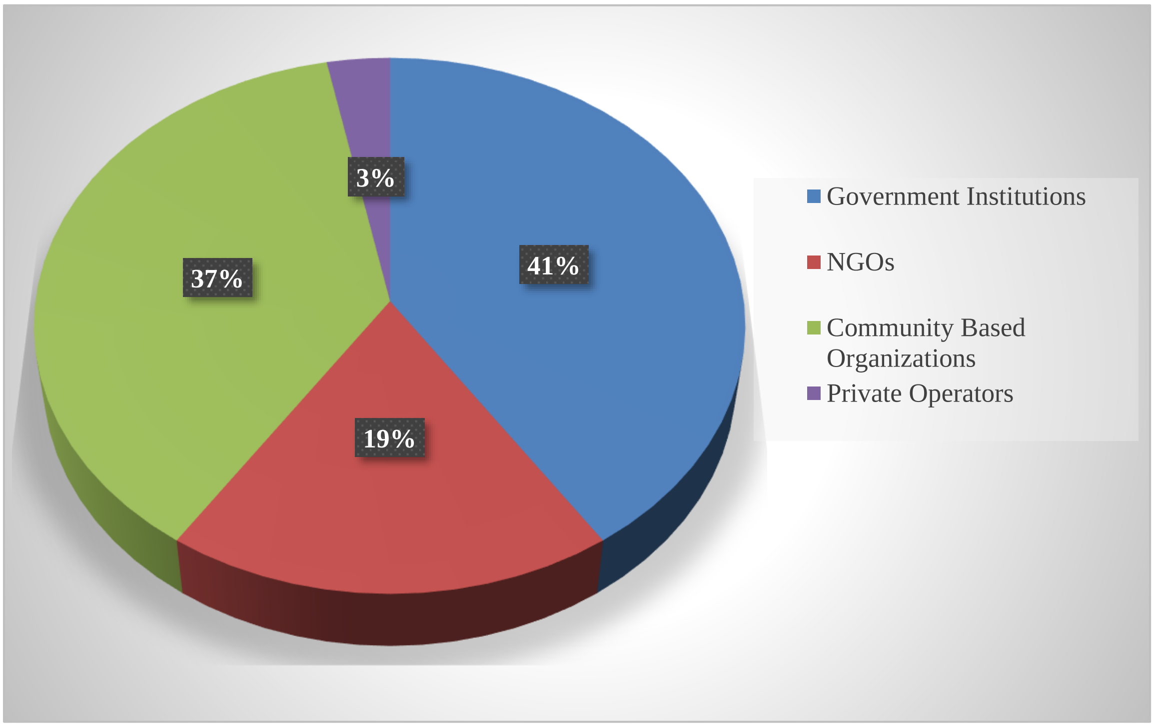

Fig 4.2. Types of institutions assessed in the context of water security

These institutions whether governmental, private or civic are involved in key activities contributing to water security in the Oti Nord sub-Basin. Figure 4.3 shows the role of the assessed institutions in ensuring water security in the Oti Nord sub-basin. Most of the assessed institutions play a range of roles and that explains why the total exceeds 100%. They are mainly involved in sensitization or education (50%), water resources management (34%), juridical interventions (31%), water resources mobilization (28 %), water bodies protection (22%), control of pollution (16 %), tree planting (13 %) and the control of water quality (6%). Other roles include building water data bank, searching for water activities funds, adoption of sound agricultural practices and water conflicts resolution.

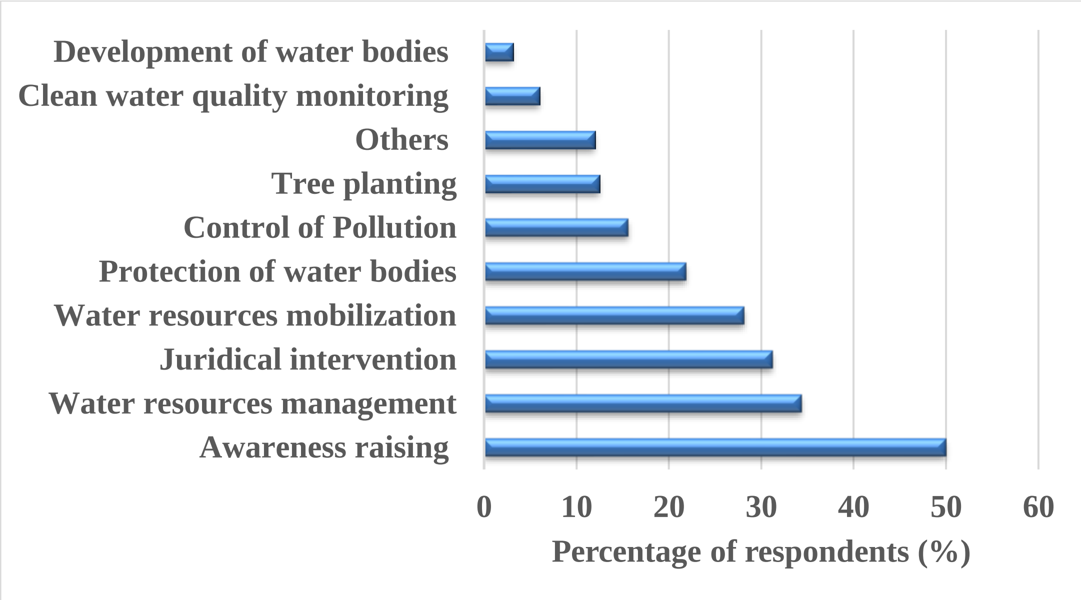

Fig 4.3. Institutions' roles in ensuring water security in the Oti Nord sub-basin (n=32)

The following are the details of the role performed by each institution:

1) Awareness raising

One of the actions carried by the existing institutions towards water security in the sub-basin is awareness raising (Figure 4.4). It involves mainly trainings and education on key aspects such as the benefits of clean water consumption (44%), hygiene and sanitation (18%), sustainable use of water resources (12%), tree planting (12%) among others.

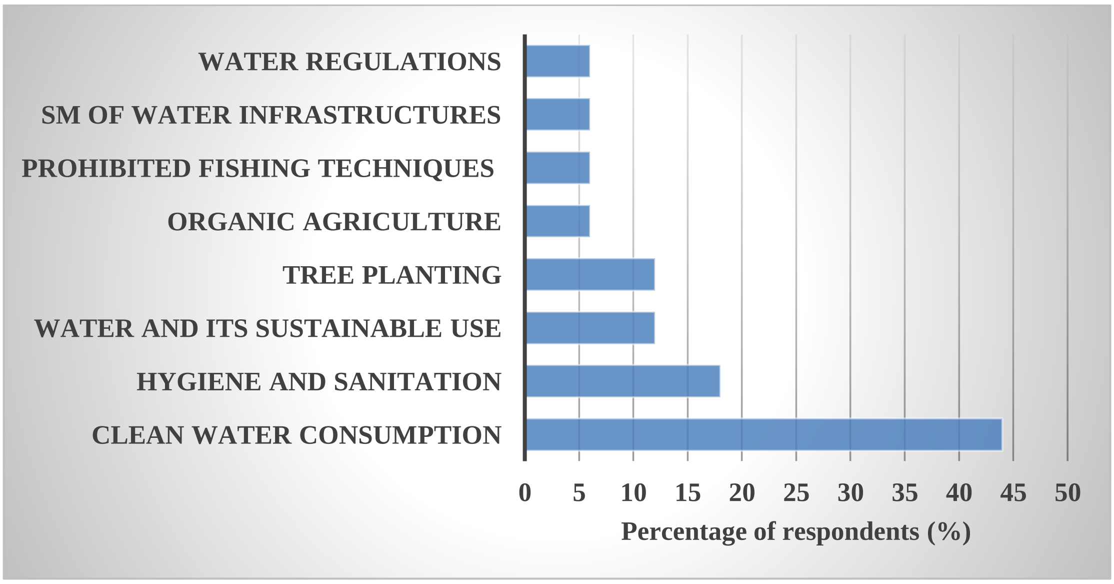

Fig 4.4. Institutions' contribution to WS through awareness raising (n=16)

The educational training on the benefits of clean water consumption was meant to ensure that people consume water from improved sources (taps, kiosks) instead of water from unimproved sources (unprotected well, rivers, dams). In addition, awareness raising is meant to shape communities' conception as well as their behaviour towards hygiene and sanitation which play key role in provide good quality water to household. Finally, the notion of sustainable use of water as a resource has been impacted into communities through those trainings. These actions are carried by almost all types of institutions (especially government institutions, NGOs and community-based organizations).

2) Water resources management

Water resources management in the sub-basin consists of soft and hard measures.

Soft measures include the management of the existing water infrastructures (73%) as well as the supervision of the management process (18%). These efforts are ensured by both community-based organizations (especially water committees and the clean water users and sanitation associations) and government institutions (regional directorate). So far, water committees have contributed to the management in terms of the maintenance of existing water supply infrastructures (through repair of water infrastructures and sanitation of their surroundings). On the other hand, the hard measures consist of building water conservation infrastructures (9%), mainly meant to control and store water in order to keep humidity in the soil and avoid early drying up of wetlands, associated with impacts on crops. These structures include gabions, stone bonds and groynes which are built by communities with the support of NGOs. Moreover, these structures are also known for their contribution to the recharge of water tables. The overall water resources management aspects are shown in Figure 4.5.

