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(including CLIMATE CHANGE)

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Presented by

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I, Francess Gbolare Awunor, hereby declare that this thesis represents my work, carried out 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 following the academic rules and ethics.

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DEDICATION

I dedicate this research work to my parents, Mr. S. O. Awunor and Mrs. B. O. Awunor, whose commitment to my success, priceless sacrifices and unwavering encouragement keeps me going towards my goals.

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I sincerely wish to use this medium to express my sincere appreciation to the African Union Commission (AUC) for the proposed sponsorship of this research and the knowledge impacted through its Pan African University Institute for Water and Energy sciences (including Climate Change).

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ABBREVIATIONS AND ACRONYMS

AMCOST	African Ministerial Council on Science and Technology
AOSTI	African Observatory of Science, technology, and Innovation
ASRIC	African Scientific, Research and Innovation Council
AUC	African Union Commission
AUC	African Union Commission
M&E	Monitoring and Evaluation
NEPAD	New Partnership for Africa's Development
PAU	Pan African University
PAUWES	Pan African University of Water and Energy Sciences Inc. Climate Change
R&D	Research and Development
STI	Science, Technology, and Innovation
STISA	Science, Technology and Innovation Strategy for Africa

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ABSTRACT

For the realisation of the Science Technology and Innovation goals across water sector in Africa, the need for frequent assessment of existing scientific research in water programmes under the auspices of the African Union remains paramount. Notwithstanding the voluminous policy efforts and strategies, or the commitment to research under the Pan African University [PAU] Programme, a failure to establish existing link between the Science Technology and Innovation Strategy for Africa 2024 (STISA-24) with the Research in Water Sector for Africa, will keep widening the gap to research and policy connected implementation results. In assessing existing research in water sector for Africa towards the implementation of the STISA-24 policy, this paper seeks to establish well actionable links between the STISA Policy and PAU water research works; Assess the available water research thesis work in Pan African University Institute for Water and Energy Sciences, including Climate Change [PAUWES] between the First and Fourth cohorts [years 2016-2019], and design a working theory of change model for research in water sector towards technology and innovation in Africa's water sector. By critically conducting detailed analysis of existing STISA policy documents and PAUWES Research agenda and policy documents, an analysis of 93 master's thesis in water sector for Africa, this paper will be presenting the statistical trends and analysis of the available research in water sector across Africa towards the realisation of the Science Technology and Innovation Strategy for Africa 2024.

The Science Technology and Innovation Strategy for Africa (STISA-24) presents the African Union's ten years strategy established to make innovation a key driver to accelerate Africa's transition from a resource-based economy to a knowledge-based economy (STISA, 2014) (AOSTI, 2014). This paper provides analyses to drive results for water sector innovation across Africa through knowledge-based research under the R&D scholarship programme of the African Union. It prepares a working Theory of Change which has as its overall impact target to be the realisation of Evidence-based technology and innovation in Africa's Water sectors across Africa". It concludes by giving suggestions that can be applied at institutional levels.

KEYWORDS: STISA-24 Policy; Science Technology and Innovation Strategy for Africa (STISA); Pan African University (PAU); PAUWES; Research & Development; Research in Water Sector; Africa

CHAPTER ONE

1.0 INTRODUCTION

1.1 BACKGROUND

The Science, Technology, and Innovation Strategy for Africa 2024 (STISA) (AOSTI, 2014) is an African Union ten years program which has been established to make innovation a key driver to accelerate Africa's transition from a resource-based economy to a knowledge-based economy (STISA, 2024) (AOSTI, 2014). Its successful implementation would help to address the challenges that hinder development in critical sectors such as agriculture, energy, environment, health, infrastructure, mining, security, and water. The strategy, as part of the long-term people-centred AU Agenda 2063, is anchored in six distinct priority areas that contribute towards the African Union vision and includes four strategic action areas to be undertaken.

Several institutions in both decision making and program implementation are involved as key stakeholders for a better achievement of STISA. The Pan African University as an implementation stakeholder is set to "exemplify excellence, enhance the attractiveness and global competitiveness of African higher education and research and establish the African University at the core of Africa's development." Each year, students from several African Countries conduct and produce research on relevant development problems of Africa to contribute to the achievement of the continental goals. Universities around the World are increasingly required to demonstrate and measure the impact of their research beyond academia.

