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Presented by

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TITLE: Assessing the Potential for Water Stewardship Partnership Using Water Risk and Action Framework: The Case of Nzoia Basin, Kenya

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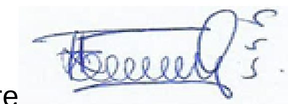
DECLARATION

I Kasiti Felix Isundwa, 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.

Signature  . Date: 15 September 2018

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ABSTRACT

Water is the most important substance that forms the basis of life. It is essential in agriculture, business sector and an important ingredient in most industrial processes. There is an increase in water stress and water scarcity. Collective actions among different sectors, institutions and stakeholders are needed to reduce future water risks. This study aimed to assess the potential for a water stewardship partnership in River Nzoia Basin to reduce future water risks to the ecosystem, agriculture, businesses, and other sectors by mapping stakeholders and determining the potential for a water stewardship partnership, by which we can identify the major challenges facing the basin and offer a systematic solution to resolve them.

Nzoia river basin covers an approximate area of 12,696 Km^2 home for over 3.5 million people. Water Risk and Action Framework (WRAF) provides a stepwise guide to water stewardship from Prepare, Assess, Commit, Act, to Scale and Exit phases using dedicated tools for each step to achieve the successful partnership. Water risks have been quantified using indicators from remote sensing platforms and secondary sources with indicators such as Leaf Area Index (LAI), Rainfall Use Efficiency (RUE), and Soil Water Stress (SWS). Priestley-Taylor Alpha Coefficient was used to derive the Water Risks Index (WRI). Stakeholder mapping was conducted using stakeholder analysis guide that was developed by the International Water Stewardship Programme (IWaSP), while stakeholders' views about water stewardship partnership were collected using questionnaires.

The results showed that there is a high fluctuation in the vegetation cover and primary productivity in the basin pointing to a possible degradation and deforestation. It was also notable that there is an increase in the frequency and severity of drought over the years with the first three months being most affected. There is a high evapotranspiration in parts of the basin due to the low vegetation cover in the basin, which have increased soil water stress.

The above-mentioned factors indicated that Water risk had increased between 2000 and 2014 in different parts of the basin at different magnitude of risk. The conducted interviews found that the basin lacked a stewardship programme although there were observed water shortages within the basin. However, there was a potential for a successful stewardship partnership among stakeholders and a significant number of stakeholders within the basin showed their ability to spearhead the stewardship programme.

Last but not least, this study showed that Nzoia river basin faces challenges that need to be urgently addressed such as the increased droughts over the years, deforestation, highly variable weather, catchment and land degradation. Therefore, forming a water stewardship programme can help in tackling the challenges that are facing the basin. the proposed water stewardship programme should be built on commitment, transparency, and inclusivity.
Key Words: Water Risk Index, Water Stress, Water Risk, Degradation, Water stewardship etc.

RÉSUMÉ

L'eau est la substance la plus importante qui constitue le fondement de la vie. Il est essentiel dans l'agriculture, secteur d'activité et un ingrédient important dans les processus industriels. Il y a une augmentation du stress hydrique et la pénurie d'eau. Actions collectives entre différents secteurs, les institutions et les intervenants sont nécessaires pour réduire les risques de pénuries d'eau. Cette étude visait à évaluer la possibilité d'un partenariat de gérance de l'eau du bassin de la rivière Nzoia pour réduire les risques de pénuries d'eau à l'écosystème, l'agriculture, entreprises et autres secteurs cartographie des parties prenantes et de déterminer le potentiel pour une eau partenariat de gérance, par lequel nous pouvons identifier les défis majeurs pour le bassin et proposer une solution systématique pour les résoudre.

Bassin de la rivière Nzoia couvre une superficie approximative de 12 696 Km2 abrite plus 3,5 millions de personnes. Risque de l'eau et cadre d'Action (WRAF) fournit un guide par étapes à l'intendance de préparer, évaluer, Commit, acte, aux phases d'échelle et sortie à l'aide des outils dédiés pour chaque étape à réaliser le partenariat de l'eau. Risques de l'eau ont été quantifiés à l'aide d'indicateurs de distance plates-formes de télédétection et de sources secondaires avec des indicateurs comme l'indice de surface foliaire (ISF), efficacité d'utilisation des précipitations (URE) et sol eau Stress (SWS). Coefficient Alpha de Priestley-Taylor a servi à calculer l'indice de risques eau (WRI). Des intervenants de cartographie a été réalisée à l'aide du guide de l'analyse des parties prenantes qui a été développé par le Programme de gérance de l'eau International (IWaSP), tandis que les vues des parties prenantes sur le partenariat de gestion de l'eau ont été prélevés à l'aide de questionnaires.

Les résultats ont montré qu'il existe une importante fluctuation du couvert végétal et la productivité primaire dans le bassin pointant vers une éventuelle dégradation et la déforestation. Il est également notable qu'il y a une augmentation de la fréquence et la sévérité de la sécheresse au cours des années avec les trois premiers mois étant plus touchées. Il y a une forte évapotranspiration dans certaines parties du bassin en raison de la couverture de végétation basse dans le bassin, qui ont accru le stress hydrique du sol.

Les facteurs mentionnés plus haut ont indiqué que risque de l'eau a augmenté entre 2000 et 2014 dans différentes parties du bassin à l'autre l'ampleur du risque. Les entrevues menées a conclu que le bassin n'avait pas un programme de gestion mais il ont été observés des pénuries d'eau dans le bassin. Cependant, il y avait un potentiel pour un partenariat réussi intendance parmi les intervenants et un nombre important d'intervenants au sein du bassin ont montré leur capacité à diriger le programme d'intendance.

Enfin et surtout, cette étude a montré que le bassin de la rivière Nzoia est confrontée défis qui doivent être abordées d'urgence tels que les sécheresses accrues au cours de l'années, météo très variable, déforestation, bassin et dégradation des terres. Par conséquent, formant un programme de gestion de l'eau peut aider à relever les défis auxquels sont confrontés le bassin. le programme de gestion de l'eau proposée devrait reposer sur l'engagement, de transparence et d'inclusivité. Mots clés : Indice de risque de l'eau, Stress hydrique, risque d'eau, dégradation, etc. de l'intendance de l'eau.

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Finally, this is the zenith of a journey that started with a single step and gradually developed into one mighty task! My joy and sense of fulfilment would not be complete without making mention of everyone who offered help and support, in one way or another, during the entire period of this MSc study. The succinctness of this acknowledgement does not in any way downplay the support I have received from anyone mentioned, or not mentioned, herein.

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LIST OF ABBREVIATIONS

AET - Actual Evapotranspiration
AfSIS - Africa Soil Information Service
ANPP - Annual Net Primary Productivity
CGIAR-CSI - Consultative Group on International Agricultural Research - Consortium for Spatial Information - Consortium for Spatial Information
CHIRPS - Climate Hazards Group InfraRed Precipitation with Station data
EC - European Commission
EEA - European Environment Agency
ENSO - El Nino Southern Oscillation
EU - European Union
GDP- Gross Domestic Product
GIZ - Deutsche Gesellschaft für Internationale Zusammenarbeit
IPCC - Intergovernmental Panel on Climate Change
IWaSP - International Water Stewardship Programme
KNBS - Kenya National Bureau of Statistics
LAI - Leaf Area Index
MODIS - Moderate Resolution Image Spectroradiometer
MWI - Ministry of Water and Irrigation
NDVI - Normalized Difference Vegetation Index
NGO - Non-Governmental Organization
NVI - Natural Vegetative Index
PAC - Priestley-Taylor Alpha Coefficient
PET - Potential Evapotranspiration
RUE - Rainfall Use Efficiency
SAVI - Soil Adjusted Vegetative Indices
SWS - Soil Water Stress
USD - United States Dollar
VI -Vegetation Index
WFN- Water Footprint Network
WRAF - Water Risk and Action Framework
WRI - Water Risk Index
WWF - World Water Fund

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CHAPTER 1: INTRODUCTION

1.1 Background to the study

Water is the most important substance on earth that forms the basis of life and is also an essential ingredient in the production process of the industrial and agricultural sector and there are diverse ways in which water use can pose a threat to business and other sectors (Smith et al., 2011). Nearly 80% of the world population is exposed to a high water scarcity threat, while rich nations offset the high stressor levels through heavy investments in the water sector without solving the underlying causes, less rich countries remain vulnerable to water stress (Vörösmarty et al., 2010). Water scarcity, a key challenge in the 21st century is manifested at a local and catchment level but has a regional and global cause, which underpins food security, energy security, poverty reduction, climate change adaptation and biodiversity loss (Stuart et al., 2009).

Stewardship is the willingness to be accountable to a larger group that is operating in a service and working to achieve a fundamental change (Shepheard and Norer, 2013). Water stewardship is viewed as a comprehensive concept that includes the evaluation of the sustainability of water use across the entire value chain (Hoekstra, 2017). Companies in water-intensive industries have weak management and disclosure of water-related risks and demonstrate the need for companies to bear the responsibility in their impacts on water resources particularly regarding freshwater scarcity and water governance (Lambooy, 2011).

Globally, food and beverage companies such as Britain Food, Coca-Cola, PepsiCo are addressing water stewardship as a part of their corporate social responsibility since concerns about water are increasing their goals to ensure business efficiency and business continuity (J. Peter et al., 2015). In Australia, water stewardship formed successfully a stewardship community, with the help of local partners, they formed a stakeholder engagement stewardship that led to a collaborative and supportive partnership (Jones, 2017). In the United Kingdom, water stewardship for the 21st century was advocated to ensure resilience due to the impacts of extreme weather changes (Simpson, 2014). The Coca-Cola Company, through partnerships with thought and leaders opinion, began to assess the growing water risks to the company's operation and concluded that there was a quantifiable risk to business as a unit (Stewart, 2008). Water footprint, which is a measure of humanity's appropriation of fresh water in volumes of water consumed and/or polluted allow a better understanding of water risks and opportunities at different scales (WFN, 2016). Unlike the conventional discharge measurements, freshwater uses measures and impacts allows businesses to understand where pressure lies (Wyness, 2011).

In India, Nestlé, which is the world's largest food and beverage company, has continued to support climate actions and accelerate individual and collective efforts in addressing climate change impacts. They have developed a Natural Resource Stewardship under their Rural Development Framework promoting efficiency, pollution reduction, adaptive climate, zero wastes among others (Khajuria, 2016).

In Lusaka, a successful partnership to protect wellfields in an environmentally, socially, and financially sustainable manner securing groundwater supply for Lusaka's residents and businesses were reached and different partners agreed to minute their commitment (Farrington, 2016).

In Uganda, over 500Ha of wetland areas were restored through a partnership between companies and local industries operating in River Ruwizi Catchment (Parr, 2017). In Tanzania, a partnership was formed between development partners aimed at restoration of Mlalakua River and prevent further pollution from solid and liquid pollution which succeeded (Behnsen, 2016).

In Kenya, the Government of Kiambu County seeking to address the protection of water and the environment sought support from IWaSP to facilitate collaboration between private sector and Water Resources Users Association in the county leading to positive feedbacks from companies involved on the potential partnership (Ran, 2017). A water stewardship partnership program was launched in Lake Naivasha Basin whose goals were to improve water availability for domestic and business use within the basin and to improve water quality by implementing soil and water conservation activities(INWaSP, 2011).

There is a growing need for businesses to assess the various risks related to water in order to come up with a plan to collectively mitigate them and reduce the risk on business in future.

1.2 Statement of the problem

The government and the business sector together share the risks related to water scarcity, poor management or a change in water regulation. Physical risks may occur where there is too little, too much or polluted water from the various sources. The concerns about water have increased due to the increase in water demand, population growth, and the impacts of climate change. Therefore, water risk assessment is needed for the government and the businesses sector within a watershed to design a holistic approach in which business, government, and communities will combine their efforts in managing water resources to reduce possible future water risks. Therefore, this study aims at assessing the potential for a water stewardship partnership at Nzoia Basin, Kenya.

1.3 The objective of the study

The main objective of this study is to assess the potential for a water stewardship partnership within Nzoia Basin, Kenya. To achieve this objective, the following are the specific objectives;

I. To quantify water risks in Nzoia River catchment.
II. To map out the potential partnership stakeholders in the Nzoia River basin.
III. To assess the potential for stewardship partnership in Nzoia River basin.

1.4 Significance of the study

Countries globally are categorised as water stressed if their annual renewable freshwater supplies are between 1,000 and 1,700 m^3 per capita per annum and categorised as 'water scarce' if their renewable freshwater supplies are less than 1,000 m^3 per capita per annum (UNESCO, 2006). Kenya is both a water stressed and a water scarce country. The annual renewable freshwater supplies had decreased from 647 m^3 per capita in 1992 to 500 m^3 in 2010 and it is projected to drop further to 235 m^3 per capita in 2020. Kenya has a great variability and unpredictability in rainfall across the country, which worsened the situation leading to prolonged droughts and frequent floods in arid and semi-arid areas (MWI, 2009). Surface and groundwater resources in Kenya are increasingly becoming polluted from both point and non-point sources caused by the activities of agriculture, urbanization, industry, leachate from mining and garbage dumps, sediments, salts, eutrophication of lakes, infiltration of fertilizer and pesticide residues, all of which increase catchment degradation.

The Nzoia river basin, whose waters originate from two of the five water towers in Kenya is characterised by deforestation, river bank encroachment, population growth, uncontrolled settlement, uncontrolled abstraction of water, climate change, drought, and damaged wetlands at the catchment area (Onywere et al., 2006), all of which have increased water stress level and led to a water scarcity. Land degradation caused a reduction of 3%, about USD 390 million in the national GDP (Kyengo et al., 2016). Human and natural factors have reduced groundwater levels, increased runoff in the river basin, increased food insecurity and increased poverty. Flooding, a frequent phenomenon in the lower Nzoia has been attributed to siltation of the river channel caused by degradation and erosion of the upper reaches of the catchment with up to 3767.9 tons of sediments a month is projected for the year 2030 compared to 1400.79 tons/month recorded in the year 1990 representing over 160% increase (Joab et al., 2016).