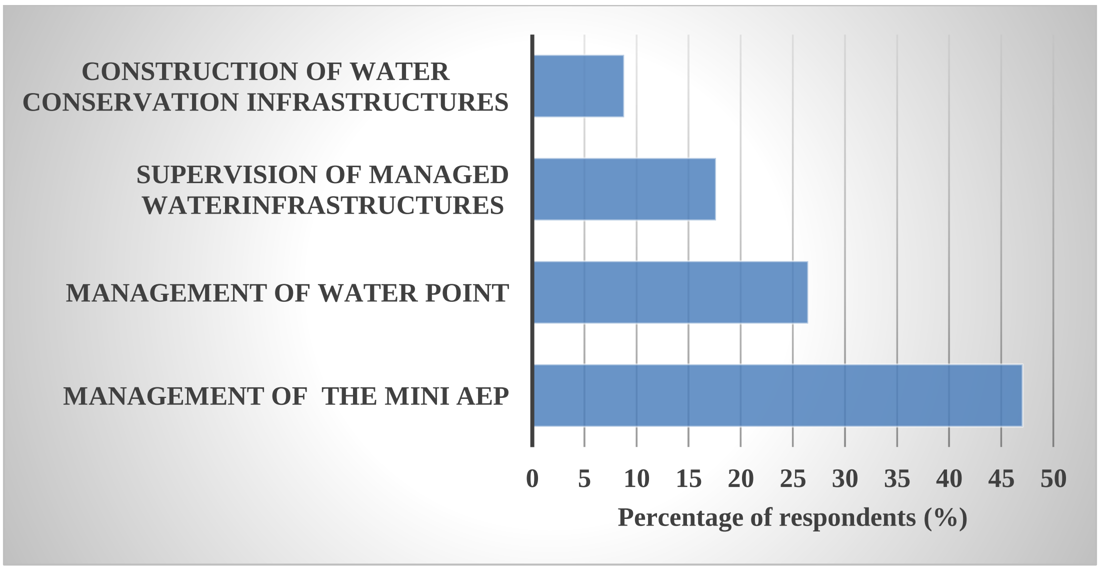

Fig 4.5. Institutions' contribution to WS through water resources management (n=11)

3) Juridical interventions

Mainly ensured by the central government institutions (particularly the Ministry of Water and Rural Water Systems and its different directorates) in concertation with other key institutions (Regional directorate as well as other ministries and actors in water sector), juridical interventions done to ensure water security in the Oti Nord sub-basin is done as in any other basin. It is done through the definition of policies and regulations such as the national water policy, water code among others (81%), the reinforcement of water policies and regulations (81%), the drawing up of water programs (52%), the implementation of programs (29%) and the evaluation and monitoring of these programs (10%) (Figure 4.6).

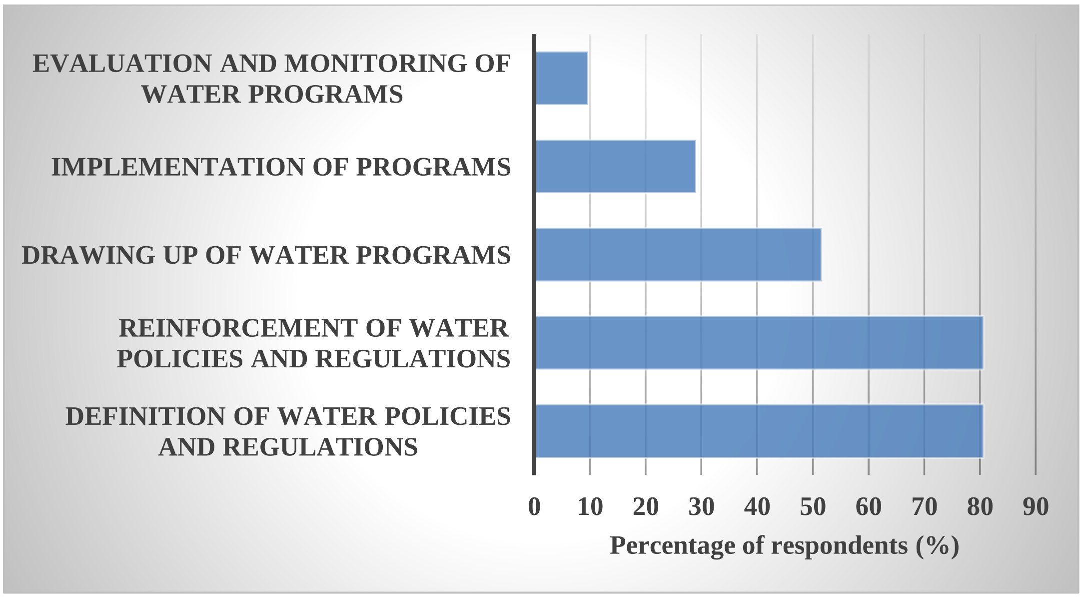

Fig 4.6. Institutions' contribution to WS through juridical intervention (n=10)

4) Water resources mobilization

Water resources mobilization includes water for drinking, economic (especially vegetable growing and livestock watering), ecosystem sustainability and water storage purposes.

Water mobilization for drinking purpose has been achieved through the construction of drinking water infrastructures (such as water point, mini-DWS) (79%), the rehabilitation of water points or boreholes (32%), the extension of water supply network (21%), and the production and commercialisation of clean water (68%). At the other side, water for economic purpose is mobilized through the construction of vegetable growing wells, the development of wetlands and the construction of livestock watering ponds. Finally, dams and water ponds are built (68%) in order to store water either used for drinking or economic purposes.

The overall aspects of water mobilisation in the sub-basin are depicted in the Figure 4.7.

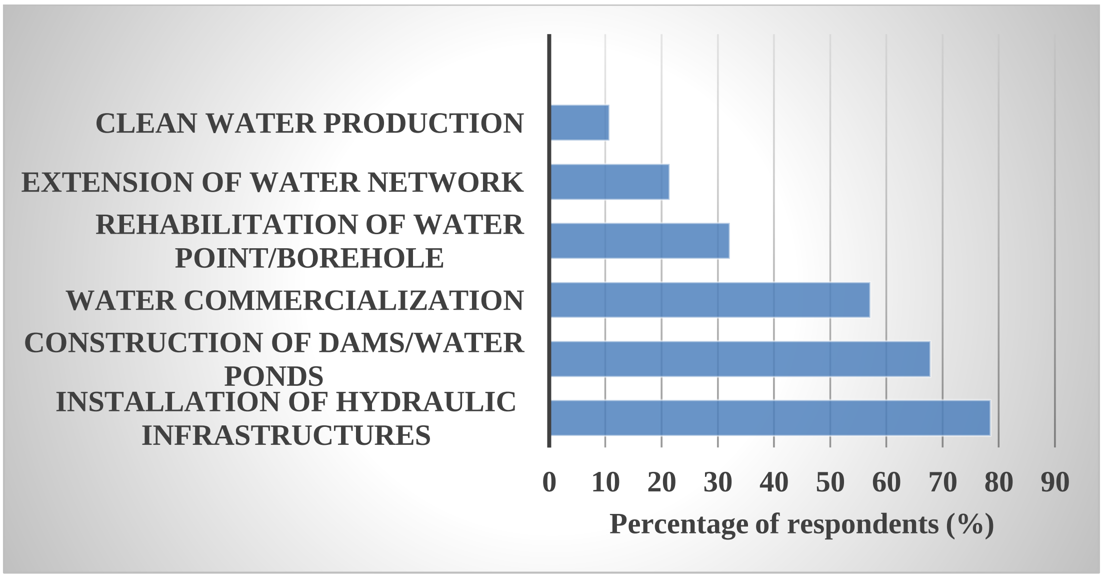

Fig 4.7. Institutions' contribution to WS through water resources mobilisation (n=9)

5) Protection of water bodies

The protection of water bodies is mainly done through the establishment of buffer zones and the protection of those zones. The buffer zones are established by planting trees on the river banks (73%) or by keeping defined zone along the river in fallow (14%) (Figure 4.8). In the sub-basin the establishment of the buffer zone is ensured by the government institutions while the protection of those buffer zones (14%) is ensured by the communities (especially vegetable growing as well as fishing communities) in collaboration with NGOs.

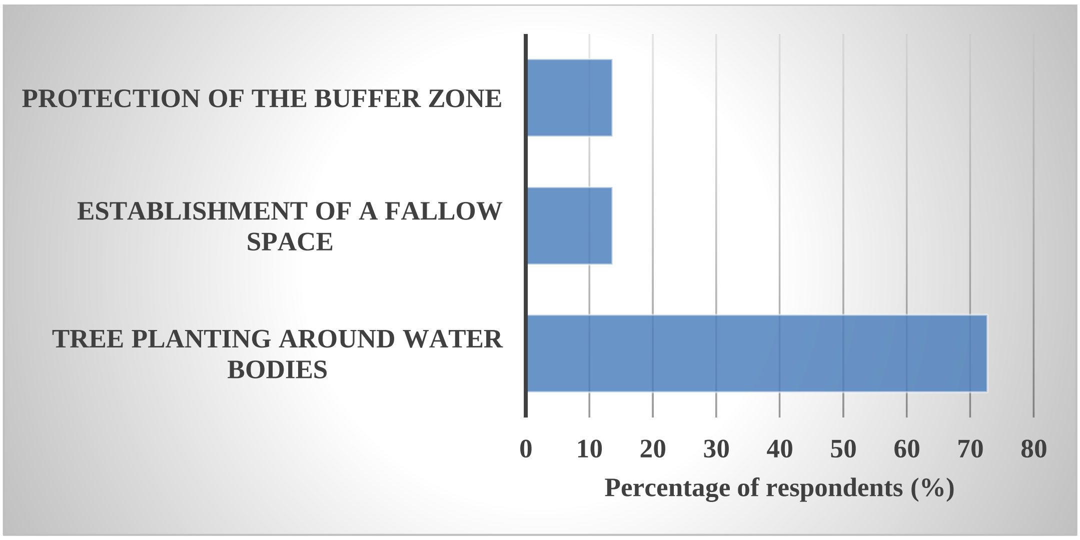

Fig 4.8. Institutions' contribution to WS through the protection of water bodies (n=7)

6) Control of pollution

The control of pollution in the sub-basin concerns more surface waters. Actions carried out include the transition to organic farming (56%), the construction of latrines (25%) and the chemical-based fishing monitoring (19%) (Figure 4.9). For community-based associations, the transition to organic farming is done through a shift to the use of organic and bio-fertilizers (use of Tabaco and compost) and the use of authorized insecticides and pesticides (Interview, 2018). However, it is pointed some issues related to the availability of the compost (which depends on animals' availability) as well as the high price of authorized chemical (compared to the product found on the market). The governmental institutions, NGOs and community-based organisations (especially the farming and fishing organizations) are key in this fight.