1.2. STATEMENT OF PROBLEM

For the achievement of policy objectives of innovation in the water sector, demand for evaluation of research programmes is increasing and this now ranges from evaluating the quality of research (via peer review) to assessing the outcome, output and impact of public R&D. Most importantly, to assess the contribution of these research efforts towards the realisation of policy strategies and goals. Evaluation of publicly funded research has become a central concern of policy makers for two main reasons. First, there is growing demand for evidence-based policies and for evaluation of the results of public investments. More precisely, governments increasingly seek to determine how much they should invest in science and technology (S&T), research and development (R&D), and innovation. They wish to know

where to invest and what society gets in return. Ideally, evaluation should help determine the economic effects of both public investment in R&D and innovation and the social impacts. Policy makers also increasingly want public investment to help meet global challenges, such as energy, security and climate change. (OECD, 2009). Second, the demand for evaluation has expanded because OECD countries have substantially increased public investment in R&D despite budget constraints. Governments not only finance R&D in economic sectors of its states, but for the achievement of its development goals, which in this case is that of innovation in Science Technology and Innovation, as it relates to the water sector.

A key gap problem which this research seeks to bridge is the wide gap in the evaluation of the PAU research in the water sector for the implementation of STISA 2024 for the AU countries. For the realisation of the Agenda 2063 goals, the AU has developed and funded the Pan African University research scholarship projects towards the achievement of the research goals for Science Technology and Innovation. The assessment and subsequent evaluation of the relevance of research in water sector emanating from this African R&D program, will help to access the evolution of STI research for the achievements of the STISA 2024 strategy.

1.3 SIGNIFICANCE OF THE STUDY

Providing an assessment of the current impact of the continent's research & development water sector program is essential, as it could help equip program managers and policy makers at the forefront of Africa's Science, Technology and Innovation (STI) policies, with necessary information needed to improve their programs and to communicate effectively to others the full range of benefits from R&D efforts.

This research can be ultimately used by the African Union Commission (AUC) as a base information for a peer review (Expert panel and focus group discussions) of the PAU research in water sector towards the implementation of the STISA 2024 for Africa.

1.4 OBJECTIVE OF THE STUDY

General Objective:

To assess the impact of R&D program in the water sector for effective implementation of STISA-2024.

Specific objectives:

- To explore the content of STISA 2024 and PAU program in relation to Africa's water sector development and innovations.
- To establish the link between the Pan African University's research and the STISA program with regards to water sector;
- To examine the contribution of the research in the water sector on the achievement of STISA's objectives

1.5 RESEARCH QUESTIONS:

- How is the PAU research in water sector program linked to the STISA-24 policy of the African Union?
- How has the existing PAU research in water sector positioned its priorities for water development in Africa?
- What is the contribution of research in water sector under the PAU R&D program to the implementation and realization of the STISA-24 goals and objectives?

1.6 ORGANISATION OF STUDY

This research contains five sections: chapters one, two, three, four and five. The first chapter gives an introduction to the study, providing the background, problem statement, aim and objectives, research questions to be answered in this research, and the significance of the study. Chapter two reviews existing literature and gives an exposition on the theories underpinning this research study as well as the methodologies adopted in this research study. Chapter three looks at the method used for carrying out the data analysis. Chapter four looks at the results and discussions as well as the major findings then, chapter five presents the research conclusion and recommendations.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 AFRICAN UNION'S POLICY PROJECTIONS FOR SCIENCE, TECHNOLOGY AND INNOVATION IN AFRICA (BACKGROUND APPRAISAL OF THE STISA-2024 POLICY)

The Assembly of the AU Head of States and Government adopted in its Twenty-Third Ordinary Session the Science, Technology and Innovation Strategy for Africa -2024 (STISA-2024) as continental framework for accelerating Africa's transition to an innovation-led, knowledge-based economy within the overall framework of the AU Agenda 2063, Malabo Equatorial Guinea, June 2014 (Assembly/AU/ /Dec.520(XXIII)). The AU Science, Technology and Innovation Strategy for Africa 2024 (STISA-2024)1 is the 1st decade incremental strategy that is designed to address Africa's challenges within the context of the AU Agenda 2063 with the ultimate goal of contributing significantly to the AU vision "An integrated, prosperous and peaceful Africa driven and managed by its own citizens and representing a dynamic force in the international arena". (AOSTI, 2014)

The Science, Technology and Innovation Strategy for Africa (STISA-2024) is part of the formulation of the Agenda 2063 of the African Union. Running under the mission "Accelerate Africa's transition to an innovation led knowledge-based economy", STISA-2024 places emphasis on the impact of science, technology and innovation in driving Africa's economic sustenance and competitiveness across all the domains, including agriculture, health, energy, security, environment, etc., to produce African Science, Technology and Innovations output. (STISA, 2014)