The river basin, being home to over 3.5 million people whose main economic activity is farming through mixed subsistence farming and commercial farming, relies heavily on rainfall with no irrigation projects in the basin thus farming is the only source of the income for the majority of the population. The upper basin is characterized by intense agriculture works and the use of pesticides, which caused of deterioration of water and soil quality in the basin. Over 60% of the population live in the rural areas while the remaining are residing in towns. The urban population and industrial activities have had a significant impact on the quality of water with heavy pollution from domestic and industrial waste discharge being reported downstream. Generally, there is a growth of population in the country and the same is expected within the basin thus exerting more pressure on the degrading land resource due to the increased water demand, food and land for settlement these, in turn, are expected to lead to further water stress and scarcity. High poverty levels in the basin are likely to exert more pressure on the forest resource leading to further degradation while rural-urban migration in search of jobs will have an adverse effect on the water demand and water quality due to the sprouting of informal settlement. Therefore, a better understanding of the underlying driving forces of water scarcity risks can help decision makers to assign focus areas for different types of adaptation strategies for the public (Veldkamp et al., 2016).

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter details the literature that was studied while conducting the research. It details the overview of stewardship and risk assessment.

2.2 Water Risks Assessment

Risk is defined as the chance, high or low, that something could be harmed by hazards, together with an indication of how serious the harm could be (Burt, 2001).

Water risks defined as the effect of water-related uncertainty such as pollution, water scarcity, governance, inadequate infrastructure and extreme events. Water risks have been categorized into three types: physical, regulatory and reputational risks. Physical risk is related to water quantity (lack of water and flooding) and water quality (water pollution). Regulatory risk is defined as the risks relates to the imposition of restrictions on water use by government or the regulatory authority such as tariffs, licensing etc. Reputational risk is defined as how water will impact a company's brand and image and can affect customer purchasing decisions manifested through conflicts and tensions around access to water (Smith et al., 2011).

For the purpose of this study, the risk assessment focused on physical risks that occur where there is a little or too much water or the deterioration of the quality due to human activities. Water scarcity is human-driven due to the increase in water demand. Climate change is likely to increase the variability of precipitation and frequency thus causing water scarcity uncertainty scenarios. Climate change and human activities have the greatest impact on the ecosystem (Stuart et al., 2009).

There are several factors that cause physical water risk in quality and quantity such as climate change and population growth with the population being estimated to have the greater weight than climate change at a global and regional scale and thus increase water scarcity risk towards 2080 (Veldkamp et al., 2016). Physical water risks deteriorating water quality due to eutrophication, human activities and the over-exploitation of the rivers and the groundwater (EEA, 1999).

Water resources in Europe are affected by activities in the agricultural, industrial and household sectors for both quality and quantity (EEA, 1999). As water distribution is uneven in the continent, most of the countries are already utilizing their fresh water above the long-term sustainable limits (Spain, Malta, Bulgaria etc) with 11% of the European population being affected by water scarcity (EC, 2010). European Union's immediate vulnerability is water scarcity, but most of the EU food imports, about 92%, comes from regions faced low to moderate drought with the highest drought risk being at 32% in Tunisia which grows olives (Ercin: et al., 2016). The is a concern that continued inefficient use of water could threaten Europe's economy, productivity and ecosystems and recommendations were suggested to policymakers (Kinver, 2012).

Asia, home of more than half of the world's population, is facing water-related problems and experts agreed that the access to fresh water will be reduced in future due to climate change and other factors leading to impaired food production, loss of livelihood security, and large-scale migrations within and across borders (Chan; et al., 2018). If the current population and climate change trend continue, Asia will face a high risk of severe water stress in 35 years that could lead to high taxation of water in relation to the served people (Kramer, 2016). A model combining climate hazard, sensitive adaptive capacity maps, and vulnerability assessment framework of the Intergovernmental Panel on Climate Change (IPCC) was used to determine the areas that are susceptible to extreme risk occurrence of a climatic hazard event. A combined index based on hazard, exposure, and adaptive capacity is introduced to identify areas susceptible to extreme risk with the analysis of individual climate-related hazards indicates that floods and droughts affect agricultural areas the most, followed by extreme rainfall, extreme temperature, and sea level rise. This model identified that most regions of Bangladesh in South East Asia was vulnerable to the climatic hazard (Amarnath et al., 2017). A self-consistent risk-based assessment of water availability and use under future climate change and socioeconomic growth established that socioeconomic growth increases water stress, and climate change drives the ensemble central tendency toward an increase in water stress in China but a reduction in India and abstraction will exceed the storage capacity in the mid-20th century pointing to the need to combat global climate change to reduce the risks (Gao et al., 2018).

Unlike other studies in the region, precipitation was used as the renewable water supply endogenous to the area, and consider natural and human uses of this water thus enabling mapping of the states with their risk index due to droughts (Shi et al., 2013).

In South Africa, there has been a tremendous deterioration of water quality in dams over the last 20 years and its attributed to pollution by mining, industry, agriculture, development and human settlements and the WWF used Water Risk Filter to assess the risk to the business. The indicator uses risk factors such as aridity, rainfall variability, monthly water depletion, groundwater abstraction drought, regulatory risk indicator, and pollution to derive a global water risk map. This has indicated that various regions of South Africa face high water risk with regions classified as facing water deficits (WWF and KFW, 2018). According to Water Security Risk Index, Algeria, Egypt, Libya, Tunisia and Niger are facing extreme water risks. This risk was derived by measuring countries' water stress; population rates; reliance on external water supplies; sustainability of water use; intensity of water use in the economy; government effectiveness; and virtual water use (VM, 2018).

In Kenya, the demand for water in the capital city has outstripped the supply by 600% and has been a cause for alarm (SD, 2018). However, there are no studies that have quantified water risks locally considering the local and global dynamics.

In previous studies, risks had been quantified to address business risks that faced an event of water stress and had combined the use of satellite imagery, climate data, vulnerability assessments and other economic indicators for spatially map and quantify risks. Analysis has been done by looking at domestic water needs and water supply for industrial use where regions with water scarcity or regions facing higher water risks have been mapped basing on these needs. Looking at the various developed water risk indicators, most of them have used indicators such as climate hazards, pollution, population growth aridity, water demand, rainfall variability, groundwater abstraction and drought etc. These studies have quantified water risks successfully, however, they have failed to consider the indicators or factors that lead to water risks such as degradation, rainfall use efficiency by drops, vegetation factors and soil water stress while also have neglected the ecological water requirements. There are indicators that are directly related to water availability and their relationship could point to water risk situation in a water basin. Vegetation indices such as LAI, NDVI, NVI are used to show land degradation which has a direct relationship with water availability. Climate variability data is an indicator how the likely changes that are occurring and historical data will point to the variation with time of weather elements such as rainfall and temperature. Soil water information is used to show the water stress that plants could be facing during various times of the year and at different growth stages. The methodologies used in previous studies are complex and are not suitable for policymakers. Therefore, there is a need for a simpler method for risk quantification with the inclusion of factors into the assessment of water risks and develop a Water Risk Index taking into consideration ecological and human water requirements.

Several factors lead to water insecurity in Kenya and are of importance in the assessment of future water risks such as floods, droughts, forest degradation, land degradation, population growth, lack of water supply management, and water contamination among others (Marshall, 2011). Deforestation in Kenya is attributed to agricultural mechanization and resettlement which have been magnified due to the institutional failures, lack of consultations and poor resource decentralization (Atela et al., 2015). Industrial pollution is estimated as the highest source of pollutants as in the case of Athi River Kenya (Munyao et al., 2017). Deforestation, human settlement and agricultural activities are observed in most catchments in Kenya (Achieng et al., 2017) while the Ministry of Forestry and Wildlife stated that besides climate change factors, population growth and poor governance as drivers of deforestation and degradation, other factors such as agricultural extension (subject to population pressure, poverty, limited source of alternate income etc), excision, logging, livestock grazing and infrastructure development as drivers of degradation (MoF&W, 2013).

Drought in Kenya has been attributed to ongoing climate change while the severity of the drought impacts w made worse and may be attributed to a series of events which are human (Kioko, 2013). Floods have reportedly increased in the recent times in Nzoia basin (Odira et al., 2010) and both phenomena attributed to land use changes in the basin that has led to land degradation. The increased agricultural lands over the years increased the peak flows in the river during the rainy seasons while reduced the flow during the dry seasons. The area under forest cover has decreased thus affecting runoff and peak streamflow while the area under agriculture and riverine agriculture has increased also having a similar effect on stream flows (Odira et al., 2010).

2.3 Stakeholder mapping

There is a growing need for greater stakeholder engagement in order to assess, manage and communicate about risks (Vance-Borland and Holley, 2011). Stakeholders mapping in similar groups builds cohesion and bridges gaps among stakeholders leading to a successful participation (Reed and Curzon, 2015). Stakeholders values overlap based on the interest they vest upon a resource necessitating for specific management practice in an area thus mapping of stakeholders informs best management regulations to be implemented (Ruiz-Frau et al., 2011). Stakeholder mapping is a collaborative process of research that draws from multiple perspectives to determine a key list of stakeholders across the entire stakeholder spectrum and involves the steps of identifying, analysing, mapping and prioritizing stakeholders based on the group they fall in, perspectives and interests, relationship with other stakeholders and their relevance to the objectives (Olson; et al., 2011).

2.4 Water Stewardship Partnership

Stewardship is the willingness to be accountable to a larger group by operating in service or accountability without control or compliance (B. Peter (1993). Stewardship is a form of collaborative planning, responsible management of the environment through sustainable natural resources management with respect to the ecosystem function (Mathevet et al., 2018). Water stewardship for business was defined by (WWF, 2013) as an improved water use and reduced water-related impacts from internal value chain operation while committing to the sustainable management of the shared water resources in the public interest through collective actions with other stakeholders.

While assessing the triggers of environmental stewardship in the environmental stewardship model, religion was one of the important factors in promoting environmental stewardship as it makes individuals refrain from environmentally harmful activities (Azizan and Wahid, 2012). Motivational barriers to stewardship among users of private wells are limited knowledge on the importance of stewardship while poor education and policy efforts contribute to poor stewardship (Malecki et al., 2017). Stewardship can be in form of reformist, adaptive, sustainability and transformative (Mathevet et al., 2018). The critical element of stewardship is public engagement in formal and informal way (Miller et al., 2015). Stewardship evaluation at a catchment level showed that stewardship, in form of restoration, is influenced by the population density, political and program boundary, financial and technical resources, collaboration and communication (Sheppard et al., 2017). Trust among different stakeholder is the key to the success of a stewardship program by focusing on a single problem at a time (Carrie et al., 2016).

With the wake of climate change uncertainties, the current business models seems unsuitable and pose a threat to the food and beverage industries (J. Peter et al., 2015) and there is a need for all sectors to work together (Carrie et al., 2016), to link uplands with the aquatic environment, and a need to link stewardship activities to the conservation goals and objectives (Sheppard et al., 2017). There is an increasing trend towards environmental stewardship, however, there is a need to understand ecological and social impacts of stewardship for prioritizing project (Sheppard et al., 2017).

Although there is an increase in environmental stewardship, water stewardship has been taken as corporate sustainability while stewardship is driven by environmental concerns and is framed within the existing business models of companies (J. Peter et al., 2015). Since water reduction and quality deterioration will have a great impact on businesses, there is a need for all sectors to be involved in the management of the environment. Locally, there is a need to quantify the various risks that are likely to be faced by business and different sectors within the catchment and a need to understand the vulnerability transfer of socio-ecological dynamics.

CHAPTER 3: METHODOLOGY

3.1 Introduction

This chapter details the methodology used in the study which includes a description of the study area, the study design, data collection and subsequent presentation of the result.

3.2 Study Area

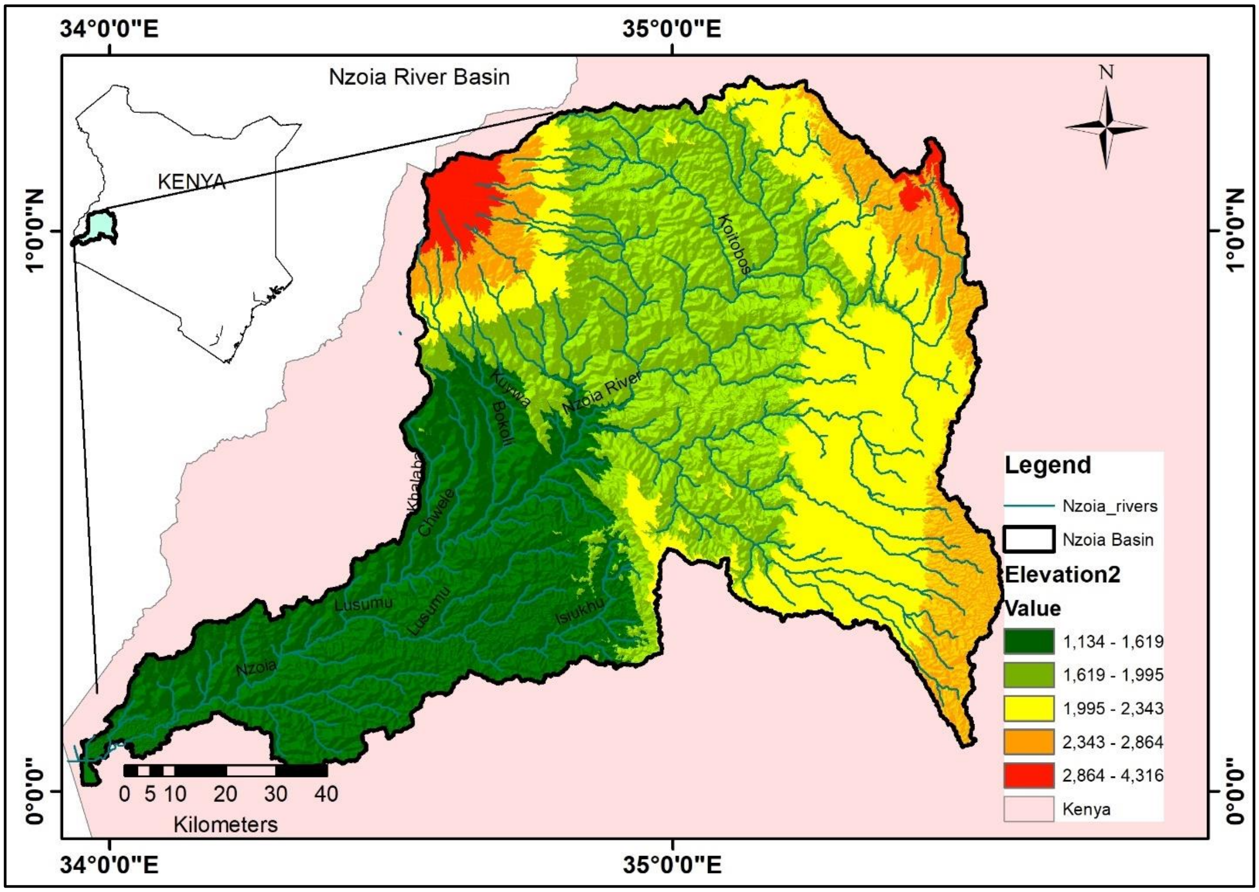

Figure 3.1: Map of Nzoia River Basin. Source Ministry of Water and Irrigation (WRA, 2018).