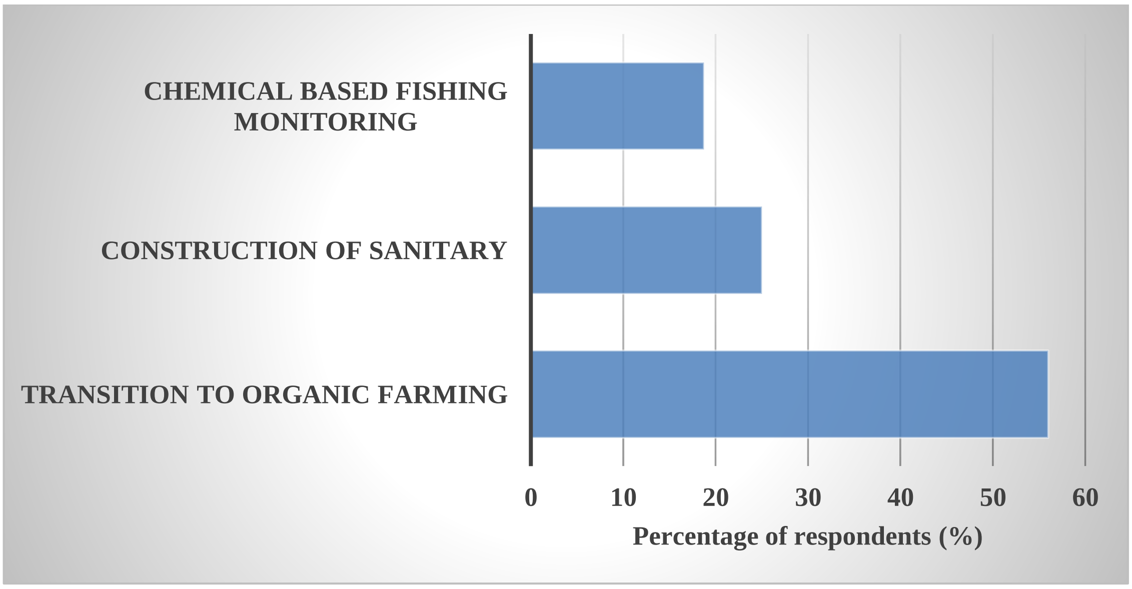

Fig 4.9. Institutions' contribution to WS through the control of pollution (n=5)

In summary, institutions working in the Oti-Nord sub-basin contribute greatly in efforts to ensure water security in the area. The study has shown that the existing institutions contribution to WS is either directly (through water resources mobilisation, water resources management, control of pollution, protection of water bodies, development of water bodies, and the control of water quality) or indirectly (through juridical intervention, awareness raising and tree planting). In addition, this study revealed that apart from governmental institutions, NGOs and private sector actors which carry out their mandate, community-based organizations (meaning local communities) play a key role in ensuring water security even if their efforts are not directly related to water, it takes their will. These actions include planting of tree, adoption of sound agricultural practices/soil conservation measures, and the acceptation and promotion of organic agriculture.

4.3 Water Security in the Oti Nord Sub-basin

In this study, 23 indicators were considered and organized in 5 sub-systems, making the water security system. The observed (2010 and 2015) and projected values of each indicators (2025) were obtained from the governmental institutions (i.e. Ministry of Water and Rural Water Systems and its directorates; Sanitation and Hygiene regional directorate; Water and rural water systems regional directorate; Agriculture, livestock and fishing regional directorate), public institutions (National Meteorological services) and private institutions ("Togolaise des Eaux"), etc. For the lacking data, some indicators values have been approximated while for others the regional or national values (e.g. GDP growth rate, population growth rate, quantity of water for irrigation) or the values of available years close to the year of assessment (stream flow index and the GDP growth rate) have been attributed. The overall data obtained are depicted in Table 4.3.

Table 4.3. Basin level water security indicator values (observed and projected)

Sub-systems	Indicator	2010	2015	2025
Water-Resources Security (WRS) (B1)	Modulus of surface water (C1) (10^6 m^3 km^{-2})	0.23	0.23	0.23
	Modulus of ground water (C2) (10^6 m^3 km^{-2})	0.125	0.125	0.125
	Stream flow index (C3)	0.7	1.37	1.12
	Ground water recharge capacity (C4) (mm/year)	177	177	177
	Per capital water resources availability (C5) (m^3/capita/ year)	3860	3478	3033
Water-Society Security (WSS) (B2)	Per capital water consumption (C6) (m3/ person/year)	15.51	20.08	24.64
	Urban population with access to improved water (C7) (%)	43	45	100
	Rural and semi-urban population with access to improved water (C8) (%)	50.88	99.52	100
	Surface water quality factor (C9)	21.5	21.5	21.5
Water-Economic Security (WES) (B3)	Economic water consumption rate (C10) (%)	0.49	0.69	2.09
	Commercial/industrial (of fountain and water kiosks) revenue per m3 of water (C11) (FCFA/m3)	75	75	75
	Livestock revenue per m3 of water (C12) (FCFA/m3)	5385	5385	5385
	Non-agricultural (fountain and water kiosks) water price (C13) (FCFA/ m3)	315	315	315
	Agricultural (livestock) water price (C14) (FCFA/ m3)	0	0	0
Water-Environment Security (WEES) (B4)	Surface water quality factor (C15)	0.5	0.5	0.5
	Ground water quality factor (C16)	0.09	0.09	0.09
	Population with access to improved sanitation (C17) (%)	68.4	66.37	100
	Water re-use rate (C18) (%)	0	0	0
	Water resources utilisation rate (C19) (%)	0.65	1.1	2.09

External-Environment Security (EES) (B5)	Population growth rate (C20) (%)	2.84	2.2	2
	Land degradation rate (C21) (%)	62.25	77.25	107
	GDP growth rate (C22) (%)	4.02	5.1	5.31
	Temperature (C23) (°C)	29.3	29.3	30.21

The data compiled from various sources are normalized. For the indicators expressing better condition when their values are large, thus known as "larger is better" (positive) the formula (1) is used while the formula (2) is used for the indicators known as "smaller is better" (negative). The formula used are given below:

$$Xi' = \frac{Xi - Ximin}{Ximax - Ximin} \quad (1)$$

$$Xi' = 1 - \frac{Xi - Ximin}{Ximax - Ximin} \quad (2)$$

Where, i is the indicator, Xi the original value of i, $Ximin$ and $Ximax$ are respectively the minimum and maximum value of the indicator i.

The values of the indicators were transformed into dimensionless values ranging between 0 and 1 as shown in the Table 4.4.

Table 4.4. Values of the selected indicators after normalization

Sub-systems	Indicator	2010	2015	2025
Water-Resources Security (WRS) (B1)	Modulus of surface water (C1)	0	0	0
	Modulus of ground water (C2)	0	0	0
	Stream flow index (C3)	0	1	0.6269
	Ground water recharge capacity (C4)	0	0	0
	Per capital water resources availability (C5)	1	0.5381	0
Water-Society Security (WSS) (B2)	Per capital water consumption (C6)	1	0.4995	0
	Urban population with access to improved water (C7)	0	0.0351	1
	Rural and semi-urban population with access to improved water (C8)	0	0.9902	1
	Surface water quality factor (C9)	1	1	1
Water-Economic Security (WES) (B3)	Economic water consumption rate (C10)	0	0.125	1
	Commercial/industrial (of fountain and water kiosks) revenue per m3 of water (C11)	0	0	0
	Livestock revenue per m3 of water (C12)	0	0	0
	Non-agricultural water price (C13)	1	1	1
	Agricultural (livestock) water price (C14)	1	1	1
Water-Environment	Surface water quality factor (C15)	1	1	1
	Ground water quality factor (C16)	1	1	1

Security (WEES) (B4)	Population with access to improved sanitation (C17)	0.0604	0	1
	Water re-use rate (C18) (%)	0	0	0
	Water resources utilisation rate (C19) (%)	1	0.6875	0
External-Environment Security (EES) (B5)	Population growth rate (C20) (%)	0	0.7619	1
	Land degradation rate (C21) (%)	1	0.6648	0
	GDP growth rate (C22) (%)	1	0.1628	0
	Temperature (C23) (°C)	1	1	0

As shown by the Table 3.4 (Chapter 3), taking into consideration the theory of catastrophe models, the water security system as well as the sub-system B1 meet the Wigwam model while the remaining sub-systems (B2, B3, B4 and B5) meet the butterfly model. Based on the fuzzy membership function of each involved model and the principle of mean value (in sub-systems as well as the overall water security computation), the synthetic values of catastrophe assessment for the year 2010, 2015 and 2025 were calculated. The equations (5), (6) and (9) were used for the establishment of the fuzzy memberships:

The butterfly catastrophe: $Xa = a^{1/2}$; $Xb = b^{1/3}$; $Xc = c^{1/4}$ and $Xd = d^{1/5}$ (5)

The Wigwam catastrophe: B= $f[\, Xa = a^{1/2}; Xb = b^{1/3}; Xc = c^{1/4}; \; Xd = d^{1/5} \;\; Xe = e^{1/6}]$ (6)

Value of each sub-system is computed using the equation (8) while the overall water security level is computed using the equations (9) and (10):

$$B = \frac{Xa + Xb + Xc + Xd + \cdots Xn}{n} \qquad (8)$$

$$WS = f\ [XB1 = (B1)^{1/2}; XB2 = (B2)^{1/3}; XB3 = (B3)^{1/4}; XB4 = (B4)^{1/5} \text{ and } XB5 = (B5)^{1/6}] \qquad (9)$$

$$WS = \frac{XB1 + XB2 + XB3 + XB4 + XB5}{5} \qquad (10)$$

The overall results of the values of the sub-systems and the water security in Oti Nord sub-basin are shown in the Table 4.5.