It may be recalled that the AU Science, Technology and Innovation Strategy for Africa (STISA-2024) was endorsed as a continental framework for accelerating Africa's transition to an innovation-led and knowledge-based economy by the AU Head of States and Governments in Malabo, Equatorial Guinea in June 2014 (Assembly/AU/ /Dec.520 (XXIII)). (AOSTI, 2014) The STISA-2024 was designed based on recognizing the cross-cutting nature of Science, Technology and Innovation (STI) to all other AU priority development policies and agendas including the AU Agenda 2063. Compared to the preceding policy, Africa's Science and Technology Consolidated Plan of Action, STISA-24 has science, technology and innovation at the forefront of Africa's socio- economic development and growth, where it was designed to

meet the knowledge, technology and innovation demands of the various AU's economic and social sectoral development frameworks and policies. (AUC, 2015)

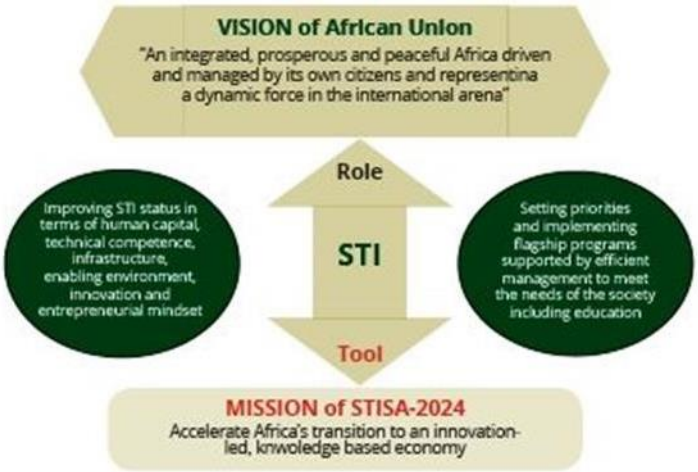

Figure 1The role of STI in achieving the vision of African Union (STISA, 2014)

Towards the end of 2014, the STRC engaged in the development of a policy analysis for the STISA-2024 to ensure its smooth implementation. The analysis was developed within the considerations of STIs for economic development in Africa. Against this backdrop, the STISA-2024 was subjected to critical analysis considering present, past and future based on the needs and gaps that yielded all the pre-requisite and required systems and mechanisms including policies and institutions needed were identified. The analysis was made to ensure that Member States and RECs are informed on the systems needed for the domestication and implementation of the strategy. The output of this policy analysis was presented in parts. Part 1, Identifying Policies and Institutions for the STISA-2024 Implementation, where the pillars of STISA were analysed using the Finite Element Analysis and the Problem Tree Methodology to identify the policy gaps and institutional arrangements that may or may not exist in the majority of our Member States and/or Regional Economic Communities. Part 2, Defines the policies and institutions for the STISA-2024 implementation, clarifies on the possible predefined 13 policies and 7 institutions needed for the STISA-2024 implementation, and also provides a guideline and common understanding and approach to AUC and its Specialized Institutions, Member States, RECs and Partners. The policy analysis report was developed with the ultimate goal to garner support and buy-in of all relevant stakeholders. The policies and institutions, which are identified within the report, as well as a design to link with the aims, objectives, and the expected results of the STISA-2024. (AUSTRC, 2016)

2.2 SCIENCE, TECHNOLOGY AND INNOVATION IN WATER SECTOR (FOR SECTOR DEVELOPMENT AND MANAGEMENT)

Our freshwater resources are limited and face mounting pressures from drought, flooding, pollution, increase, and competition from many uses (e.g., ecosystem protection, beverage, agriculture, energy production, recreation). Technology innovation can help address our water challenges and put us on a more sustainable path while supporting economic process. Intergovernmental and governmental organisations ought to be catalysts that promote and support technology innovation to protect and ensure the sustainability of our water resources. These cuts across various ideas and plans for advancing technology innovation across various water programs and may extend to addressing the business concerns for water technology innovation and market opportunities in order to see technology innovations solve water challenges. (EPA, 2014). The United States of America's Environmental Protection Agency's (EPA) report on blueprints for water innovation and technology, for instance, provides examples of emerging innovation pioneers, identifies tools for assessing water risk, and frames a more robust set of actions that EPA will fancy promote technology innovation for clean and safe water. (EPA, 2014)

Technology innovation in water resources defined as:

"The development and deployment of latest technologies and processes; new applications of existing technology; production changes; and organizational, management and cultural changes which will improve the condition and sustainability of our water resources". (EPA, 2014)