3.2.1 Geography

River Nzoia catchment lies between longitude 34^0 E - 36^0 E and latitude $0^0$00’N - $1^0$15’N covers an approximate area of 12,696Km^2 (Figure 3-1) and receives an annual rainfall range of 1134-2700mm annually with an average of 1350mm (Li et al., 2009). The altitude of the basin is between 1070m south-west – 2700m north-west with the highest point at 4321m which is the peak of Mount Elgon which is also the source of tributaries Ewaso Rongai, Koitobos, Kuywa, Soisio while Sosiani, Nureni, Kipkaren originate from Cherangany (Kirugara and Nevejan, 1996).

3.2.2 Socioeconomic

Nzoia basin has a population of approximately 3.5 million people (2009 national population census) with an approximate gender distribution of 50.8% women to 49.2% men. The population density varies from 0.23 persons/Km^2 around forested areas to 10,300 persons/Km^2 in urban areas. Poverty having a gender dimension, there are more women headcount with poverty in both rural (50%) and urban areas (46%) while there is a relationship between education and poverty with 68.7% of the household with no education in urban area compared to 22% of those with secondary education and 1.5% poverty incidence for households with university education (KNBS, 2007).

3.2.3 Environment and Hydrology

Nzoia basin experiences two rainy seasons (long and short) with long rains coming between March and June while the short rains between July and September while the driest months are between December and February. There are six soil types distributed over the catchment; clay light, heavy clay, loam soil (sand and silt), sandy clay, sandy loam and sandy clay loam with the upper parts of Mount Elgon dominated by clay while the middle regions of the basin dominated by clay light.

The basin is drained with several rivers and streams draining into the main river which flow into Lake Victoria. The length of the longest channel is approximately 355Km with the mean discharge of 118 m^3/s. however, the flow varies from 20 m^3/s in extreme drought to 1100 m^3/s in extreme flood (Joab et al., 2016).

From a physiographic and land use point of view, the basin has four distinct zones: a mountain zone, plateau zone, transition zone and lowland zone. The mountainous area faces degradation since its covered by forests, the plateau zone is an agricultural zone majorly (Odira et al.). forest cover had reduced between the 1970s and 1980s by 43.1% and increased by 41.3% between 1980s and 2000 with the decrease attributed to logging, clearing of land for settlement and agriculture while the increase to government initiative of tree plantation. The major land use types are montane forests, forests, bush/shrub, agriculture, sugar cane and settlement areas (Dulo et al., 2010).

3.3 Study Design

3.3.1 Water Risk and Action Framework (WRAF)

The Water Risk & Action Framework was developed in 2013 by the International Water Stewardship Programme (IWaSP) working alongside public bodies, civil societies, GIZ among other development partners with the aim of identifying and reducing shared water risks. WRAF was developed to help in forming and executing water stewardship partnerships using the cross-sector approach that has five phases (Figure 3-2) to help in increasing the quality of the partnership and ultimately achieving water security (IWaSP, 2018).

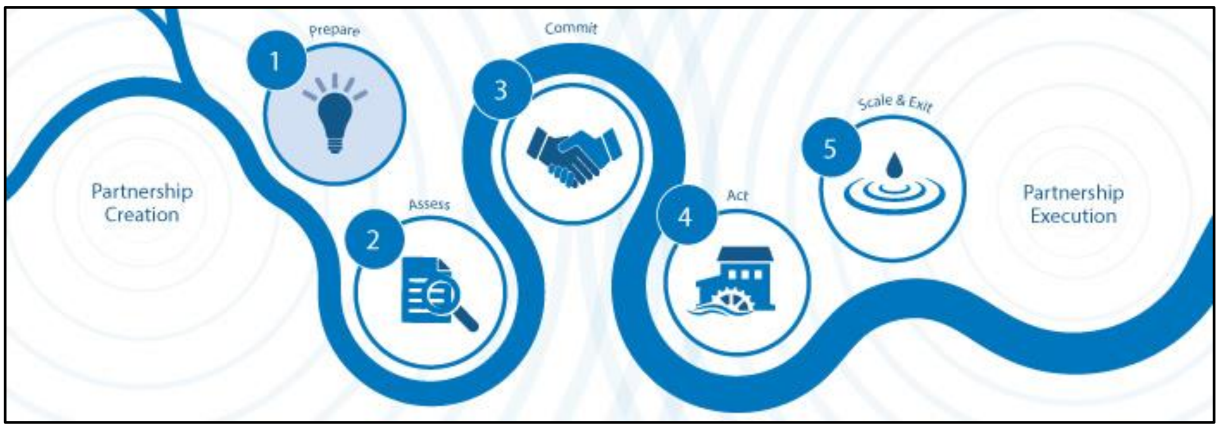

Figure 3.2: WRAF stages, (IWaSP, 2018).

Prepare phase integrates elements of the **Assess** phase which all together involves; Identify stakeholders and markets, share problems and recognize interests, prepare roadmap, assess risks and opportunities, determine costs and benefits, shape partnership. **Commit** phases involves developing business cases, developing a mode of delivery and securing the commitment of actors. **Act** phase consists of Empower and advises actors, coordinate and manage implementation and monitor progress. The final phase **Scale and Exit** involve the evaluation of impact and lessons, leverage impact at scale and phasing out. There are tools designed for use in several theme areas such as risk assessment, water risks mitigation among others (IWaSP, 2018).

For the purpose of this study, themes from the prepare and assess phases were used to assess the potential for a water stewardship partnership. The study begins with an assessment of water-related risks in the catchment followed by mapping of the potential stakeholders' partnership.

3.3.2 Quantifying water risks

In this study, indices were assessed to quantify water risks in the catchment by aggregating the various indices: Leaf Area Index (LAI), the Priestley-Taylor Alpha Coefficient, Rainfall Use Efficiency, Soil Water stress, slope and Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) was aggregated into a single Water Risk Index.

3.3.2.1 Leaf Area Index (LAI)

The energy, water and carbon exchanges between the land and atmosphere are highly depended on photosynthesis and is a function of plant leaves. This is largely controlled by the stomata as it is the bridge between highly water-saturated tissues in the leaves and the atmosphere in the exchange of mass used in energy and sugar synthesis using carbon and other nutrients(Sellers et al., 1997). An adequate amount of information on the inclusion of leaf functioning for climate simulation models requires quantitative information about the vegetation (Dickinson, 1995). LAI is defined as the projected area of a leaf over a unit of land in (M^2M^2) and sometimes it is expressed as the basis of all leaf surface area., LAI in need leaf vegetation is defined as the projected need leaf area per unit ground area.

$$L=N_p * N_l * A_l \qquad (1)$$

where:

N_p is the number of plants per unit area

N_l number of leaves per plant

A_l is the mean area of the leaf in m^2.

The number of plants occurring in a location is determined by the percentage of the establishment and the number of seeds sown, influenced by temperature, soil moisture, management practices soil aggregate, size of leaf and leaf expansion which depends on temperature and Nitrogen. LAI can be used to estimate soil moisture supply climate etc. LAI gives quantitative values as opposed to Normalized Difference Vegetation Index (NDVI), which gives qualitative values on how lush the vegetation is. Determination of LAI over land is a key in determining the energy balance over the land surface. LAI is used in quantifying carbon fluxes in the atmosphere (Dickinson, 1984).

Optical remote sensing is a valuable tool to assess the changes in biomes (an area of the planet that are classified according to the plants and animals that live in it) and other ecosystem characteristics in response to climatic changes over a huge area and with multiple and long time periods (Huemmrich et al., 2010). Remote sensing methods generate dimensionless LAI values assigned per pixel and can range from 0 to 6 or more, LAI for rangeland which has sparse vegetation, values commonly range from 0 to 1. 1 indicates the vegetation covering the entire unit surface area of the ground and values less than 1 means there is bare ground between vegetation patches.

(Buermann et al., 2002) simulated LAI by observing how light is reflected using Near Infrared and visible light. the empirical relationship that is there between LAI and spectral vegetation indices such as NIR, Red band ration, and NDVI suggests that the radiative transfer method of assessing LAI is the best since NDVI is sensor specific. The field observation data that is used to validate the satellite LAI shows there is a relationship and the values are comparable according to the selected sites of study (Myneni et al., 1996). LAI values are related to climatic data and there is a direct relationship between LAI and the ENSO cycle where the anomalies in the Sea Surface Temperatures have affected the values of LAI. It was also observed that the warm temperatures promote growth (Dai et al., 1997).

The use of LAI in quantifying the biomes change in a region over a period of time is advantageous over the use of NDVI as it gives the quantitative value to LAI as opposed to the NDVI. This can be used in quantifying the likelihood of degradation or a catchment by looking at the changes of LAI over time. It can also be used to give information about the variation of temperature rainfall, ENSO and climate data which are all important factors in growth.

For global or large-scale estimation of LAI over the land surface and for a time series, remote sensing is a powerful tool that collects data from sensors mounted on satellites orbiting the earth. Moderate Resolution Image Spectroradiometer (MODIS) is one of the sensors aboard Terra and Aqua satellites which has been in orbit since 2000 and has been providing a source of LAI data with calibration and fusing from other sensors to give long-term LAI series. MODIS is aboard the space crafts is viewing and acquiring data at 36 spectral bands.

There is an indirect relationship between LAI and land degradation where an increase in LAI means less degradation as opposed to the low LAI values that point to degradation. Degradation is an indicator of Water risk in a catchment as the decrease in cover crop leads to an increase in evaporation and evapotranspiration rates on land. Therefor Water Risk (WR) can be expressed by the following equation

$$WR = 1/LAI \qquad (2)$$

3.3.2.2 The Priestley-Taylor Alpha Coefficient

The water availability in soils, soil moisture, is an important factor for plants growth. The lack of adequate soil moisture in an area leads to crop failure and hinders reforestation efforts. Areas that have high air temperature and high soil temperature experience water stress due to high evapotranspiration (ET_0). A study of the surface energy budget is used to estimate evapotranspiration. Penman equation (Penman, 1948) developed one of the methods used to estimate evapotranspiration.

(Priestley and Taylor, 1972) in the calculation of daily ET_0 (mm/ d) replaced the aerodynamic term of Penman-Monteith equation by a dimensionless empirical multiplier (α , Priestley-Taylor coefficient):

$$ET_0 = \frac{s.(Rn-G)}{S+\gamma}.\,\alpha \quad (3)$$

where:

ET_0: Potential Evapotranspiration

Rn: the net radiation ($MJ/m^2.d$),

G: the soil heat flux ($MJ/m^2.d$),

s: the slope of the saturation vapor pressure-temperature relationship (kPa/ °C)

γ: the psychrometric constant (kPa/ °C),

α: the Priestley-Taylor coefficient.

The Priestley-Taylor equation is applicable for the calculation of daily ET_0 for conditions where there is a limited data such as weather inputs for the aerodynamic term (relative humidity, wind speed). On land, the latent heat of evaporation is affected by the radiation that is received on the surface, α is very useful in the analysis in unsaturated surface and Priestley observed that unsaturated surface had lower values than saturated surfaces and the ratios of low alphas is regarded as aridity index (Priestley and Taylor, 1972).

Priestley et al. (1972) developed a streamline to solve (Penman, 1948) parameterization problem leaving the formulation of radiation and temperature-based equilibrium evaporation. However, this method estimated only the potential evapotranspiration (PET) not the actual evapotranspiration (AET). (Fisher et al., 2008) introduced a unitless function into the Priestley-Taylor equation for remote sensing studies that are used to derive the AET. The PT-FI model is based on the atmospheric moisture and vegetation indices (NDVI) and Soil Adjusted Vegetative Indices (SAVI).

Priestley-Taylor alpha coefficient (PAC) is generalized as the ratio (dimensionless) of annual AET over the annual PET and as the alpha coefficient approaches 1, vegetation is uninfluenced by water stress and is used to describe the overall aridity stress on vegetation by integrating monthly soil water availability for vegetation. The higher the coefficient the lower the water risk while a decrease in the coefficient shows higher water risks. Therefore, Water Risk (WR) is

$$WR = 1/PAC \tag{4}$$

3.3.2.3 Rain Use Efficiency (RUE)

Desertification is caused due to climatic conditions or human activities and negatively affects land productivity and reduces the plant/perennial cover, which are indicators of land degradation (Kundu et al., 2017). Rain Use Efficiency (RUE) is defined as the aboveground net primary production (ANPP) divided by rainfall and is used as an indicator of degradation (Dardel et al., 2014). Changes in rainfall distribution or pattern affect vegetation structures, LAI (primary Precipitation Use Index, PUE, driving factor) and thus a possible effect on water and carbon cycles while precipitation is the standard cause of ANPP (Jia et al., 2015).

The increase in mean annual precipitation increases ANPP and RUE (Bai et al., 2008). Globally, remote sensing data such as MODIS has been used to develop RUE through different methods such as Novel method (Du et al., 2018), correlation analysis (Zhao et al., 2018), meta-analysis and regression (Ruppert et al., 2012). RUE has shown a positive correlation with evapotranspiration, while both RUE and Vegetation Index (VI) are indicators of ecological multifunctionality indicators, RUE is preferred over VI due to the robustness of rainfall (Zhao et al., 2018) and shows a dynamic integration of NDVI and rainfall (Kundu et al., 2017). Although RUE varies in different biomes (Ruppert et al., 2012) and the need for further understanding of climatic and soil factor on growth (Sun and Du, 2017), the use of RUE can be used as an ecosystem indicator to show degradation.