Table 4.5. Value of indicators at different levels

Sub-Systems	2010	2015	2025
Water-Resources Security (WRS) (B1)	0.2000	0.3804	0.1780
Water-Society Security (WSS) (B2)	0.5000	0.7579	0.7500
Water-Economic Security (WES) (B3)	0.4000	0.4707	0.6000
Water-Environment Security (WEES) (B4)	0.6991	0.5872	0.6000
External-Environment Security (EES) (B5)	0.7500	0.8452	0.2500
Water security (synthetic values)	0.7841	0.8456	0.7814

The values of water security sub-systems show that the water-resources security sub-systems followed an increasing pattern over the period of 2010 and 2015. This situation may be mainly due to high stream flow in 2015 compared to the interannual stream flow (which may be due to high rainfall combined with moderate temperature). However, by 2025 the value of this system is expected to decrease compared to the year 2015 and even 2010. This situation may be attributed to the sharp increase of the temperature by 2025 (about additional 0.91 degree Celsius) compared to the year 2010 and 2015. This decrease in water-resources security in sub-basin is in concordance with the results of the WEAP assessment of ground water resources under the changing climate in the country. As a matter of fact, the whole country faces a decrease in ground water resources with savannah region to which the Oti Nord sub-basin is part, been reported to completely exhaust its ground water resources by 2053 (under the extreme scenario of the RCP 8.5) (MERF/ DE/TCN, 2015).

As for water-society security sub-system which defines the pattern between water as a resource and the society, the value has increased over the time. The value of the sub-system has shown an increasing pattern over the period 2010 – 2015. This situation may be due to efforts that are made in the overall country (including Oti Nord sub-basin) towards communities' access to improved clean water these years, with the objective of achieving the Millennium Development Goals targets concerning clean water. This result is consistent with the National Institute of statistic, demographic and economic studies (INSEED) findings reporting that access to clean water has followed an increasing pattern over the period between 2010 and 2015 (INSEED, 2016). Nevertheless, this level of security is projected to decrease by 2025 compared to 2015.

At the same time, the water-environment security which has to do with the health of the ecosystems (dependent on the quality and quantity of water) has been characterised by a decreasing pattern over the time. This situation is consistent with the transboundary diagnosis of Volta River Basin findings where the degradation of the quality of surface water associated with the degradation of aquatic ecosystems has been recognized as one of the most acute problem in Oti River Basin, Togo (MMEE/DGEA/UN-DESA, 2009; UNEP-GEF, 2013). This degradation in the study area is attributed to limited sanitation (open defecation still going on), bad management of domestic waste, bad fishing practices (use of chemicals and explosives), livestock watering in the river bed, chemical from agricultural activities (pesticides and fertilizers) but also domestic activities such as laundry in the river beds (Figure 4.10).

Fig 4.10. Sources of water pollution in the Oti Nord sub-basin (Photo credit: Mawulolo YOMO)

However, the result has shown that the ecosystem health will be a little improved by 2025 compared to the year 2015 considered as the worse. This slight increase may be due to the efforts planned for in term of sanitation which consist in ensuring universal access to improved latrines, thus eradicating totally the open defecation.

As for the water economic security, the results depict an overall increasing pattern. The increase is consistent with what is happening on the ground. The livestock in the study area is increasing while irrigation projects (development of irrigation potentials known as “agropole”) are being experimented to be executed.

The final values of water security over time in the Oti Nord sub-basin are obtained through the transformation of original synthetic values of water security. The transformation was done using the following equation (with the overall result depicted in the Table 4.6):

$$y = 9.144WS - 35.665WS^2 + 66.378WS^3 - 58.18WS^4 + 19.32WS^5 \quad (10)$$

Table 4.6. Evaluation Results

System	2010	2015	2025
Water security (synthetic values)	0.7841	0.8456	0.7814
Water security (modified synthetic values)	0.1592	0.1994	0.1578
Level of water security	Very Insecure	Very Insecure	Very Insecure

As shown in the Table 4.6, water security level assessment revealed an overall insecurity in the Oti Nord sub-basin. The year 2010 has been depicted as very insecure. Although the year 2015 is still in the same range of insecurity, the status of the sub-basin has improved compared to the year 2010. Finally, projections depicted that water security level will decrease by 2025 compared to the year 2010 and 2015 and will be the worse year among all the assessed years. This result is consistent with Gain et al (2016) findings which reported that river basins are likely to experience ‘low water security’ over the coming decades.

Water insecurity in the Oti Nord sub-basin is found to be the result of a combination of a decreasing water resources available (associated with the challenging environment such as population growth, climate change among others) and water quality deterioration (mainly due to the acute pollution). However, considering water barriers proposed by Falkenmark (1989), although the per capita water availability in the sub-basin is decreasing over time, the lowest values obtained (3033 m^3 per capita per year) is higher than water stress threshold (estimated at 1700 m^3 per capita). This imply that the water insecurity in the Oti Nord sub-basin is much more quality than quantity related.

Sensitivity analysis

Water security index was also computed changing the inner logic relationships and the importance of the sub-systems in the overall water security system. Table 4.7 shows the values of water security after each change of sub-systems inner logic relationship and importance. The resulting values depicted an overall decrease in the water security level in the future (up to a value of 0.1490 in 2025) (Table 4.7). However, the increase access to clean water (implying more investments) as well as the consideration of the existing ecosystems' health (environment) will improve the overall security level in the sub-basin in the future (up to a value of 0.1796 in 2025).

Table 4.7. Sensitivity Analysis Results

	2010	**2015**	**2025**
Water security 1 (WRS, WSS, WES, WEES, EES)	0.15915	0.1994	0.1578
Water security 2 (WSS, WES, WEES, EES WRS)	0.17571	0.223	0.1796
Water security 3 (WES, WEES, EES, WRS, WSS)	0.1756	0.20546	0.1661
Water security 4 (WEES, EES, WRS, WSS, WES)	0.1858	0.2189	0.1587
Water security 5 (EES, WRS, WSS, WES, WEES)	0.175604	0.22559	0.1490

WRS = Water-Resources Security; WSS = Water-Society Security; WES= Water-economic Security; WEES = Water-Environment Security; EES= External-environment Security

4.4 Potential Barriers to Water Security in the Sub-Basin

Efforts are made to ensure water security in the Oti Nord sub-basin. Nevertheless, institutions respondents recognized that there is barriers and potential barriers in achieving this security (97%) (Figure 4.11).

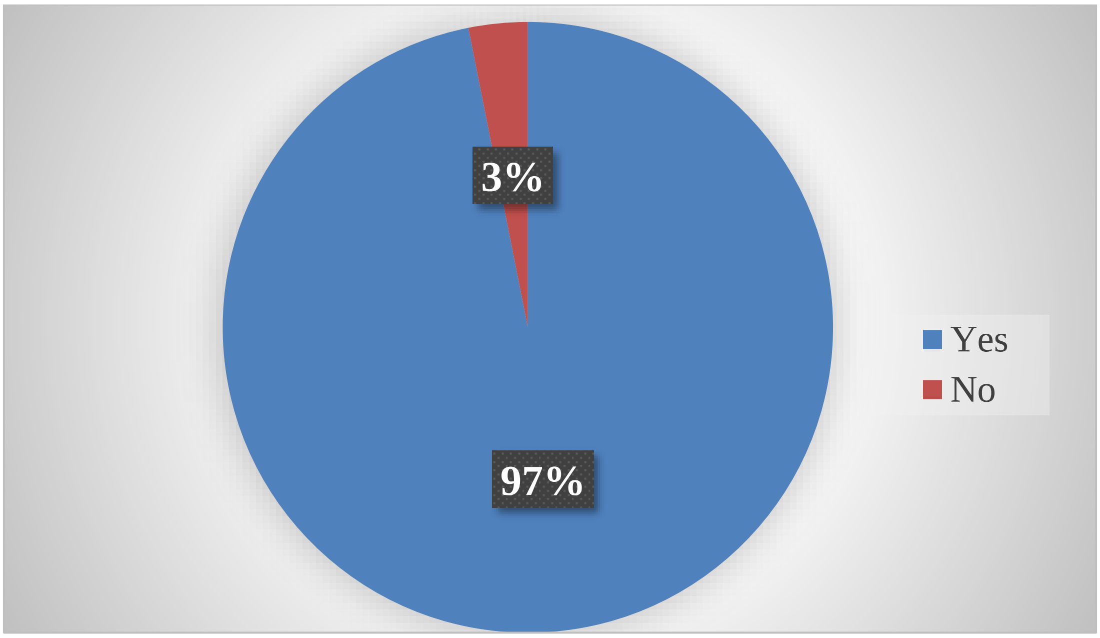

Fig 4.11. Presence of potential barriers to WS in the Oti Nord sub-basin (n=32)

Several barriers have been depicted with the most recognized being technical (63%), institutional (44%), juridical (44%), environmental (37%), socio-cultural (22%), hydrogeological (19%) and demographical (19%) (Figure 4.12). Other barriers include the siltation of river and unbeneficial source of energy for water mobilisation. Most of the assessed institutions highlighted a range of barriers making the water level insecure in the sub-basin (explaining why in some cases the total exceeds 100%).