By way of deduction, this definition includes: (1) new technologies; (2) new management approaches (e.g., regional coordination); or (3) techniques that increase the efficiency of existing systems (e.g., sensors and controls). (EPA, 2014)

Global water resources challenges in dire need of water technology innovations, includes amongst others, the following:

Water Scarcity: Aquifers are being depleted at a much higher rate than natural precipitation and ground water recharge is refilling them. Several predictions show that half of the world's population will live with chronic water shortages by the year 2050. (EPA, 2014)

Water Quality: Many of the world's coastal waters, estuaries, rivers, streams and lakes remain impaired as a result of pollution and/or physical alterations. Increases in population and land development present additional challenges such as increased storm-water runoff from impervious surfaces. Declining source water quality poses challenges for conventional water treatment plants in meeting beverage standards.

Aging Infrastructure: Africa's water and wastewater infrastructure are aging and mostly dilapidated. Ranking from drinking water transport infrastructures, to waste water and stormwater removal channels. (EPA, 2014) There is a need for innovative ideas for replacement of sustainable water channelling systems for African countries.

Climate Change Impacts: Climate change is exacerbating the challenge of protecting water resources, ecosystems and our water infrastructure. Warmer air, warmer water and changes in precipitation patterns increase water pollution problems. More extreme weather events (e.g., flooding) can have devastating impacts on water and wastewater infrastructure and aquatic systems. Rising sea levels will alter ocean and estuarine shorelines, and the increased frequency, severity and duration of drought will affect public water supply, agriculture, industry and energy production uses. Warmer water and changing flows alter aquatic biology. Many, or all, of these things combine to change the availability of drinking water. (EPA,2014)

2.3 AFRICA UNION RESEARCH AND DEVELOPMENT PROGRAM IN WATER SECTOR (PAU SCHOLARSHIP, PAUWES INSTITUTE FOR WATER)

One of the objectives of this research is to establish a link between the Pan African University research programmes in water resources, which in this case relates specifically to PAUWES, with the STISA 2024 strategy program for Africa. Both of these policy programs fall under the auspices of the African union and the primary literature existing for them include documentary archives of policies, conference discussions and organisational papers/publications. This research shall be exploring the available documents which includes PAUWES Recommendations for a Research Agenda at PAUWES: Scientific Contribution to Agenda 2063. (PAUWES, 2017) The document, PAUWES Recommendations for a Research Agenda at PAUWES: Scientific Contribution to Agenda 2063 of the AU (Oct. 18, 2017) Pre-Final Draft, was developed to strategically highlight the research Agenda in the context of the African Union strategies. In this document, it was highlighted that The African Union (AU) deems that

research and innovation are key tools for leveraging its human capital in order to further benefit from the region's resources. (PAUWES, 2017) Additionally, in relation to the research in water sector, it was presented that PAUWES has an opportunity to inform and support regional agencies such as the Intergovernmental Agency for Water and Sanitation for Africa (WSA) in achieving their goals for research and training whilst advising the Member States to promote appropriate technologies, participatory, operational and financial strategies in water access, hygiene and sanitation. Country specific vision documents identify water as an extremely vital component of development in developing countries (Bernhard / ZEF, 2018).

2.4 EVALUATION OF R&D PROGRAMS (EXISTING METHODS)

To understand the historical roots of research evaluation one should consider the state of the art as reported in one among the earliest reviews of the evaluation of publicly funded research. The intentions of the historical authors were to "identify useful approaches for evaluating R&D programs conducted and sponsored by the federal government". (Salasin, et. al,. 1980) In pursuit of that objective they interviewed quite 200 evaluation experts, most of them based in industry. It has been reported by the OECD (2009) that methods of measuring impacts of research and development are neither straightforward nor easy, as many dimensions through which STI affects society aren't easily captured by existing statistical frameworks as they're difficult to live or evaluate. (OECD, 2009) This makes it difficult to link social impacts to policy interventions in sort of R&D programmes. Nonetheless, this methodological challenge shouldn't cause cessation in efforts to live the impact of R&D programmes.