3.3.2.4 Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS)

Studying floods and droughts require accurate rainfall data over a period of time, satellites offer an alternative to access rainfall data in regions with sparse rain gauges and in inaccessible regions (Toté et al., 2015). CHIRPS is a 30 plus years quasi-global rainfall dataset from 1981 to the near present with a 0.05^0 resolution with in situ data for trend and drought monitoring (CHG, 2018). CHIRPS is built on previous approaches on smart interpolation and high-resolution long period of precipitation estimates based on Infrared Cold Cloud Duration Observations and several algorithms developed for daily monthly data etc (Chris Funk et al., 2015). Satellites perform better in data sparse regions with complex terrain and offer high-resolution data (C. Funk et al., 2015). CHIRPS performs better as compared to other data types although it overestimates rainfall events frequency (Toté et al., 2015) up to 31% at decadal scale but are better at skills in determination of rainfall event, volumetric rainfall estimation and better bias values (Ayehu et al., 2018). This data is vital to study drought and floods as most countries are experiencing population growth thus the need for food security to suffice the population.

Africa Soil Information Service (AfSIS) derived RUE using MOD17A3H NPP (Net Primary Production) and CHIRPS (Climate Hazards Group InfraRed Precipitation with Station) with results in g/Cm^2.mm, and tC/ha.mm (AfSIS, 2015) and has been suggested as a measure of land degradation. RUE is given as the annual sum NPP/ annual sum CHIRPS and is given as using tC/ha .mm: the amount of biomass produced (tons of Carbon Mass per hectare) per mm of rainfall. The higher the RUE value the lower the Water Risks in the catchment thus giving the inverse proportional relation of RUE to Water Risk (WR).

$$WRI=1/RUE \qquad (5)$$

3.3.2.5 Soil Water Stress

Water is an essential molecule in the plant biomass since it is essential for physiological processes and water stress occurs when the supply of water to the roots become limiting (Lisar et al., 2012). The state of water in soil is expressed in terms of the amount of water and the energy associated with the forces holding water in the soils while the amount of water is described by the content and the energy state which influence the plant growth, soil temperature, chemical transport and groundwater recharge (Bilskie and Scientific, 2001). Drought is the most limiting factor for field crops in arid and semi-arid regions with the varying degree of drought stress affecting the amount of dry matter produced and the quality of seeds produced by crops (Gholamhoseini et al., 2013). The percentage of the maximum soil water content that is available for evapotranspiration is equal to the soil water stress coefficient and is a measure of the soil stress expressed monthly. These values expressed monthly ranging from 0-100 with higher values indicating high potential of evapotranspiration thus a lower water risk.

WR=1/SWS………………………………..(6)

3.3.2.6 Water risk Index (WRI)

Leaf Area Index (LAI), the Priestley-Taylor Alpha Coefficient, Rainfall Use Efficiency, Soil Water stress, are indicators of the Water Risk in the basin and aggregation of these risk indicators give a WRI of the basin. Using equations 2,4, 5 and 6:

$$WRI = \frac{1}{LAI * RUE * SWS * PAC}$$

3.4 Data collection on stakeholders

3.4.1 Sampling and data collection

Purposive sampling technique (Tongco, 2007) with a target sampling population of 50 respondents was used. Semi-structure questionnaires were used to collect stakeholders' views and the informants were selected based on their geographic locations, interactions and interest in water resources within the study area. Stakeholders were assigned categories based on the type of organization they represented.

3.4.2 Stakeholder data analysis and representation

Stakeholder mapping is guided by stakeholder analysis template developed by (IWaSP, 2018) and the stakeholder responses on their willingness to partner was analyzed using Microsoft Excel and represented in form of charts, tables and graphs by applying descriptive statistics on the collected responses.

3.5 Data analysis and Assessment

3.5.1 Water risk data

LAI and RUE data were obtained from (AfSIS, 2015) with spatial resolution on 1000 meters in a GeoTIFF format for Africa continent. SWS and PAC data was acquired from (Trabucco and Zomer, 2010) with a resolution of 30 arc second in ESRI grid format for global data. SWS and PAC raw data were downloaded from the (NASA, 2014) and batch scripts were used to automate the interaction with the MODIS reprojection and GRASS GIS, in a LINUX environment, to geoprocess and mosaic all the tiles relevant for Africa (GitHub, 2010) with a resolution of 1000m. SWS and PAC data is in global format while LAI & RUE were for Africa continent. PAC data was obtained from the Consortium for Spatial Information (CGIAR-CSI) (Trabucco et al., 2010) with a resolution of 30 arc seconds (~920 m at the equator). The data clipped in ArcGIS 10.2 using the spatial analyst tool with River Nzoia Basin as the mask as the processing extend.

3.5.2 Data analysis tools

ArcGIS programme was used to analyze the data using the raster calculator to derive the Water Risk Index (WRI). WRI was derived by combining the different indicator that all together form offers an indication of the risk factor within the catchment. Aggregation of these indicators into one will give a Water Risk Index that will show the spatial-temporal variation of risk factors within the basin. The indicators were combined using the formula:

$$WRI = \frac{1}{LAI * RUE * SWS * PAC}$$

The resulting output is a unitless raster value with values between 0-0.05. The Raster is assigned classes with the various risk levels

Table 3.1: Risk analysis classification

	Classes	Assigned Class	Risk category
1.	0 to 0.01	1	No Risk
2.	0.01 to 0.015	2	Low Risk
3.	0.015 to 0.020	3	Medium Risk
4.	0.020 to 0.025	4	High Risk
5.	Over 0.0250	5	High Risk

3.6 Ethical consideration

The research involved carrying out interviews and there were ethical issues that were critical and provided standards the norm, behavior and the moral standard and relationship between the researcher and the responded. The researcher took approaches to ensure confidentiality of the collected data such as non-inclusion of personal information in the questionnaire, the collected data was not used for any reasons other than they specified study, the collected data was kept relatively safe, non-pressured decision making to participate in interview and unbiased and accurate reporting (Ritchie et al., 2013).

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the results of the analysis in determination of the water risks in the basin and stakeholder analysis on the potential for a water stewardship partnership.

4.2 Quantifying the Water Risk

Water risk in the basin was determined by a combination of four indicators that include LAI, RUE, Priestley-Taylor Alpha Coefficient and SWS.

4.2.1 Leaf area index

The LAI data (Figure 4.1) is a representation of the standard deviation values with a temporal range between February 2000 and December 2016. The data shows a major portion of the basin has had low variation in the LAI value since 2000 with a sizable area of the basin having high values of LAI variation. The north-west and northeastern parts of the basin which is high altitude areas and considered as the water towers of the basin seem to be most affected in the LAI values variation. LAI is affected by natural factors(interaction between vegetative and reproductive components, climate) and human factors (Pruning of trees, farming, deforestation) while it has been observed that LAI affects partitioning between green water (evapotranspiration) and blue water (infiltration, aquifer recharge, streamflow) making it an important indicator of the ecosystem function and status (Taugourdeau et al., 2014). From the data below, it is evident that there is deforestation along the slopes of Mount Elgon and along the Cherangany ranges which fall along the North West and Northeast of the basin. There is evidence of degradation along these areas too due to the variation of LAI with the central part of the basin experiencing high LAI variation.

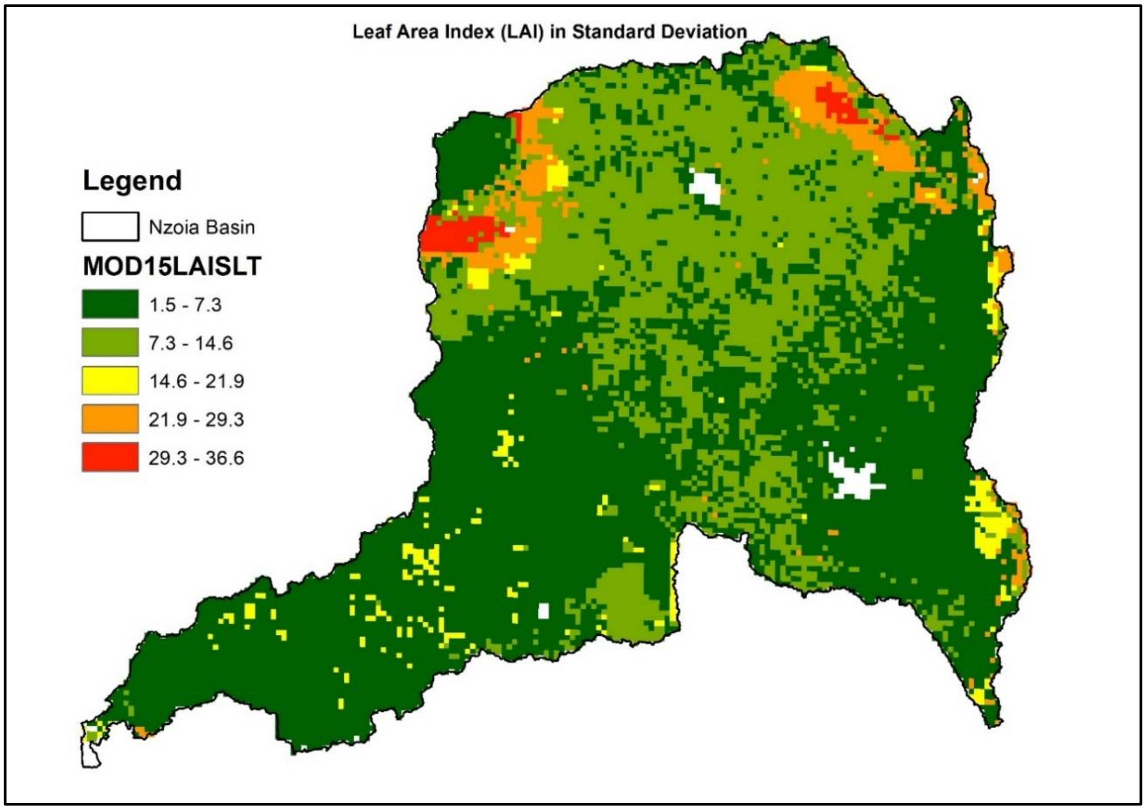

Figure 4.1: MODIS MOD15A2 Leaf Area Index(Temporal Range: Feb 2000 - Dec 2016) (GitHub, 2010)

4.2.2 Priestley-Taylor Alpha Coefficient

The PAC is generalized as the percentage of annual AET over an annual PET. As the alpha coefficient approached 100%, vegetation was uninfluenced by water stress. This effectively indicated the effects of aridity stress on vegetation since it integrates monthly soil water availability for vegetation requirements through a generalized soil water balance (Trabucco et al., 2010).

From the data analyzed (Figure 0.2) between 2000 to 2014, in about a third of the basin, there is a 46-60% chance that the vegetation in those areas are affected by water stress while the rest of the basin is less likely to be affected by water stress. This is an indicator that a third of the river basin is likely to experience higher evapotranspiration rates with low water content in the soil. From the results, there is the likelihood of an increased degradation and increased weather variation in the basin that leads to high evapotranspiration rates.

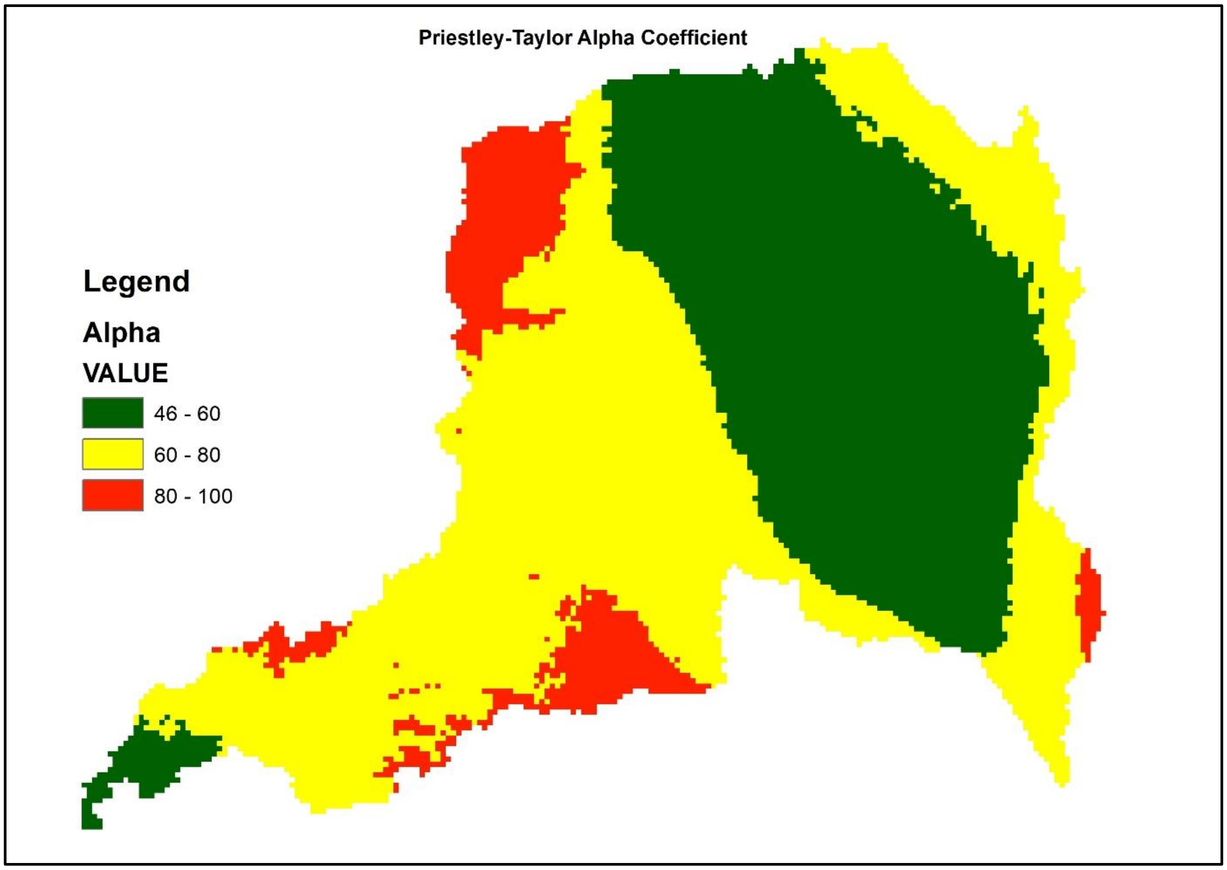

Figure 4.2: Priestley-Taylor alpha coefficient from 1950 -2000 source:(CHG, 2018).