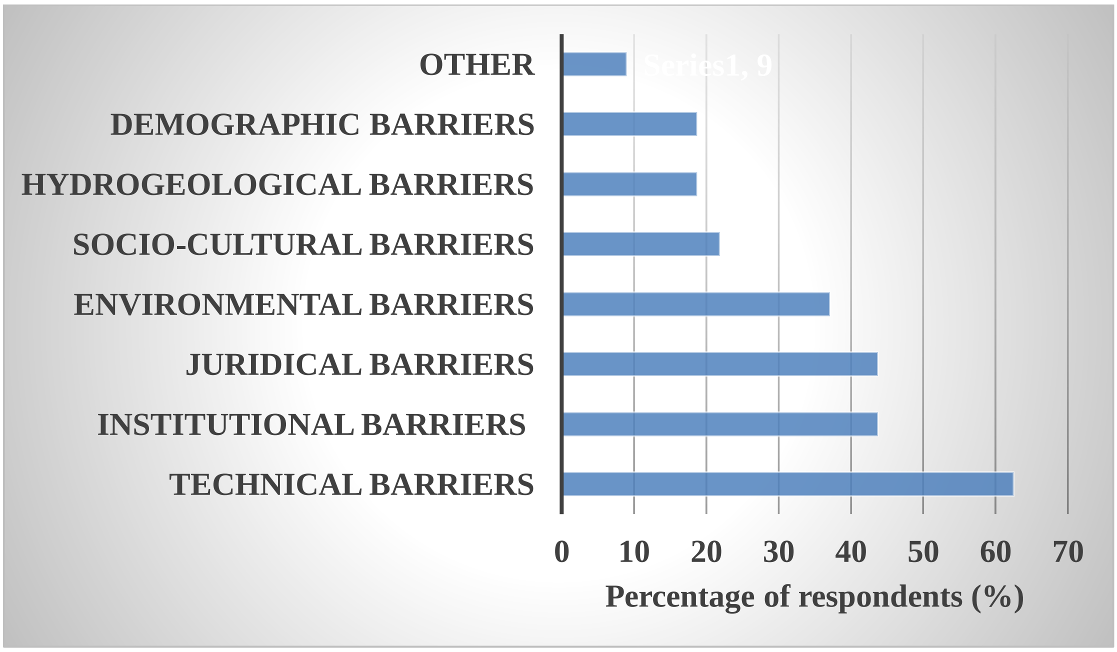

Fig 4.12. Potential barriers to water security in the Oti Nord sub-basin (n=32)

The following are the details of barriers to water security in the Oti Nord sub-basin:

1) Technical barriers

The main technical barriers highlighted are the limited fund (89%), the lack or limited water related data (40%). The other barriers are the limited human resources and expertise (10%) and limited water infrastructures (5%) (Figure 4.13). Most of the assessed institutions have highlighted a range of technical barriers, that explains why the total exceeds 100%.

The limited fund is both in terms of government investment in water sector as well as the external aid in the efforts for universal provision of clean water. For the government, access to clean water is one of the many priorities of the country. Thus, there are limited fund to be allocated to this need as well as other needs.

Limited water related data highlights the fact that the data necessary, required for any sound planning, mobilisation and development of water is lacking (considering the available time series as well as the quality of those time series). These data include the exact values of potential renewable water resources in the country or at basin level, and the sectoral (i.e. agriculture, energy, environment) needs for water among others. This situation is reported to be associated with the either an overestimation or underestimation of resources available.

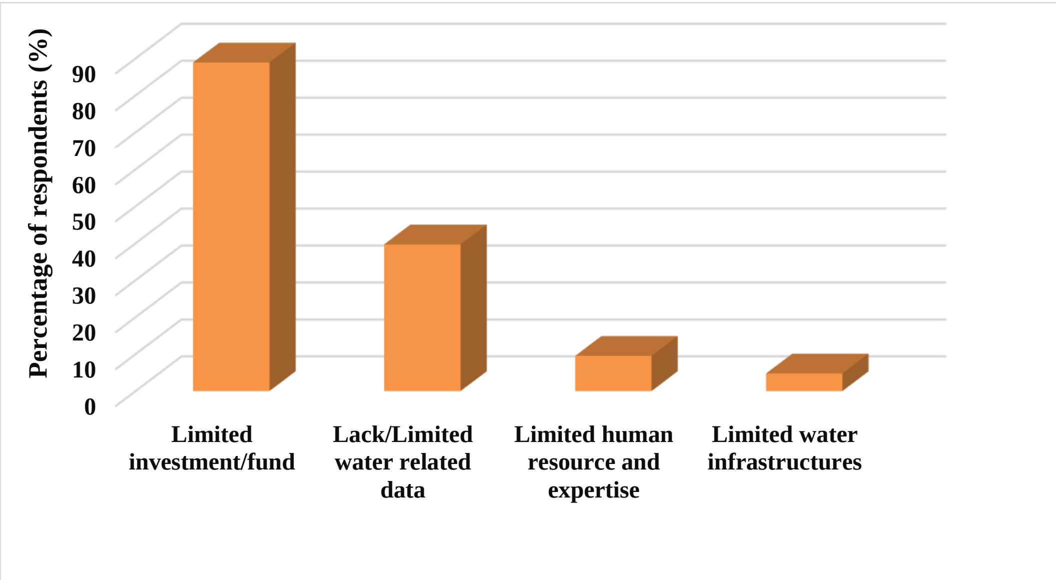

Fig 4.13. Technical barriers to WS in the Oti Nord sub-basin (n=20)

2) Institutional barriers

Key institutional barriers highlighted are the limited collaboration among water actors (43%), the institutional instability (36%), the inadequacies in water and related sector evolution (20%), absence of decentralised water structures (14%) and the limited coordination within the water sector (14%). Most of the assessed institutions have highlighted a range of institutional barriers, that explains why the total exceeds 100% (Figure 4.14).

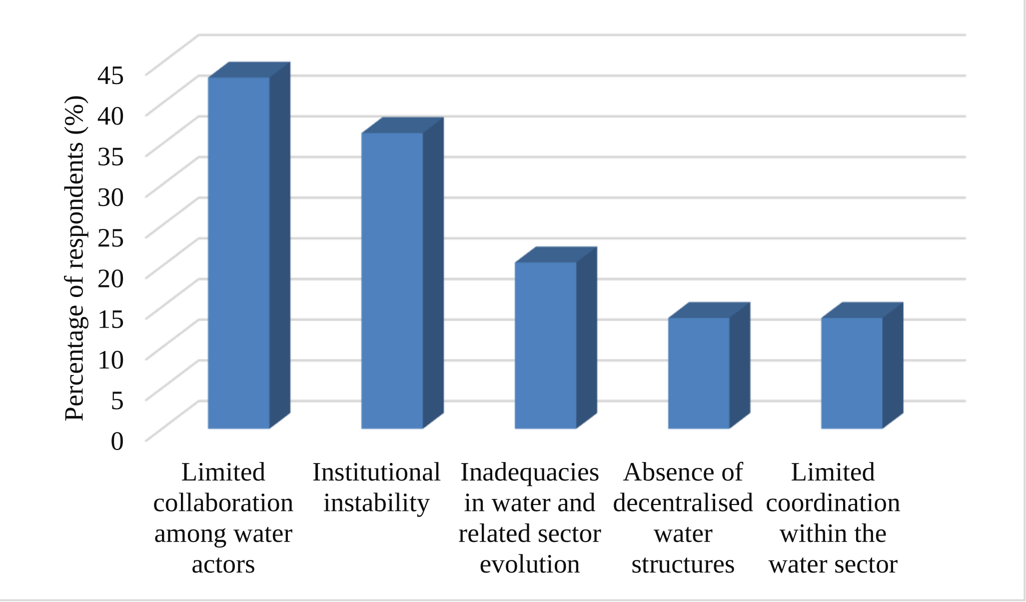

Fig 4.14. Institutional barriers to WS in the Oti Nord sub-basin (n=20)

The limited collaboration among water actors has to do with the limited concertation meetings between actors (which is very sporadic even if it is planned to be regular) and the ineffective monitoring of water committees and clean water users and sanitation associations (AUSEPAs) which represent the local water management institutions. Another aspect of the collaboration is the transboundary collaboration with the Volta River Basin riparian countries (especially between Togo and Burkina Faso). As a matter of fact, fishing communities in the sub-basin reported that the quantity of water in Oti river in Mango regulated by the Kopienga dam (in Burkina Faso) has been having impacts on the capture, thus affecting their revenue. The community reported that the incident started since 2006, as the result of a continuous release of water from the dam.

The institutional instability has to do with the fact that the Ministry of Water and Rural Water Systems which oversees water resources development, mobilisation and management have been submitted to an alternation of status, acting sometimes as autonomous institution and at other times as dependent institution (to other ministries). As a matter of fact, the ministry has acted as an independent structure only under the government of 2006 (year at which the ministry has been for the first time established), between 2009-2013, and in 2018 while its dependency covered the periods of 2006-2008 (under the ministry of mining and energy) and 2013-2017 (under the ministry of rural equipment and the ministry of agriculture). This situation has been reported to be associated with perturbations in the process of implementation of activities at the central level, as the priorities of the ministry to which it is attached are in most of the cases privileged. Moreover, this instability has had impacts (in terms of collaboration) at regional level, especially on institutions working with the governmental institutions in their efforts to ensure water security.

Inadequacy in the water and related sector evolution concerns water sector and sanitation sector. Efforts are made to ensure water security (in terms of quality and quantity), however, respondents recognized that sanitation sector is still lagging (open defecation is still going on) and reported the sector to be the "poor parent". As a matter of fact, this aspect has been reported as being "brain teaser" to water security.

On the ground, one can observe that activities even at the local level (regional level) are still being managed by the central structures. All the directorates at the central level are not represented at local level and all the water related activities are coordinated only by the regional water and rural water systems directorate which is mandated to be only a technical service.

3) Juridical barriers

The non-application of juridical texts (77%), the non-operationalisation of management organs (36%) and the political will (20%) are key factors that have been reported as being the juridical barriers to water security in the Oti Nord sub-basin. Most institutions have highlighted a range of juridical barriers and that explains why the total exceeds 100% (Figure 4.15).

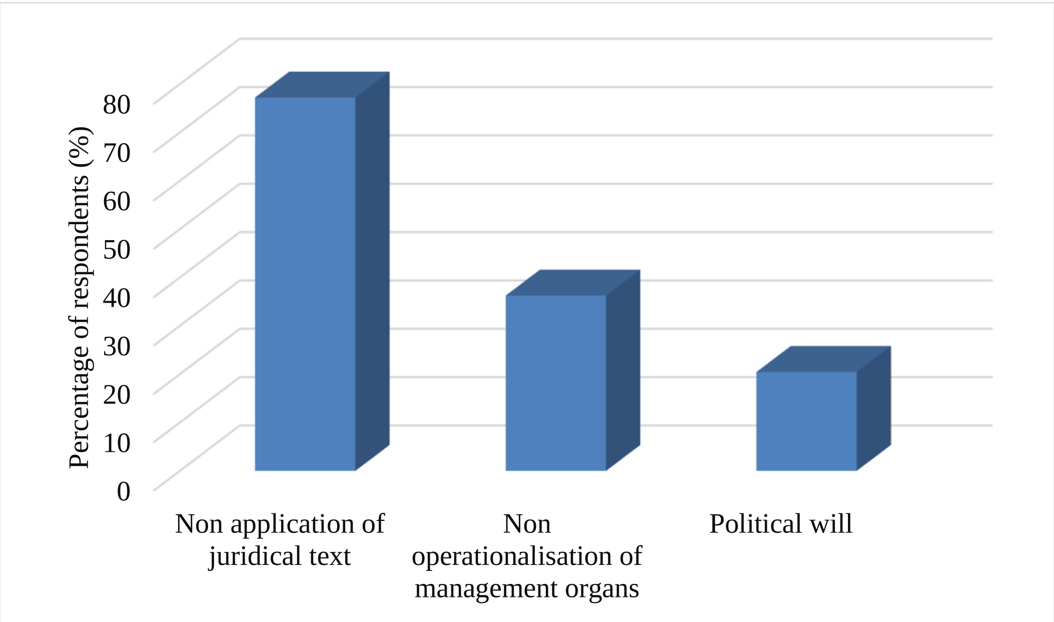

Fig 4.15. Juridical barriers to WS in the Oti Nord sub-basin (n=20)

The non-application of adopted texts and regulations and the non-operationalisation of management organs go together. According to the institutions respondents, organs to be adopted according to the code of water to ensure an effective water resources management at hydrological basins are not established (basin agencies and basin committees) and even those established are not operational (National Water Council). This situation can be explored from evaluated National Plan for Integrated Water Resources Management (Annex 1).

The political will in this context has been referred as wrong oriented priorities of the government (as much effort is made towards infrastructures, housing and electricity while water sector is neglected). Another aspect of this will is that water mobilisation is sometimes politically based. As a matter of fact, water is provided in some cases as reward to some key political actors for their faithfulness and not on the basis on the need expressed. Finally, the evolution of the implementation of IWRM approach adopted has been highlighted. As a matter of fact, although adopted by the water code as key approach for water resources management, the IWRM approach is still considered as a detail and not a priority (which is reported to be the provision of water to communities). In short, this approach is still seen as a vision.

4) Environmental barriers

Environmental factors depicted as hindering water security in the sub-basin are mainly water pollution (76%), flood disaster (16%) and climate change (8%). Most of the assessed institutions have highlighted a range of environmental barriers and that explains why the total exceeds 100% (Figure 4.16).

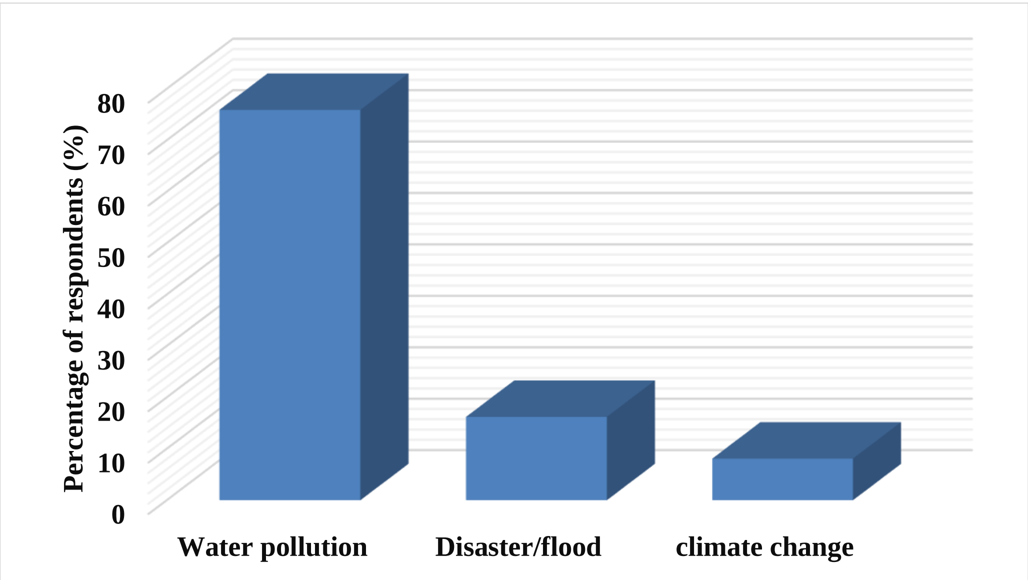

Fig 4.16. Environmental barriers in the Oti Nord sub-basin (n=20)

Water pollution has been attributed to limited access of the population to sanitary facilities but also the norm of realisation of those facilities (regarding the water tables) and the treatment of the sludge (quite lacking). It has been reported that in some case the sealing mechanism in not considered. Out of these situations both ground water as well as the surface water quality is undermined. Another aspect of the pollution is the pollution by domestic waste (both solid and liquid), mainly due to an unsustainable management of waste in the area and even in the whole country.

Some respondents highlighted flood as a barrier as in some of the communities in the sub-basin as flooding events in these cases are associated with the destruction of water infrastructures (i.e. case of pipes), leaving the communities without water for years.

7) Hydrogeological barriers

These barriers are those related to the natural availability of water as well as the easiness for that water to be abstracted (which depends on the productivity of existing aquifers). As a matter of fact, across the communities it has been observed a drying up of shallow water points (wells and rivers) and difficulties to pump water from boreholes during a certain period of the year (i.e. February – June) as shown in the Figure 4.17.

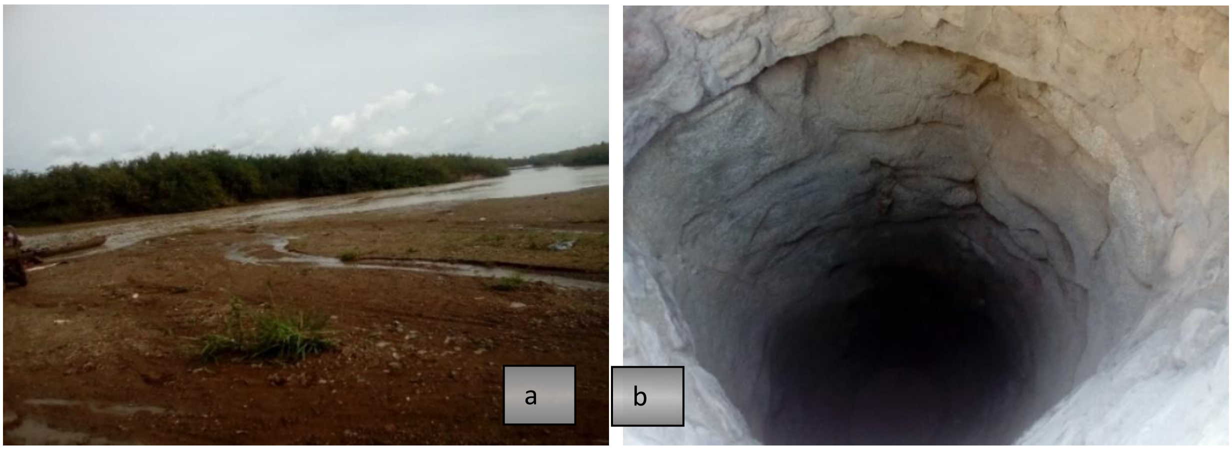

Fig 4.17. Level of water in the Oti river at Mango (a) and a well in Korbongou (b).

As a matter of fact, institutions respondents highlighted that in some areas, "boreholes are drilled, just to see that there is no water". This situation is explained by the fact that, the sub-basin falls under the Upper Proterozoic ages Volta basin which is sedimentary associated with discontinuous and localised aquifers. The productive layers are the sandstones of Bombouaka with the Dapaong group (with the Korbongou and Tossiegou formations) and Mont Panbako group (with the Bogou formation) which lie in high depth in the area, especially around Oti prefecture characterized by thick layer of clay.

Thus, it requires to go very deep in some areas to have access to water (making water abstraction complex). In addition, ground water is in some areas either too much mineralized or with unwilling elements such hydrogen sulphide. This situation is mainly due to the deep location of productive layers, making the recharged water to sojourn for long period in rocks. In addition, the recharge capacity in the study area is one of lowest (about 177 mm per year against 363 mm per year in Kara).

8) Socio-cultural barriers

The socio-cultural barriers regarding to water security in the area is the lack of the sense or spirit of paying for water services, especially in rural areas. This situation impacts the profitability or cost effectiveness of the infrastructures, thus, the inability of the management committees to ensure the maintenance of the existing infrastructures. This is mainly because water is still considered as a gift from gods, making it "free". Another source of the problem is that communities do not really weight or ignore the impact of unimproved water on their health. As the can state that "our fore parents use to drink water from rivers and they were strong". The last socio-cultural factor encountered is regarding to the use of latrines. For culture conservators, based on taboos, it is forbidden to use latrines (considered as a whole). This situation explains one of the reasons why open defecation is still going.

9) Demographic barriers

Population growth represents also a key barrier in ensuring water in sufficient quality and quantity to communities. This because it requires the extension of water network, calling for fund (which already is lacking). This situation is worsened by the fact that water in Togo is considered as a social good, thus having impact on the company in charge to capitalise and ensure in return the extension of the existing water network to reach those living in remote areas yet to be supplied.

In summary, water insecurity in the Oti Nord Sub-basin are related to existing water governance (including policies and regulations, management institutions and investments), the nature (i.e. hydrogeological characteristics), the culture (i.e. taboos and buy laws) and biophysical factors (i.e. disaster, climate change). However, emphasis has been made on water governance.

CHAPTER FIVE: CONCLUSIONS AND POLICY RECOMMENDATIONS

5.1 Conclusions

The study which was conducted in the Oti Nord sub-basin on the water security level in a challenging environment came up with the conclusions shown in the Table 5.1.