4.2.3 Rainfall Use Efficiency

RUE is expressed as the amount of biomass produced (tons of Carbon Mass per hectare) per mm of rainfall. The comparison of RUE between 2000, 2010 and 2014 (Figure 0.3) shows an increase in the areas with low RUE values with the year 2000 having the smallest area with low RUE values between 0 to 0.011 tC/ha .mm while the basin recorded higher RUE values of between 0.022 to 0.0279 tC/ha.mm. In 2010, the area with the lowest RUE efficiency of between 0 to 0.005 tC/ha.mm significantly increased while the highest recorded values of RUE were between 0.011 to 0.016 tC/ha.mm. In the year 2014, approximately 70% of the basin recorded RUE values of between 0.002 to 0.011 tC/ha .mm with the highest values between 0.016 to 0.022 tC/ha.mm being recorded. From the map below, it is evident that there has been an increase in the areas with lower RUE values between 2000 and 2014 while there has been a decrease in the areas with higher RUE values with the highest values decreasing from 0.0279 tC/ha.mm to 0.016 tC/ha.mm in 2010 with 2014 recording 0.022 tC/ha.mm. It is evident that there is a decline in the primary productivity of in the basin over the years and a likely increase in losses of rainfall through runoff and evapotranspiration. These indicate a degrading catchment in terms of soil, and vegetation with a possible land use changes for settlement and infrastructure development occurring in the catchment.

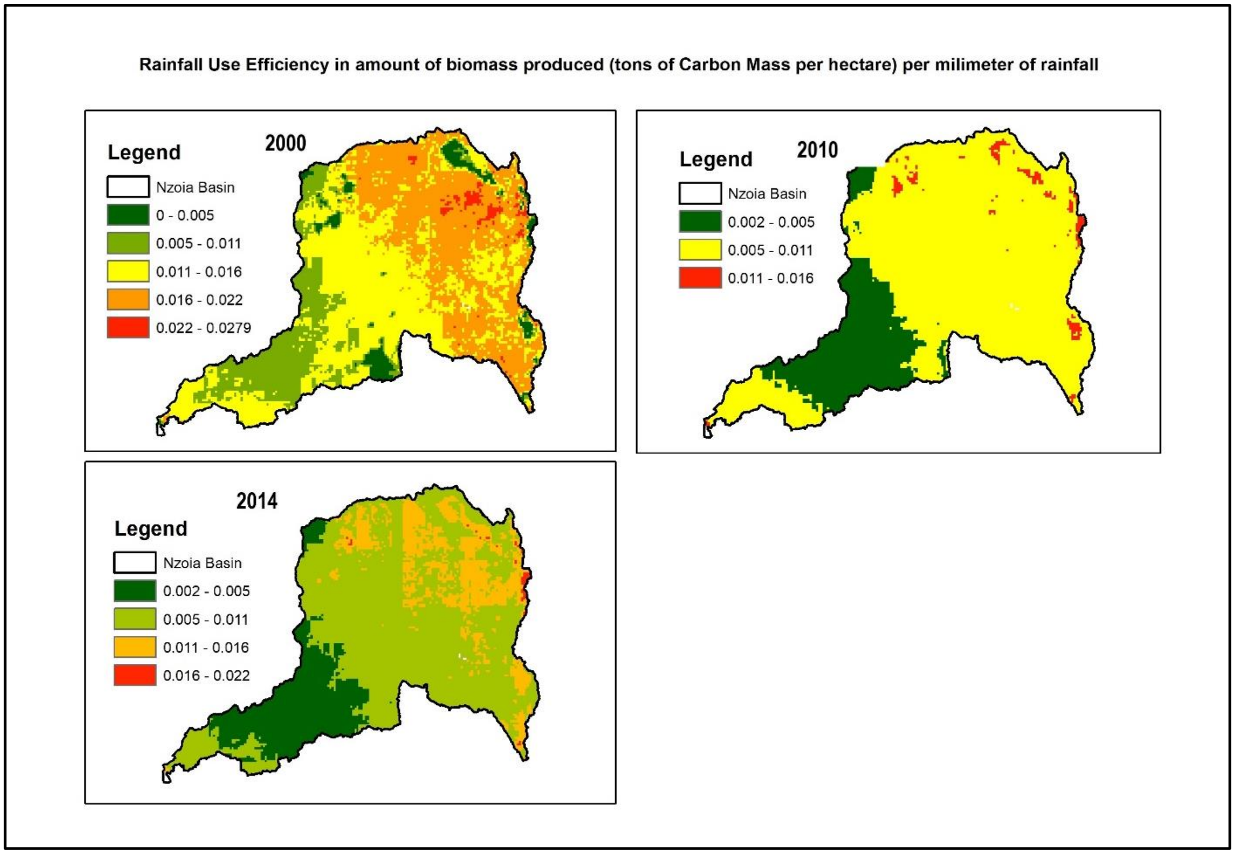

Figure 4.3: Rainfall Use Efficiency for 2000, 2010 and 2014 (AfSIS, 2015).

4.2.4 Soil water stress

SWS indicates the monthly fraction of Soil Water Content available for evapotranspiration process expressed as a percentage (percentage of Maximum Soil Water Content) (Trabucco et al., 2010). Figure 0.4 shows that the comparison of monthly SWS data bellow, January, February, March, and April have the lowest percentage with values below 40% of water available for evapotranspiration thus higher stress levels in the soil. About 40% of the catchment area experience low soil water capacity in these months. The rest of the basin recorded a fairly high amount of soil water content in the subsequent month with the majority of the basin recording values of above 40% while a significant area recording values of up between 80 and 100% indicating very low water stress. The water stress increases with the decrease in the amount of Soil water content thus the months of January, February and March experience higher soil water stress in the majority of the basin. This an indication of increased drought during the first three months of the year in the basin.

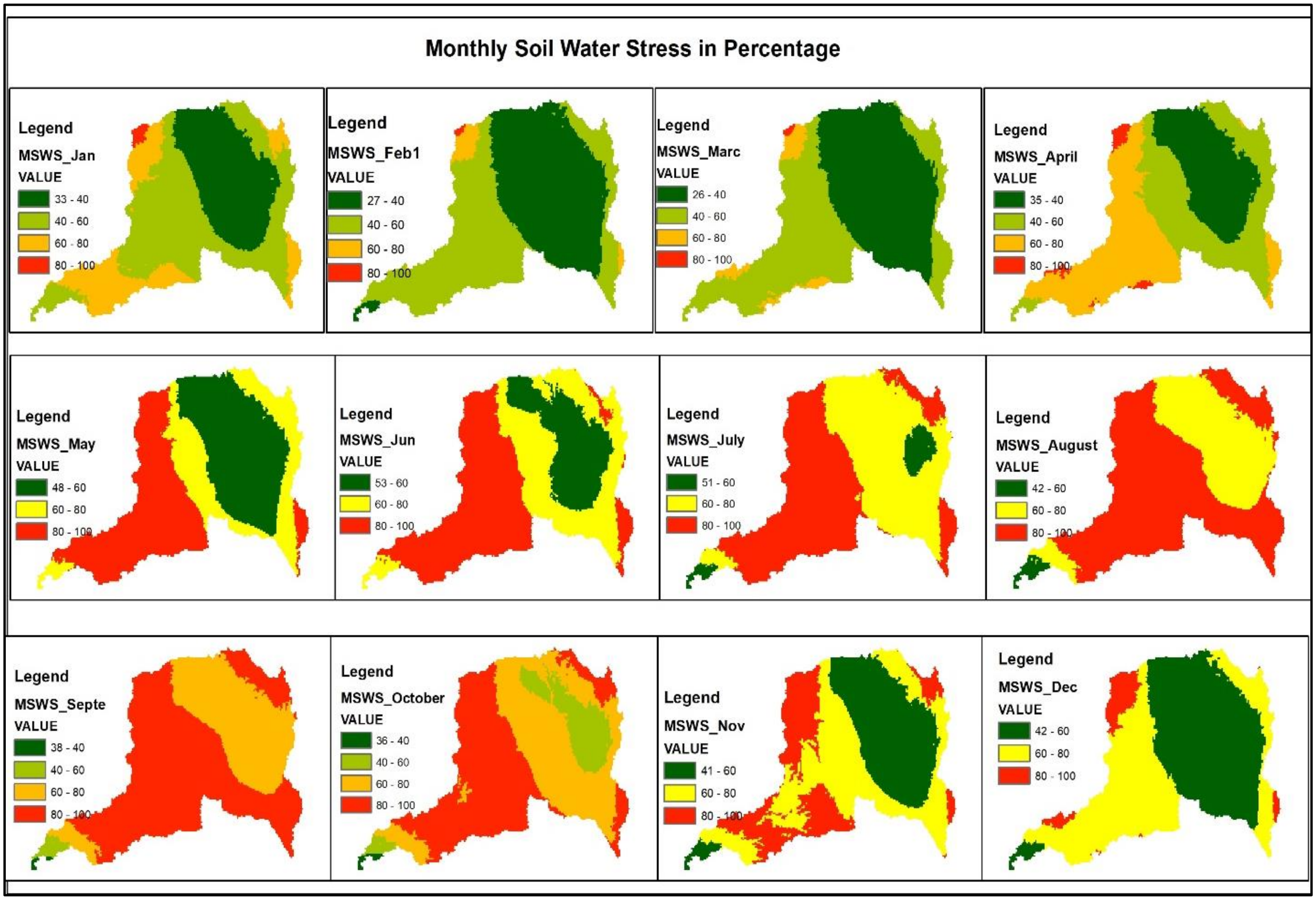

Figure 4.4: Monthly Soil water stress for the basin. Source:(CHG, 2018)

4.2.5 Water Risk Index

The WRI is calculated by combining the four indicators of risk that are LAI, RUE, SWS, and PAC. The WRI was calculated for the year 2000, 2010 near past 2014 on a monthly basis from January to December. The water risks have been categorized into 5 classes from 1 to 5 with 5&4 being high risk, 3 being medium risk, 2 being low risk and 1 NO/Negligible risk. Areas falling between 4 and 5 have faced water stress for both human and ecosystem use.

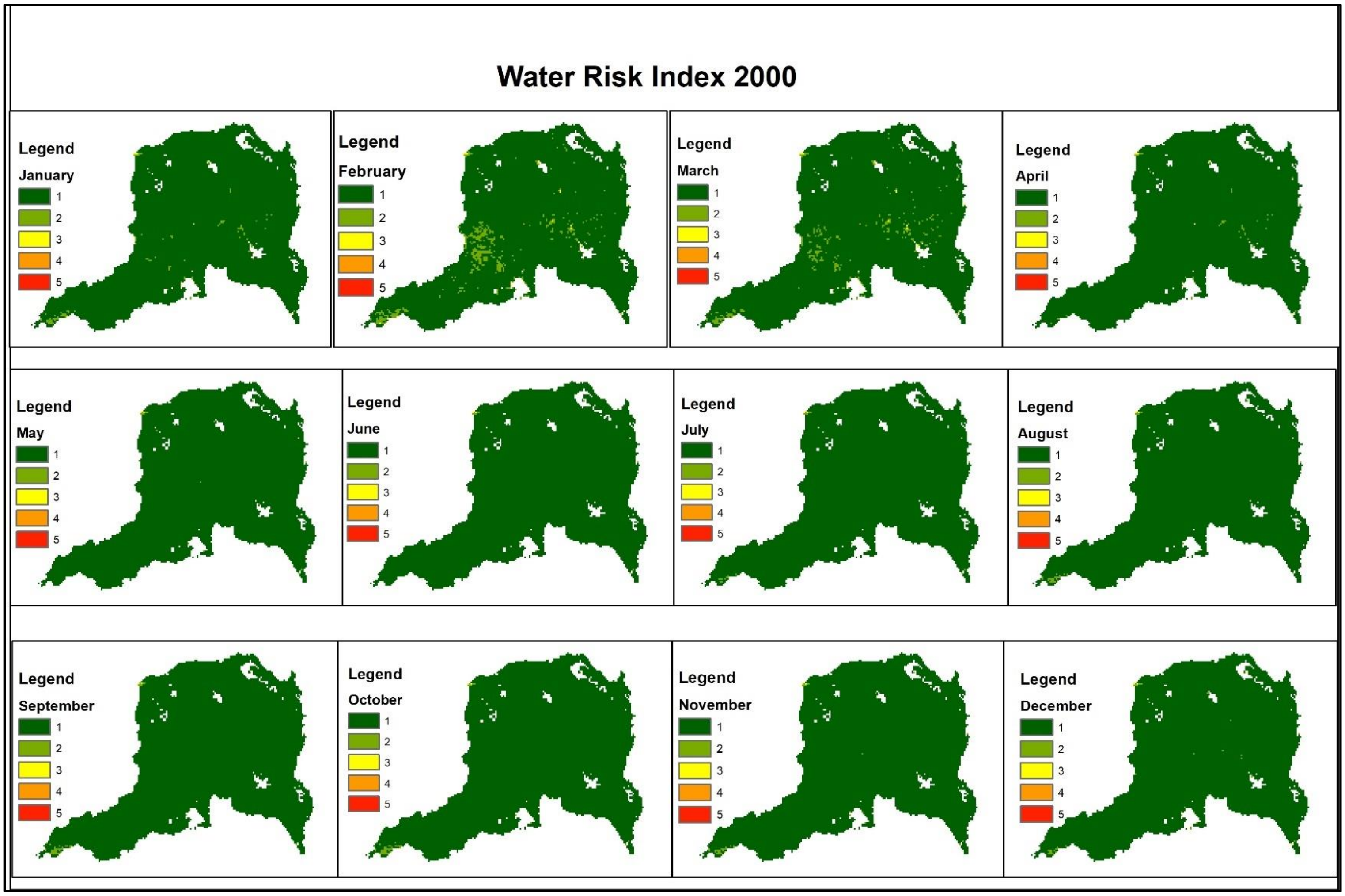

Figure 4.5: Water Risk Index for the catchment for the year 2000(AfSIS, 2015; CHG, 2018; GitHub, 2010)

From the analysis for the year 2000 (Figure 0.5), a major area of the basin faced no water risk throughout the year. January, February, March, and April faced low water risk in areas less than 15% of the entire basin while the rest of the year experienced low water stress. Generally, there was no water risk or water stress in the catchment in the year 2000.

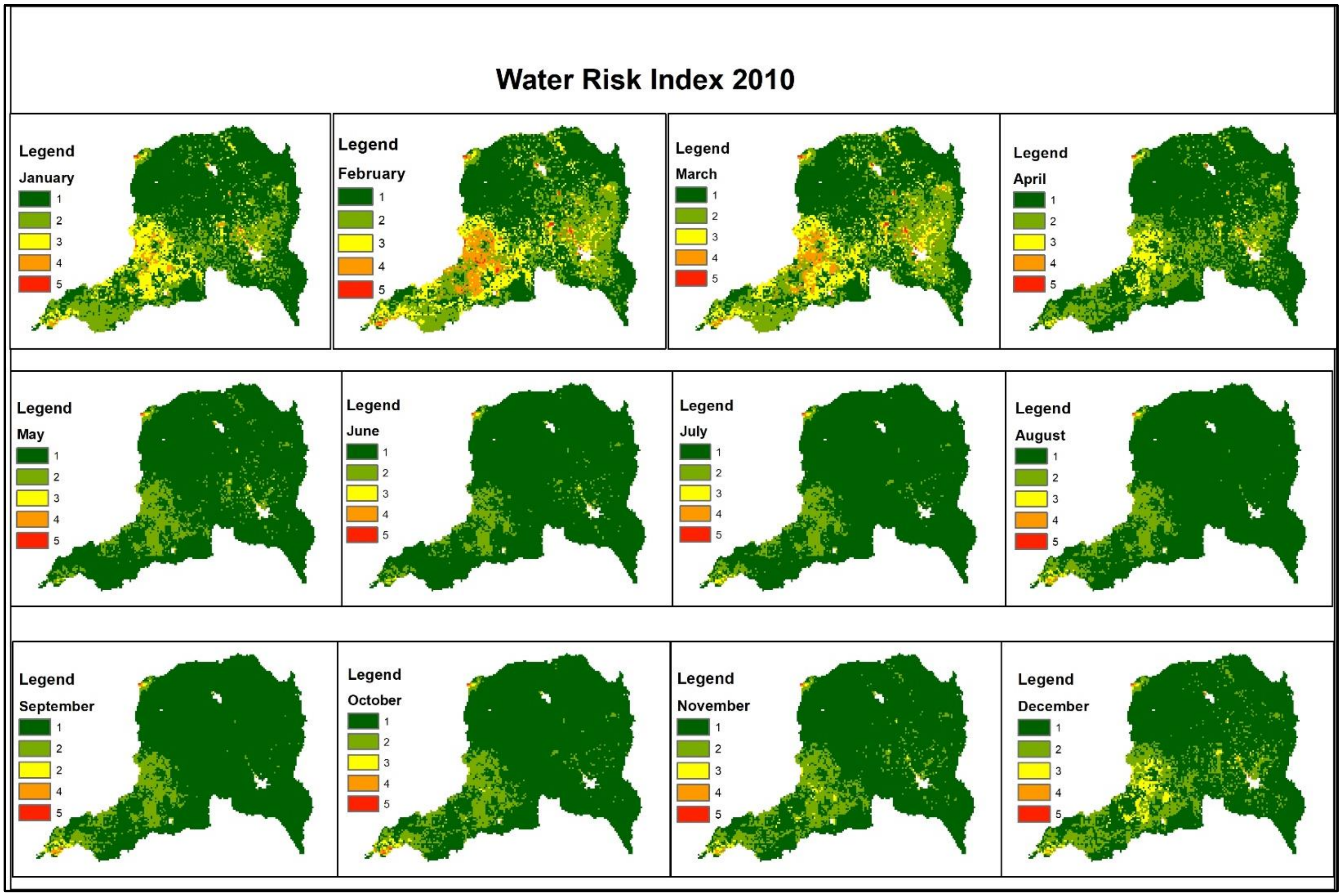

Figure 4.6: Water Risk Index for the catchment for the year 2010(AfSIS, 2015; CHG, 2018; GitHub, 2010)

In 2010, from (Figure 0.6) there was a significant decrease in areas with no water risk while there is an increase in the areas that faced low water risk, medium and high-water risks. The most affected months are January, February, and March where the approximately 30% of the basin faced medium to high water risks with the affected areas being towards the peak of Mt. Elgon, the central part and the southwestern portion downstream the river. These months are associated with low precipitation due to the migratory nature of the Inter-Tropical Convergence Zone which brings seasonality of rainfall in the region. The rest of the year, a major portion of the basin experience low to no water risk with the exception of the area around the peak of Mt. Elgon (to the North West of the basin) and the south-west towards the mouth of river Nzoia which experienced medium to high water stress throughout the year.

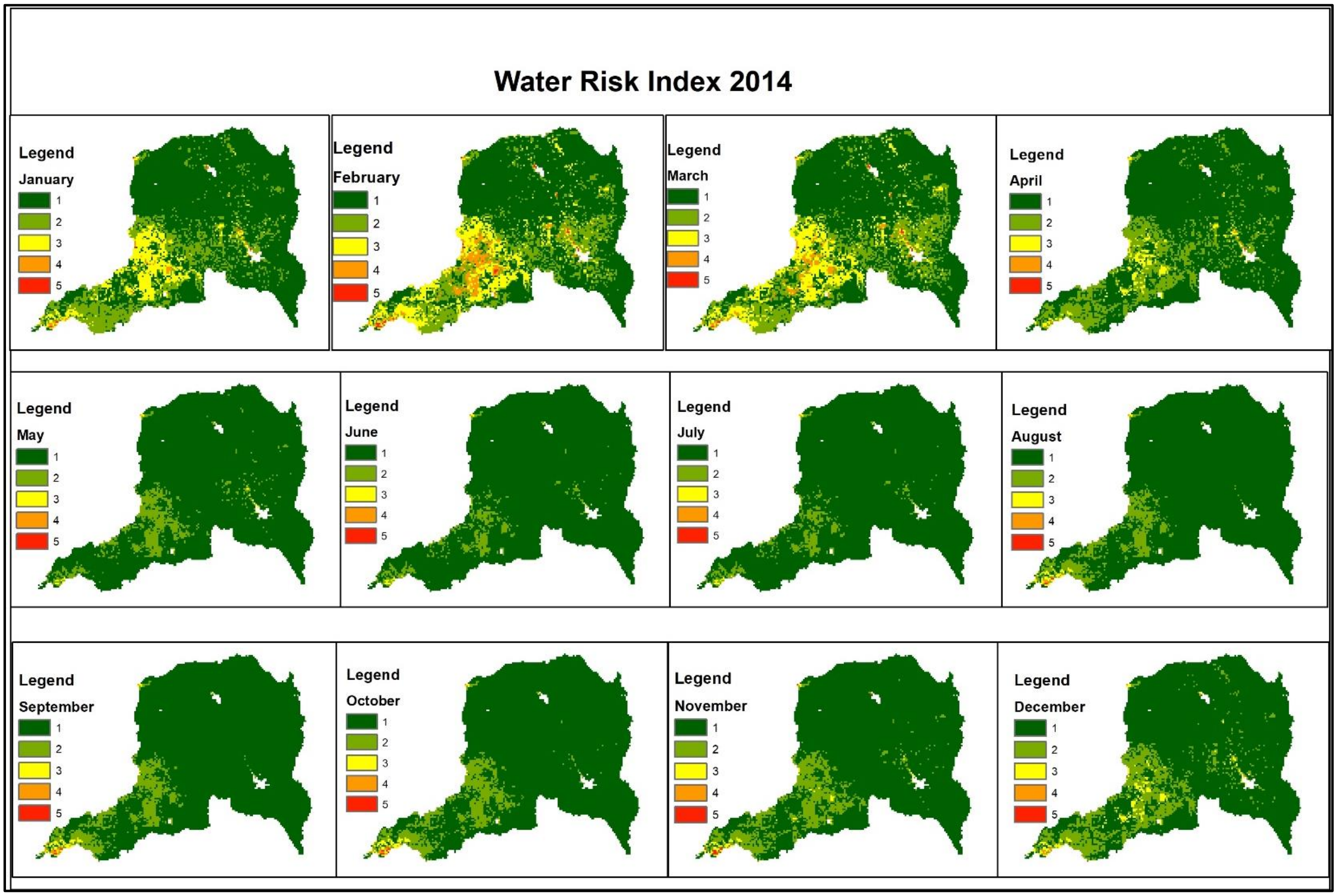

Figure 4.7: Water Risk Index for the catchment for the year 2014(AfSIS, 2015; CHG, 2018; GitHub, 2010)

In 2014, (Figure 4.7), there was a slight decline in the areas that faced medium to high water risk as compared to 2010 but the areas were large as compared to the year 2000 where the majority of the basin did not record any water risk. The first three months of the year are the most affected with approximately a third of the basin facing medium to high risks and notably the downstream/southwest part of the basin facing constant high risk throughout the year.

4.3 Partnership Stakeholders

4.3.1 Stakeholder categories

Stakeholders partnership was identified based on their roles, interest and their overall interaction with water resources (Table 4.1). The stakeholders were categorized into classes that include Government authorities, Local business, International Organization, Local NGO, Private Sector, Companies, Academia, Local community, Water User, Parastatal and Other Using the stakeholder analysis template for (IWaSP, 2018).

Table 4.1: Stakeholder categories from stakeholder mapping

Category	**Number of Stakeholders**
Government authorities	7
International Organization	2
Local NGO	3
Company	4
Academia	3
Local community	5
Water User	10
Parastatal	8
Private sector	10
Total	**52**

A total of 52 stakeholders were identified that were key in the formation of water stewardship partnership and were identified based on their interest and association to water resources. 7 governmental authorities were identified with an interest in water resources and they include the county government, the ministries of water and environment and government bodies that have interest in conservation and resource management. 2 international organizations were identified as they are interested in water resources management including GIZ. Parastatals in that are involved in water and environmental activities were identified with approximately 9 of them mapped within the basin. The private sector, farmers, and water users were identified while academic institutions with interest to water in the basin were mapped.

4.3.2 Stakeholder group

Stakeholders for the partnership were categorized into groups basing on their impact and the roles they are likely to play in the partnership. The three categories include core partners, non-core partners and target group (Figure 4.8). Core partners are critical to the success of the partnership, non-core partners will influence the success of the partnership but are not critical while the target group will influence the project and targeted for implementation of activities proposed.

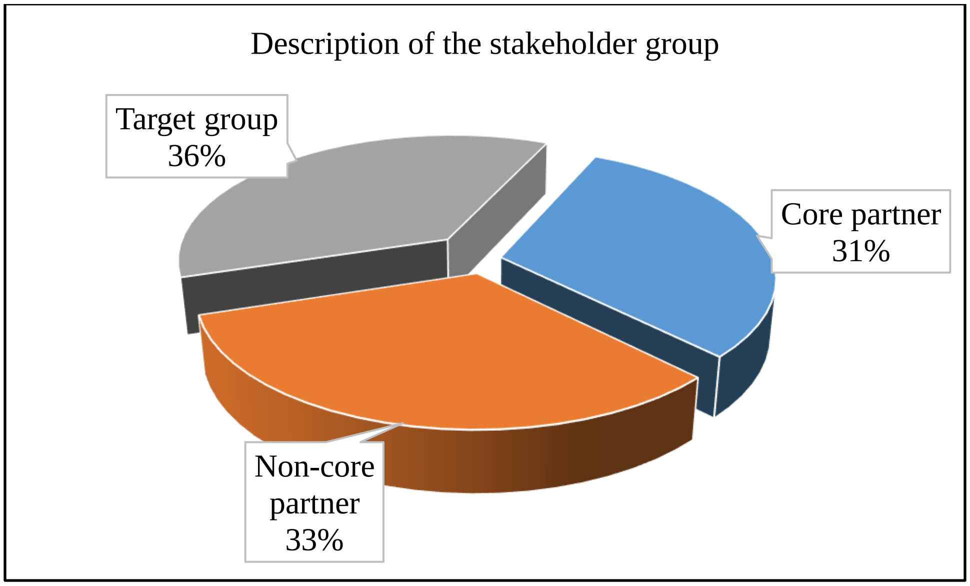

Figure 4.8: Description of the stakeholder group

36% of the stakeholders are targeted for the success of the project, 31% are core partners of the partnership while 33% are non-core partners but influence the success of the partnership.

4.3.3 Stakeholder priority

Stakeholder priority was assigned based on their roles and their impact on the partnership and a total of four categories were defined (Figure 4.9). The key stakeholder is an actor that can impact the partnership extensively, a primary stakeholder is an actor that can advance or slow down the partnership, secondary stakeholder an actor that needs to understand the basics of the partnership while the undefined stakeholder is an actor whose roles are not defined (IWaSP, 2018).

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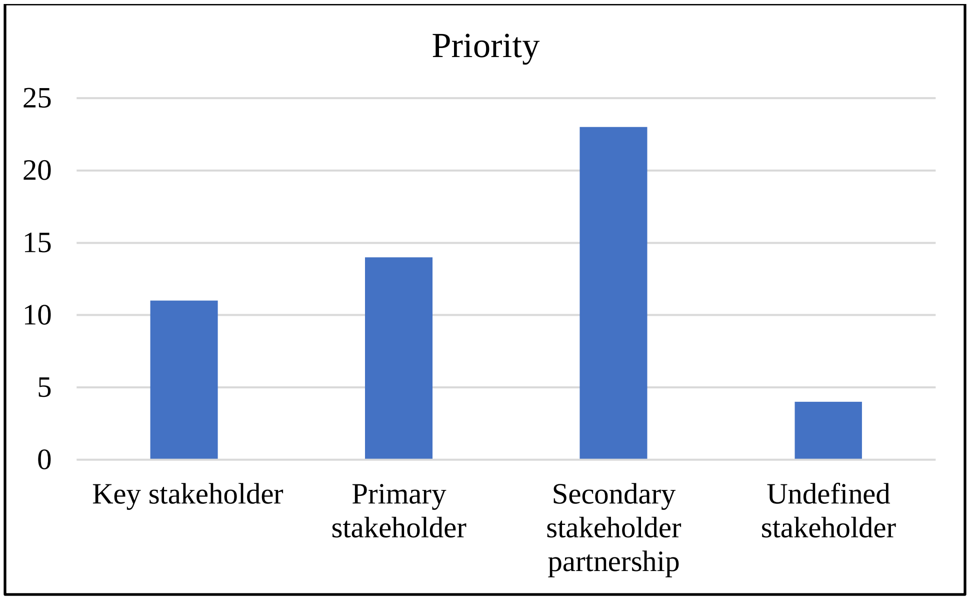

Figure 4.9: Graph of Stakeholder priority

There are 11 key stakeholders who can drive the partnership and are pivotal to the success of the partnership, 14 primary stakeholders who will advance the partnership to achieve the set targets and objectives and the majority of the stakeholders being the secondary stakeholder with up to 23 of the sampled stakeholders that need to undergo capacity building on the importance and the fundamentals of the partnership. The least of the stakeholder priority is the stakeholder with interests in water resources management, but their roles are not defined.