Table 5.1. Conclusions of the study carried out in the Oti Nord sub-basin on water security level in a challenging environment

Objectives	***Conclusion***
1. To review the existing water resources management approaches in the sub-basin	Water resources management has undergone a series of regime from the pre-colonial time till to date in Togo. From an embryonic management basically based on customary laws to the national sectoral approach (1960) and then the Integrated Water resources management (2002). The key successes of IWRM in the sub-basin are observed in the domain of water management (the adoption of the water code and the establishment of the Integrated System for Information on Water) and clean water delivery (through the privatization of water supply in urban and some semi urban area and the implementation of the FORMENT approach in rural and some semi-urban areas). Nevertheless, the implementation of the approach in the basin is hindered factors like lack of fund, inappropriate management structures and inappropriate planning and management unit. Thus, the implementation processes and implemented actions show that the IWRM in Togo is still at its early stage and not really evolving.
2. To investigate water security institutional arena in the Oti Nord sub-basin	Water resources in the Oti Nord sub-basin are currently managed by institutions from different levels (i.e. international, sub-regional, national, regional, district and village) and domains of intervention (i.e. government institutions, NGOs, community-based organisation and private operators). To ensure water security in the basin, these institutions are mainly involved in awareness raising, water resources management, juridical interventions, water resources mobilization, protection of water bodies, control of pollution, tree planting, and the control of water quality. Nevertheless, the appropriate management structures (i.e. basin agencies and basin committees) that are required to ensure full implementation of IWRM in water resources management at basin level are yet to be established.

3.	To assess water security level in the study area using the fuzzy comprehensive evaluation model	Water security level assessment revealed an overall insecurity in the Oti Nord sub-basin. The year 2010 has been depicted as very insecure. Although the year 2015 is still in the same range of insecurity, the status of the sub-basin has improved compared to the year 2010. Finally, projections depicted that the security level will decrease by 2025 and will be the worse among all the assessed years. Water insecurity in the Oti Nord sub-basin is as the result of decreasing available water (sufficient quantity and adequate quality) associated with an increase demand and decreasing water quality (mainly due to the acute pollution).
4.	To investigate potential barriers to water security in the sub-basin	There is a high agreement that there are barriers encountered in ensuring water security in the sub-basin. These barriers include technical factors, institutional factors, juridical factors, environmental factors, socio-cultural factors, hydrogeological factors and demographical factors.

5.2 Policy Recommendations

This study, thus, recommends the following:

1. The government should prepare directives for the application of adopted water policies and regulations, key in ensuring a sound and coordinated management of the available water resources and potential source of funds to carry water related activity.
2. Sound waste management system should be established by the government along with awareness raising and educative activities in order to reduce the level of water pollution (especially surface waters) in the study area;
3. The existing water information system need to be improved (in terms of both data quality and quantity);
4. To overcome the hydrogeological constraint in the area, knowing that the area is less industrialised, methods for water conservation and the use of non-traditional water resources, like rain water harvesting, should be considered and introduced;
5. Joined effort from the existing institutions in achieving water security will be of great benefit;
6. Finally, the continuation of this study must assess water security in the overall Oti River Basin and explore in detail the impacts of full implementation of IWRM approach on the overall water security level in the basin.

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ANNEXES

Annex 1. National Action Plan for the Integrated Water Resources Management in Togo: Targets and achievements

Area of action	Results	Actions	Implementation time frame	End of phase 1(as of 2015)
Favourable frame for a good water governance	A political and juridical environment favourable to the approach and the principles of IWRM is put into place	Elaborate and adopt the application texts of the law on water code	2010	I
		Popularise the law on water code	2011-2013	I
		Establish and adopt the norms (related to quality, quantity, techniques, water abstraction…)	2011	NI
		Ensure and monitor the consistency in sub-sectorial policies and the national water policy	2010-2011	
		Promote and develop collaboration in case of transboundary water resources	2010-2025	I (with the creation of the Mono River Authority and adoption of the convention and status associated, 31st December 2014) Participation of the country for the establishment of the Volta River Basin Charter.
		Define the roles of all actors in terms of the IWRM	2010-2012	NI
Institutional framework	An operational institutional framework is established	Restructure and optimise institutions of water sector in accordance with new IWRM data and reinforce their operational capacities	2011	NI
		Establishment of organs planned by the law of the water code (National Water Council, National water agency, basin agency basin committee, local organs of water management)	2010-2011, 2017,2022	NI
		Establish a pilot committee and coordination monitoring-evaluation structure of the National Action Plan for the Integrated Water Resources Management (PANGIRE)	2011-2015, 2017-2019,2021-2024	I

Management instruments	Knowledge on water resources (their development and their exploitation) on fragile aquatic ecosystems and critical environmental parameters are improved. In addition, an Integrated system on water is established	Improve the monitoring (qualitative and quantitative) of surface water	2010-2025	I (10 hydrometric stations are rehabilitated)
		Improve the monitoring (qualitative and quantitative) of groundwater	2010-2025	I (In total 10 piezometers have been realised and 13 rehabilitated)
		Improve the climatological monitoring in Togo	2011-2025	I (3 synoptic stations, 6 climatological stations and 50 posts with rain gauges)
		Establish an Integrated system on water	2010-2025	I
		Establish an operational mechanism of water demand and usage monitoring	2011	NI
		Improve the monitoring of fragile aquatic ecosystems/wetlands	2011, 2017-2018,2022-2023	NI
		Establish a mechanism of monitoring the silting of rivers	2011-2013, 2018, 2022-2023	NI
		Study and establish the monitoring of the perimeters of protection of water exploitation zones and hydraulic installations	2011-2015	NI
		Make a modelling of the water resources in the country	Non-defined	I (elaboration of mathematical model for water tables in the costal sedimentary basin)
		Reinforce knowledge on the impacts of various water abstraction and climate changes on water resources and ecosystems Propose climate change adaptation measures	2011-2013	NI
		Establish water resources monographies for each basin including aquifers.	2010-2011	NI
	Mechanisms and strategies of	Organise a round table of technical and financial partners for the funding of PANGITRE	2010	I (with No mobilisation of resources)

Economical and financial framework	financing water sector and its contribution to growth and development is set up	Establish and make operational the water resources management fund	2011	I at some extent (the structure of execution is established but non- functional)
		Establish public and private partnership for the funding of actions of IWRM	2010	NI
		Develop a national strategy of investment in activities of economic valorisation of water	2011	NI
Capacity reinforcement	Actors well informed, sensitized and trained acceded to IWRM concept and have the operational means	Advocate for the recruitment of personnel and reinforcement of the capacity of the personnel	2011-2013	NA
		Design and carry out a program of social communication campaign for the promotion of the IWRM	2010-2015, 2017-2020, 2022-2024	NA
		Reinforce the capacities of local communities and civil society in matters of IWRM by integrating the gender aspect	2011	NA
		Reinforce the education system in terms of IWRM at various teaching level in Togo	2011-2013, 2016-2019,2021-2025	NA
		Prospective study on areas with difficult water mobilization	2011	NA
Planning and management of water resources	Sketch and plans for water planning and management are developed and implemented	Develop the blueprint of water planning and management (SDAGE) of the Mono River basin	2011-2025	NI
		Develop the blueprint of water planning and management (SDAGE) of the Volta River Basin	2011-2025	NI
		Develop the blueprint of water planning and management (SDAGE) of the basin of Lac Togo	2011-2025	NI
Conservation and protection of water resources and environment	Water resources are protected against industrial pollution and	Establish a water police	2011	NA
		Sensitize the industrials for the pre-treatment of waste water	2011	NA
		Promote the afforestation of degraded zones	2011	NA

	silting of water bodies			
Natural hazards and risks associated to water	Fight against the nuisances and undesirable effects of water and prevention against future risks are reinforced	Inform communities and water users on the risks associated with the pollution of water resources	2011	NA
		Reinforce the protection of communities and users against risks associated with water	2011-2012	NA
		Promote basic hygiene and sanitation	2011, 2016-2018, 2021-2025	NA
		Reinforce the capacities of structures of control of water quality	2011	NA
		Contribute to the fight against malaria and other water related diseases	2011, 2016-2020, 2021-2024	NA
		Reinforce the coordination of fight against the risks and nuisances associated to water	2011	NA

NA=Non-applicable (the actions are not planned for the first phase) I= Implemented, NI= Non-implemented, NS=Implemented at some extend

Annex II: Questionnaire for Key Informant Interview

As part of the requirement for the award of MSc. in water sciences (water policy option), this study aimed at evaluating water security in the Oti River Basin, in the context of environmental change (including climate change, population growth and economic development) taking the Oti Nord sub-basin (including Tone, Tandjoare, Oti and Kpendjal districts) as a case study.

The information obtained through this study is not meant for any political nor governmental purposes but for the MSc. Research of the Researcher. You are assured of the confidential treatment of the valuable information you will supply to me.

Key concepts

Water security: Water security is a condition where there is a sufficient quantity of water at a quality necessary, at an affordable price, to meet both the short-term and long-term needs to protect the health, safety, welfare and productive capacity of position (households, communities, neighbourhoods or nation) but also sustain the existing ecosystems.

In the context of this study, water security system is made up of 5 sub-systems

Water-resources security: depicts the characteristics of water as a resource in the sub-basin, especially its physical availability to sustain all kind of human activity (including, domestic, agricultural, commercial, recreational among others).

Water-society security: reflects the interaction between water and society. It expresses society utilization pattern of the physical water resources.

Water-economic security: focuses on the value of water allocated for all economic activities in the sub-basin (taking into consideration activities such as agriculture, industry among others).

Water-environment security: this sub-system mainly addresses the health of surface and ground waters in study area but also the existing sanitation level. It considers the quality and quantity of water in the ecosystem.

External-environment security: refers to factors which are not directly part of the water system, but which interact and affect the overall water security system.

Name of the researcher: Mawulolo YOMO

Affiliation of the Researcher: Pan African University Institute of Water and Energy Sciences, Abou Bekr Belkaid University, Algeria

Name of the Interviewer …………………………………………………………………………

Date of the interview ……………………………………………………………………………..