4.4 Water stewardship partnership

4.4.1 Water stewardship program

Interviewing the various stakeholders showed that there is a lack of water stewardship program within the river basin, however, all stakeholders were willing to participate in the water stewardship. Majority of the stakeholders (88%) responded to a lack of stewardship program while 12% responded to a presence of a stewardship program (Figure 4-10). From the observation, it was clear that there was a lack of a clear strategy to bring water stakeholders onboard as a single platform to carry out activities that can reduce water risks in the river basin.

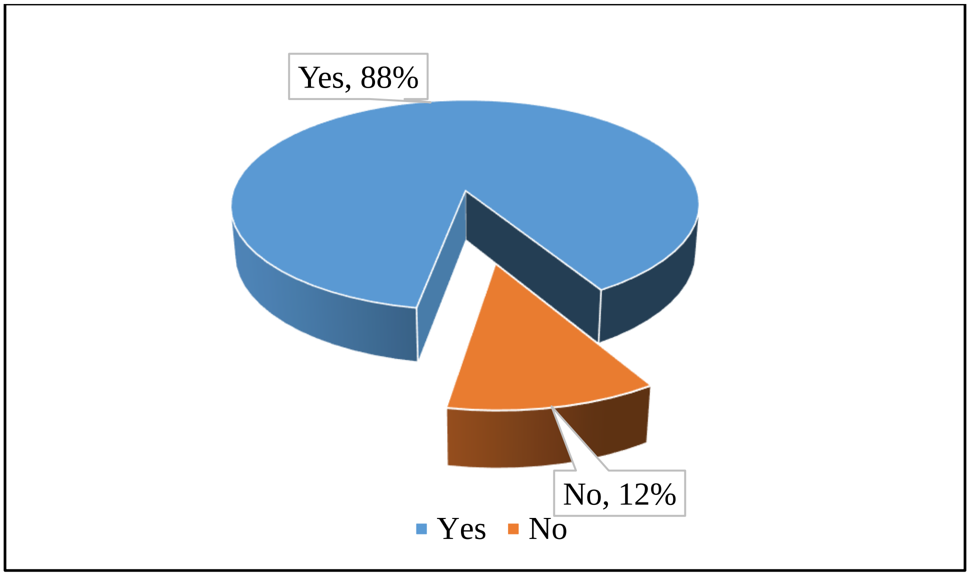

Figure 4.10: Stakeholder response to stewardship program in the basin.

4.4.2 Water shortage observation

Stakeholders acknowledged that there were water shortages observed within the river basin and attributed the causes to human activities, natural variability, and climate change. A minority of the respondents believed that the changes were due to climate change but rather believed that the human activities had brought about the changes (Figure 4-11).

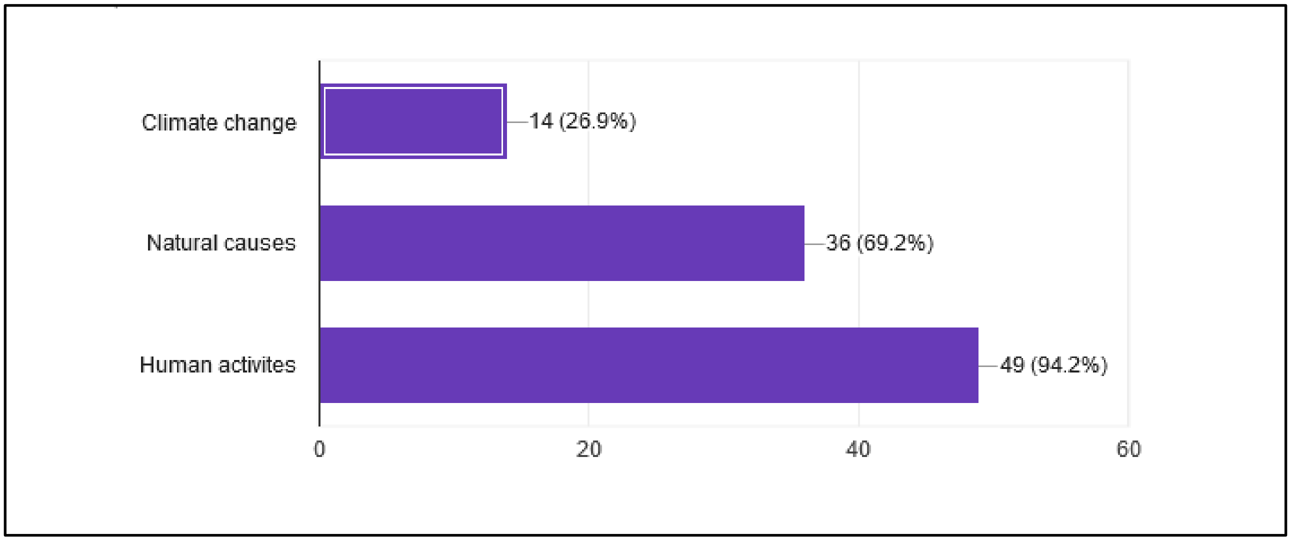

Figure 4.11: Responses to probable causes of water shortages.

4.4.3 Watershed protection activities

Currently, there are several catchment protection activities that involved the stakeholders in the study area, including tree planting, riparian land protection, soil erosion control, wetland restoration, reforestation, and capacity building. All stakeholders are involved in tree planting except one International Organisation, with the capacity building being done by 65% of the stakeholders interviewed. 46% of the stakeholders have been involved in reforestation, 21 % involved in wetland restoration with less than 20 % of the stakeholders being involved in riparian land protection and soil erosion control (Figure 4-12).

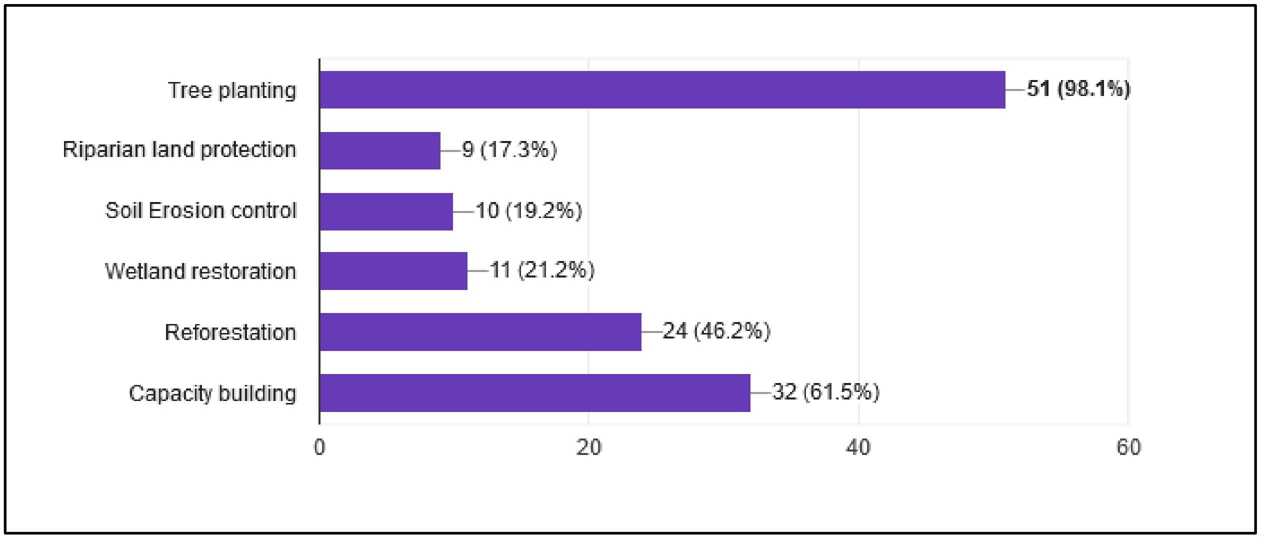

Figure 4.12: Responses on watershed protection activities.

4.4.4 Stewardship activities likely to be involved

Majority of the stakeholders were willing to participate in the conservation activities (71%) within the basin, capacity building (61.5%) during stewardship activities, catchment management activities (46.2%) while 36.5%% are willing to be involved in restoration activity with only 26.9 % ready to be involved in protection activities (Figure 4.13).

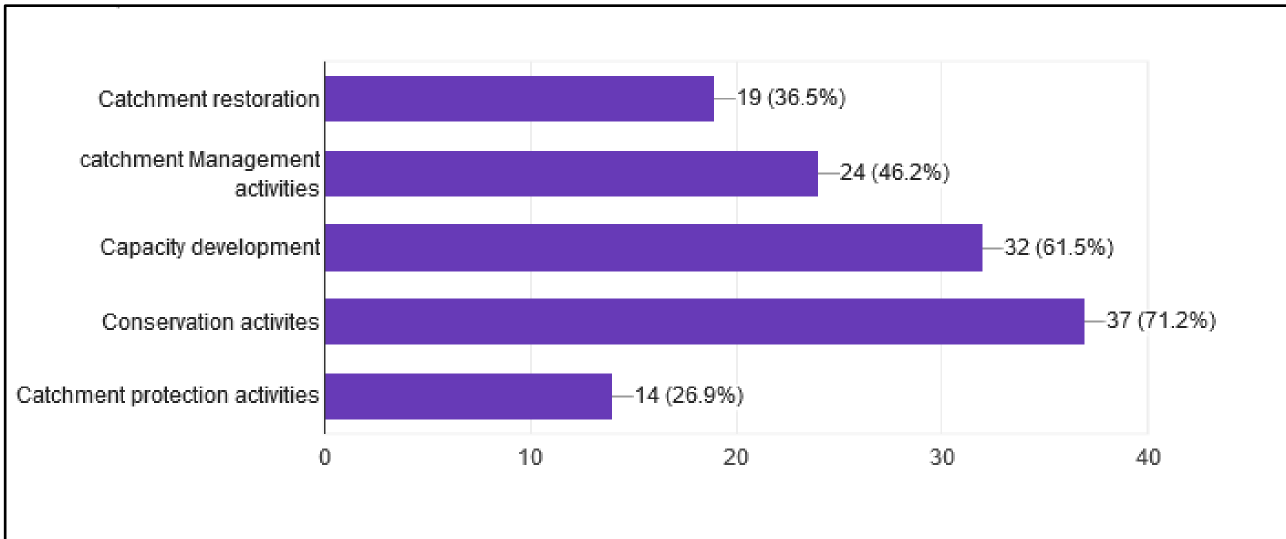

Figure 4.13: Activities of stakeholder involvement.

4.4.5 Stewardship activity for catchment restoration

The results showed that (88.2%) of the stakeholders would be involved in reforestation activities in deforested areas. A significant number of the stakeholders would love to be involved in activities aiming at improving agricultural production and capacity building. Few stakeholders would be involved in wetland restoration, solid waste management, and catchment rehabilitation through soil erosion control among other activities (Figure 4.14).

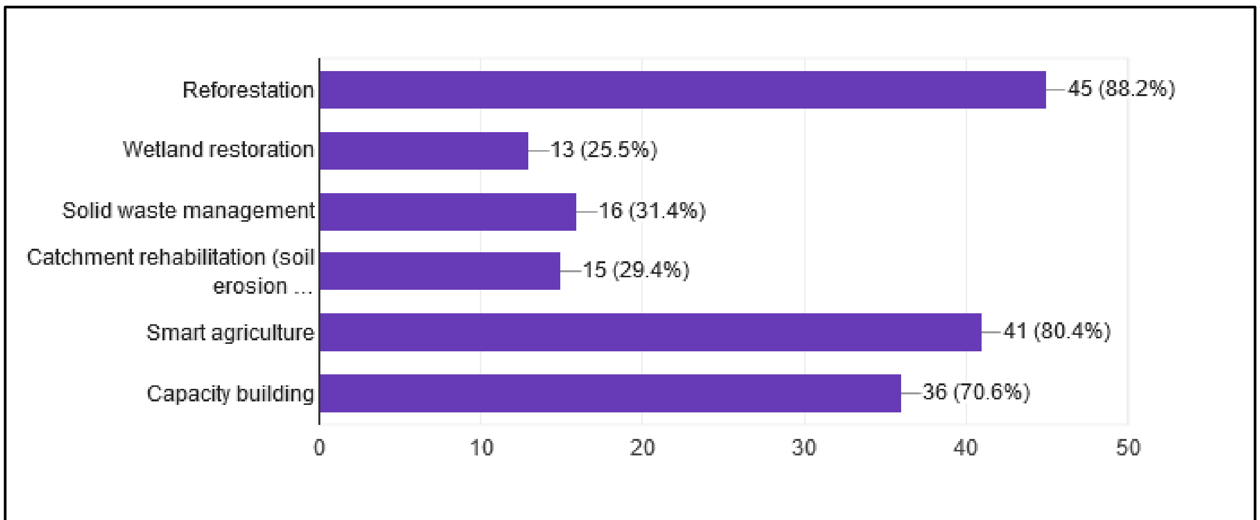

Figure 4.14: Stewardship activity for catchment restoration.

4.4.6 Stewardship activities for water risk prevention

Stakeholders were interested in working together to reduce future water risks by carrying out activities such as water resources training, participation in workshops and strengthening the monitoring and evaluation to assess the progress and effectiveness of the stewardship program. Riverbank protection, soil erosion prevention, RGS rehabilitation and water quality/quantity monitoring are among activities that people are interested (Figure 4.15).

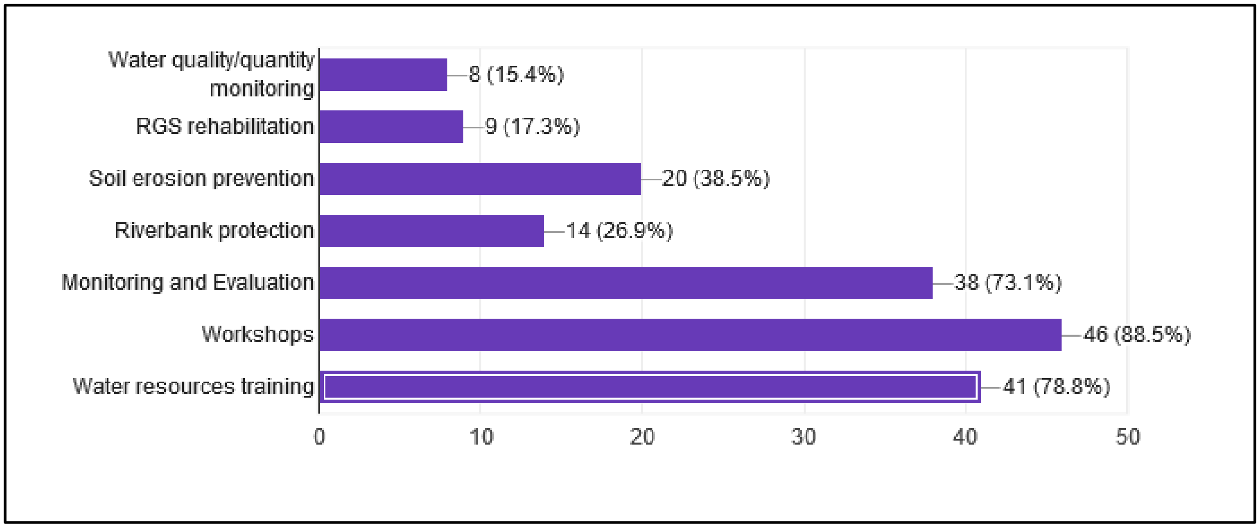

Figure 4.15: Stewardship activities for water risk prevention.

4.4.7 Monetary allocation

Respondents were asked about their willingness to allocate funds for the stewardship program and 83% were willing to allocate funds for the stewardship activities (Figure 4.16).

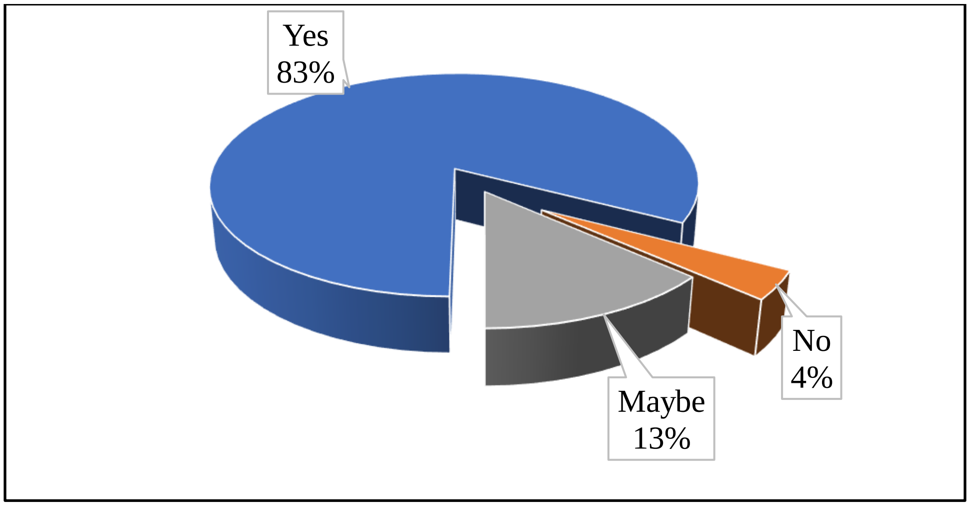

Figure 4.16: Allocation of funds chart to stewardship.

4.4.8 The expectation from the partnership

Although all stakeholders were willing to work with others for the water stewardship and were willing to commit funds towards the partnership, they had expectations that they were looking forward to from the partnership and concerns that they felt might hinder the success of the partnership. Stakeholders highest expectation from the partnership and other partners was for the program to achieve the set-out objectives (82.4%) while ensuring inclusivity in decision making (64.7%) among partners. Commitment and transparency during the partnership were also emphasized by the partners with the need to engage other government officials with the least of their concerns being regular meetings and regular feedback (Figure 4.17).

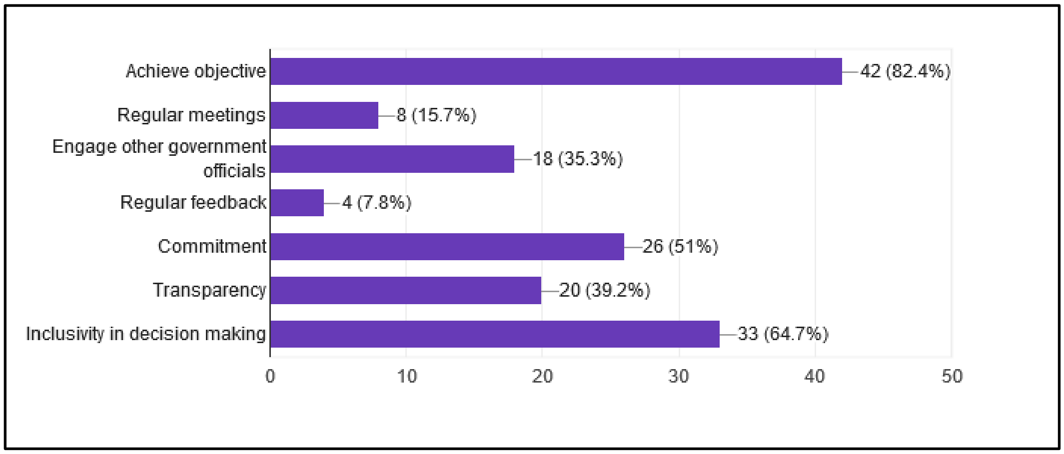

Figure 4.17: Expectation from the partnership.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

This study was carried out in River Nzoia Basin to assess the potential of water stewardship partnership using the Water Risk and Action Framework guide developed by IWaSP to provide guidance on stewardship. The study was guided by three objectives which were water risks assessment in the basin, stakeholder mapping and assessment of the stewardship potential. The study methodology involved the use of remote sensing data for the water risk assessment and application of ArcGIS computer program to derive and quantify the water risks, mapping of potential stakeholders using stakeholder template developed by IWaSP and the primary data on stakeholders collected using questionnaires to assess their willingness to form a water stewardship partnership.

From the analysis, it was clear that the basin faces water risks with different magnitudes and have been increasing since 2000. There was a spatial and temporal variation of risk in the river basin with the highest risks being experienced in January, February, and March in the middle and lower catchment. There were constantly high risks towards the outlet of the river throughout the year attributed to low rainfall, low primary productivity, and high evapotranspiration rates. The catchment faces increased deforestation, land degradation and land cover changes in the upper catchment while the middle part of the basin experiences low primary productivity likely caused by land degradation, deforestation as well as clearing of land for agriculture and settlement.

Within Nzoia River basin, there is a significant number of stakeholders from local, international, government, and private sector who have the potential to spearhead a water stewardship partnership and the majority are vital to the success of the stewardship. All water stakeholders are significant in the success of a stewardship program, but key stakeholder will advance the partnership. However, there is a need for capacity building of non-core stakeholders in order to bridge the knowledge gap and level the understanding of the importance of each stakeholder, their roles, and the importance of a water stewardship partnership.

Although there has been an observed water shortage that is attributed to both human activities, climate change, and the natural climatic variations, there lacks a platform that brings all stakeholders together with a goal of carrying out collective activities that reduce the water risks, therefore, there is a need for a systematic approach towards future water risk reduction. Although there are activities that are carried out for catchment protection and restoration, there is need to harmonize activities since the majority of the stakeholders are willing to partner in reducing water risks and are positive in the implementation of programmes for water risk reduction. With a water stewardship partnership being positively accepted, an objective oriented programme is highly likely to be successful and the partnership should be built on transparency, commitment, and inclusivity. There is a potential for a water stewardship partnership in the river basin with the stakeholders willing to partner to reduce the future water risks.

Last but not least, the study show that the River Nzoia Basin faces increased droughts over the years, deforestation, highly variable weather, catchment and land degradation are the major challenges facing the basin. These major concerns need urgent attention to minimize the future risks.

5.2 Recommendations

Having assessed all the critical issues highlighted in this study, the following recommendations are suggested to offer possible solutions;

I. Catchment protection, restoration measure should be put in place by integration the different sector and partners such as agricultural, industrial, environment, urban planning whose activities cumulatively has an effect of the quality or quantity of water.

II. There is a need for reforestation of the catchment, climate change mitigation and combat land degradation to minimize the future water risks.

III. Formation of an inclusive, objective oriented partnership involving all stakeholders in the water sector with intervention activities be implemented at WRUA levels focusing on the sub-catchment level.

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APPENDICES

Appendix A

Questionnaire

I am Kasiti Felix, a student at the Pan African University Institute of Water and Energy Science (including climate change)- PAUWES based in Algeria. I am conducting a study on the Nzoia River Basin titled **'Assessing the potential for water stewardship partnership using Water Risk and Action Framework: A case study from Nzoia Basin, Kenya**. One of the objectives of the study is to determine the potential of water stakeholders, water users, management authorities and other development partners coming together and carrying out activities that will lead to reduced water risk. An assessment of the water risk in the catchment has identified risk factors such as land degradation, deforestation, increased seasonal, annual and interdecadal rainfall variability. These risk factors point towards a water insecure future and thus need collective and coordinated actions. This questionnaire targets to collect views on the activities that you/your organization/your company would be willing to participate in reducing future water risks.

Section One

1. Name/Organization:

   ……………………………………

2. Sub-county:

   ……………………………………

3. County

   ……………………………………..

4. Type of Industry:

   …………………………………….

5. Stakeholder Category

   A. Water User
   B. Non-Governmental
   C. Private Sector
   D. Academia
   E. Local business

F. Local community
G. Parastatal
H. International Organization
I. Other

Section 2: Partnership

1. Is there a water stewardship platform you are involved in?
   A. Yes
   B. No
2. Have you observed any water shortage in the watershed?
   A. Yes
   B. No
3. What is the likely cause of the water shortage?
   A. Climate Change
   B. Human Causes
   C. Human Activities
4. Would you cooperate with other stakeholders in activities aimed at reducing water risks?
   A. Yes
   B. No
   C. Maybe
5. Watershed protection activities you are currently involved in.
   A. Tree planting
   B. Riparian land protection
   C. Soil Erosion control
   D. Wetland restoration
   E. Reforestation
   F. Capacity building
6. Activities likely to be involved in (Water stewardship activities).
   A. Catchment restoration
   B. catchment Management activities
   C. Capacity development
   D. Conservation activities
   E. Catchment protection activities.
7. Activities that you would be involved in water catchment restoration
   A. Reforestation

B. Wetland restoration
C. Solid waste management
D. Catchment rehabilitation (soil erosion control, riparian land protection)
E. Smart agriculture
F. Capacity building

8. Activities you would be involved in water risk prevention
    A. Water quality/quantity monitoring
    B. RGS rehabilitation
    C. Soil erosion prevention
    D. Riverbank protection
    E. Monitoring and Evaluation
    F. Workshops
    G. Water resources training
9. Would you/ organization/ company allocate funds to these activities?
    A. Yes
    B. No
    C. Maybe
10. What do you expect from the partnership/other partners?
    A. Achieve objective
    B. Regular meetings
    C. Engage other government officials
    D. Regular feedback
    E. Commitment
    F. Transparency
    G. Inclusivity in decision making
11. What kind of concerns do you have towards the partnership/other partners?
    A. Failure to achieve objectives
    B. Potential reputation risk
    C. Government officials to do their share
    D. Failure to respect timelines
    E. Lack of inclusivity in decision making

Thank You for your time!

Appendix B

Stakeholder Analysis Template

	Stakeholder analysis			
	Stakeholder name/group	**Type**	**Description of the stakeholder group**	**Priority**
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				

Analysis Guide

1. Stakeholder Category/Type.
   a) Government authorities
   b) Local business
   c) International Organization
   d) Local NGO
   e) Private Sector
   f) Company
   g) Academia
   h) Local community
   i) Water User
   j) Parastatal
   k) Other
2. Description of the stakeholder group
   a) Core partner
   b) Non-core partner
   c) Target group
3. Stakeholder priority (Assigned values based on the type of stakeholder)

a) Key stakeholder - an actor can impact the partnership extensively
b) Primary stakeholder - an actor can advance or slow down the partnership
c) Secondary stakeholder - actor needs to understand the basics of the partnership
d) Stakeholder´s role is not identified

Appendix B

EXPENDITURE

	Items	Description	Cost
1.	Transportation Costs	**Return Flight ticket** from Algiers to Nairobi and Back • This includes costs of transport to and from the airport	90,244
		Flight ticket to Tanzania and from Seychelles to Nairobi • This includes transport to the airport and accommodation in Dar Es Salaam and Seychelles	74,480
2.	Data Collection and analysis	Acquisition of **data and software** • Acquisition of GIS program • Acquisition of data	20,500
		Transport services for data collection • Car hire for data collection	34,500
		Data collection • Enumerator training and data collection fee • Printing of data collection materials • Acquisition of notebook, pen drive	20,383
3.	Internet and Airtime purchase	Access to **Internet service** for the entire research period • Access to **airtime** during the research period	20,000
4.	Insurance	**Insurance cover** during the internship period	20,000
5.	Preparation of final document	Printing of thesis copies	8,400
6.	Training	Design Outreach training	10,000
		Total	**298,507**

Rate: Selling 1 USD = 93.2 Ksh. Research grant Amount 3000 USD =**279,600** Ksh.