SECTION 1- Preliminary

Name of the institution……………………………………………………………………………...

Year of creation………………………………………………………………………………………..

Highest education status of the interviewee

Tertiary ☐ License /BScs ☐ MScs ☐ PhD ☐

1.1 Post occupied by the interviewee in the institution ………………………………………….

1.2 Since when are you employee of the institution?

One year ☐ 5 years ☐ 10 years ☐ More ☐

1.3 What are the areas of interest or domains of intervention of your institution

[a]

[b]

SECTION-2 DESCRIPTION OF THE INSTITUTION AND ITS EFFORTS TOWARDS WATER SECURITY IN THE OTI NORD SUB- BASIN

2.1 Based on your experience, what is your agency or institution doing to ensure water security in the Oti Nord sub-basin (including Oti, Tandjoare, Kpendjal, Tone districts). Multiple proposed options can be chosen at once.

a. Awareness raising or training

i. On water issues and its sustainable management
ii. On benefits of the use of latrines
iii. Good land use practices
iv. Planting trees
v. Sustainable management of the environment (through the management of household waste)
vi. On the water code
vii. Others………………………………………………………………………………..

Please, explain the activities carried out……………………………………………………………….

………

b. Pollution control
   i. Field work or pollution control operations
   ii. Control of illegal mining
   iii. Monitoring and water quality (garbage disposal in rivers)
   iv. Others……………………………………………………………………..

Please, explain the activities carried out………………………………………………………
……………………………………………………………………………………………………

c. Protection of water bodies
   i. Establishment of buffer zones around the Oti river or its tributaries
   ii. Planting of trees around water bodies
   iii. Other……………………………………………………………………...

Please, explain the activities carried out………………………………………………………
……………………………………………………………………………………………………

d. Development of streams or rivers
   i. Sand removal from river sections (to prevent flooding, to give more space for water to flow)
   ii. Straightening of the river bed (specify)
   iii. Other……………………………………………………………………...

Please, explain the activities carried out……………………………………………………….
……………………………………………………………………………………………………

e. Legal intervention
   i. Define and strengthen policies and regulations for the protection and sustainable management of water resources
   ii. Define and reinforce the policies and regulations for clean water supply to the population
   iii. Development, implementation and monitoring of water resources programs
   iv. Development, implementation and monitoring of public equipment programs related to the field of hydraulics.
   v. Development, implementation and monitoring of clean water supply programs
   vi. Other ....

Please, explain the activities carried out……………………………………………………….
……………………………………………………………………………………………………

f. Mobilization of water resources
   i. Installation of hydraulic infrastructures (boreholes and pump)
   ii. Production of clean water
   iii. Other ………………………………………………………………………………

Please explain the activities carried out ....

....

g. Sanitation
   i. Maintenance and operation of wastewater collection networks
   ii. Maintenance and operation of rainwater harvesting networks.
   iii. Other……………………………………………………………………………..

Please explain the activities carried out ....

....

h. Control of water quality

Please explain the activities carried out ....

………………………………………………………………………………………………………

i. Management of hydrological and hydrogeological measurement networks (Data collection, processing and storage).

Please, explain the activities carried out ....

………………………………………………………………………………………………………

j. Management and exploitation of water points

Please explain the activities carried out ....

………………………………………………………………………………………………………

k. Development of water resources

Please explain the activities carried out ....

....

l. Funding/ Sponsoring water mobilization projects or activities (related to the management of water resources or the establishment of water points)

Please explain the activities carried out ....

……………………………………………………………………………………………

m. Contribution to the establishment of water points

Please explain the activities carried out ....

……………………………………………………………………………………………

n. Other……………………………………………………………………………..

Please explain the activities carried out ....

....

SECTION 3- POTENTIAL BARRIERS TO WATER SECURITY IN THE OTI NORD SUB-BASIN

3.1 Do you think that there are potential barriers that impede or can impede the availability of sufficient water with adequate quality, at an affordable price to meet the short and long term needs for water and sanitation, to protect health, ensure safety and a productive life while ensuring that the environment is protected and improved in the Oti Nord sub-basin (including Tandjoare, Kpendjal, Oti and Tone districts).

[a] Yes [b] No [b] Do not know

3.2 If yes, select the list factors below that you believe limit or may limit in the future the water security in the sub-basin and briefly explain each of them. Multiple choice can be made.

a. Institutional factors
   i. Inadequacy in the development of the health sector compare to the water sector
   ii. Institutional Instability (especially of the ministry in charge of water)
   iii. Limited or no collaboration between sectors or stakeholders in water management

Please explain briefly how this factor impacts water security ....

……………………………………………………………………………………………

b. Juridical factors
   i. Political will
   ii. Non-operationalization of created management bodies (National Water Council)

iii. Lack of applicability of signed decrees and texts adopted in the context of water resources management (absence of a system of taxation of fees, decree on decentralization)

Please explain briefly how this factor impacts water security ....
……………………………………………………………………………………………………

c. Technical factors
    i. Investment limit in water mobilization
    ii. Underestimation of the country's needs in water
    iii. Inaccurate knowledge of the country’s water potential
    iv. Lack or limitation in available data on water resources (hydrological, hydrogeological).
    v. Gap in terms of capacity (human resources, expertise)
    vi. Gap in terms of capacity (lack of infrastructure)

Please explain briefly how this factor impacts water security ....
....

d. Sociocultural factors

Please, explain briefly how this factor impacts water security ....
……………………………………………………………………………………………………

e. Increasing water pollution

Please, explain briefly how this factor impacts water security ....
……………………………………………………………………………………………………

f. Climate change

Please, explain briefly how this factor impacts water security ....
……………………………………………………………………………………………………

g. Population growth

Please, explain briefly how this factor impacts water security ....
……………………………………………………………………………………………………

h. Other (to be precised) ……………………………………………………………………

Please, explain briefly how this factor impacts water security ....

Annex IV: Research Grant Expenditure Report

Starting Date		01 MARCH 2018								
Ending Date		25 SEPTEMBER 2018								
N°	Date	Details	Vendor/company	Amount in CFA	Exchange Rate (CFA to Dollars)	Amount in Dinars	Exchange Rate (Dollars to Dinars)	Amount in Dollars	Cumulative Total in Dollars	Budget Line Indicator
1	08/03/2018	Flight ticket (Algeria-Lomé-Algeria)	POMARIA TRAVEL			131865	105	1255.86	1255.86	Mobility
2	24/03/2018	Modem	TOGOCEL	23000	520			44.23	1300.09	Communication
3	24/03/2018	Modem ship	TOGOCEL	5000	520			9.62	1309.70	Communication
4	05/04/2018	Motorbike leasing (3months one week) for field work	AMAYI Laurent	210000	520			403.85	1713.55	Mobility
5	08/04/2018	Fuel for field work	Ets DAKAR	1600	520			3.08	1716.63	Mobility
6	09/04/2018	Stationary and printing	Ets SHANTI	5300	520			10.19	1726.82	Stationary and Communication
7	23/04/2018	Fuel for field work	TOTAL	2000	520			3.85	1730.66	Mobility
8	02/05/2018	Fuel for field work	TOTAL	2200	520			4.23	1734.90	Mobility

9	03/05/2018	Stationary and printing	Ets Shanti	885	520			1.70	1736.60	Stationary and Communication
10	01/06/2018	Printing	SAPHIR	1400	520			2.69	1739.29	Printing
11	01/06/2018	Stationary	CENPATO	1250	520			2.40	1741.69	Stationary
12	07/06/2018	Stationary and printing	Ets Shanti	1030	520			1.98	1743.67	Stationary and Communication
13	08/06/2018	Fuel for field work	TOTAL	1800	520			3.46	1747.14	Mobility
14	11/06/2018	Photocopy	SAPHIR	800	520			1.54	1748.67	Stationary and Communication
15	11/06/2018	Photocopy and printing	Ets Shanti	925	520			1.78	1750.45	Stationary and Communication
16	12/06/2018	Fuel for field work	TOTAL	1700	520			3.27	1753.72	Mobility
17	21/06/2018	Transport (Lomé-Dapaong)	Common car	9000	520			17.31	1771.03	Mobility
18	25/06/2018	Photocopy and printing	ETS SERCOM	3750	520			7.21	1778.24	Stationary and Communication
19	27/06/2018	Printing	GNTTI	1500	520			2.88	1781.13	Printing
20	30/06/2018	Accommodation in the field	AUBERGE WANGARA KRATOS	47,000	520			90.38	1871.51	Accommodation
21	02/07/2018	Data acquirement (shapefiles, some water quality data)		100,000	520			192.31	2063.82	Data acquirement
22	04/07/2018	Transport (Dapaong-Lomé)	Common car	9,000	520			17.31	2081.13	Mobility
23	05/07/2018	Fuel for field work	TOTAL	1,500	520			2.88	2084.01	Mobility
24	13/07/2018	Fuel for field work	TOTAL	1,600	520			3.08	2087.09	Mobility
25	15/07/2018	Questionnaires administration	LANKLE Egnonvi	200,000	520			384.62	2471.70	Questionnaire administration

26	20/07/2018	Fuel for field work	TOTAL	1700	520			3.27	2474.97	Mobility
27		Meteorological Data	National Meteorological Services	20000	520			38.46	2513.43	Data acquirement
28		Internet bundle for research	EKLU Ami Yayra	37500	520			72.12	2585.55	Communication
29		Credit for phone calls	EKLU Ami Yayra	13000	520			25.00	2610.55	Communication
30		Data entering	LANKLE Egnonvi	35000	520			67.31	2677.86	Data entering
31		Printing (thesis and reports)	SIFI Noureddine			2600	105	24.76	2702.62	Printing
32		Poster printing and accessory	SIFI Noureddine			2900	105	27.62	2730.24	Printing
33		Transport (Cite-Airport-House)				6800	105	64.76	2795.00	
34		Paper publication						205	3000.00	Publication
	Total Amount of Transaction								**3000.00**	
	Total Amount Received for Transaction								**3000**	
	Balance Remaining to be Accounted for								**0**	