A large number of methodologies for Research and Development (R&D) project evaluation are developed and reported within the literature over the previous couple of decades. In a research titled 'A Comparative Analysis of R&D Project Evaluation Methods', it is postulated that nearly all of those previous literatures focused on the mechanisms and underlying theoretical foundation on which the evaluation methods are based. (Poh, et. al, 2001) Little or no attention has been paid to the effectiveness and suitability of the techniques, especially a comparison of the techniques. This literature made an observation that earlier literatures presenting an assessment of R&D evaluation mechanism were focused on 'describing the mechanisms of the techniques and analysing their strengths and weaknesses based within the nature of R&D projects.' within the report of the writers, what deserved more focus in previous

literatures was the examination of the degree to which the techniques meet the wants of the evaluation process. This research literature goes ahead to also suggest a 'classification scheme' for the available R&D methods. The classifications were anesthetizing two broad categories which were termed (a) Weighting and Ranking method, and (b) Benefit-Contribution methods. Under the Weighting and ranking category were evaluation methods like comparative methods, scoring method and therefore the Analytical Hierarchy process. On the other hand, the methods falling under the Benefit-contribution category were, analysis, Economic analysis and Decision tree analysis. (Poh, et. al, 2001)

(A) Weighting and Ranking Methods:

(i) Comparative Method:

This kind of method involves comparing two projects or a group of other projects. It utilises mathematical models for clearly computing the whole merit of the projects, the strength of this method lies in its simple use and comprehension, however the downside thereto is that its reliance on subjective judgments which has severe drawbacks. as an example, there lies the large possibility of fairly unstable evaluations which changes overtime, also because the different and indirectly comparable results of varied evaluations from different people. Additionally, where there are changes effected within the projects, this might have effect on the general ranking and preferences of the choice projects. Finally, there are some circumstances where the comparative methods fail to think about the available multiple objectives.

(ii) Scoring Method:

This method adopts a way of scoring the projects individually on designed scales to reflect how the project is meeting its goals and objectives. It provides results and scores per project. Upon scoring, the projects are ranked supported their scores. This model factors during a lot of things and data adaptable to every project considered. The scoring model is reported to be an efficient analytical tool when data requirements and complexity of more sophisticated approaches aren't justified. The downside to the scoring method is that the tactic isn't as 'well-defined' and difficult to justify its use. This downside however doesn't mean the tactic is faulty in theory, rather it's thanks to its implementation.

(iii) Analytical Hierarchy Process:

The Analytical Hierarchy process was developed by Saaty in 1980.This is often a simple method which involves comparing a group of other projects to assist with complex deciding. It adopts the model of structuring complex problems into a hierarchy. The hierarchy has at its very top, the general goal of the project, then its sub-criteria and subsequently the alternatives at rock bottom level. (Poh, et. al, 2001)

(B) Benefit-contribution Methods:

This category sets to examine projects to reflect how well they are able to satisfy the organisations R&D objectives.

(i) Cost-Benefit Analysis:

This method is being used for project evaluation and capital budgeting. Here, the consequences of each project are analysed in cost and benefit measures. This analysis identifies and allows the critical considerations to factor into each evaluation by considering the cost and benefit of each project. The constraint to this particular method is that it, for one, it does not allow aggregation of costs and benefits in one single measure. Finally, it requires that the cost and benefits of the different projects be measured in the same unit, meaning all the sets of projects be measured as a lump sum, which does not permit some form of direct comparisons.

(ii) Economic Analysis:

This is based solely on capital budgeting techniques. The most common of the economic criteria being payback period, present value and rate of return on investment. Theoretically, the use of this kind of analysis is justified where the model is utilised under strict conditions which are considered satisfactory and valid. In practice, on the other hand, the reality is that the contributions of R&D projects are hardly easy to measure separately from other activities, making it difficult to get projects with strict conditions most of the time. Another shortcoming of this analysis method is that it only considers a single criterion whereas most R&D decisions are usually multiple and objective in nature.

(iii) Decision Tree Analysis:

This method of analysis is utilised where decision-makers are faced with a sequence of decisions, and between two each two successive decisions, an outcome of the previous decision intervenes (Martino, 1996). This method stems from ‘normative decision theory’. the decision

analysis deals with the structuring of the problem by enumerating all possible intervening and final consequential outcomes and applies the principle of maximum expected utility to determine the best project alternative (Poh, et. al, 2001)

The main advantage of the decision tree analysis is that it is possible to analyse a series of sequential decisions to be made over time, which is a very typical feature of R&D project evaluation. The disadvantage on the other hand is that the decision tree analysis is time consuming and can make for a clumsy and messy work in the event that the problem is a complex one. Also, the decision maker is required to assign probabilities to uncertain variables and preferences to consequential outcomes, which is a shortcoming in itself, considering that psychological results and observations have revealed that human beings are poor estimators of probabilities.

2.5 THEORY OF CHANGE FOR IMPACT

DEFINITIONS:

Theory of Change is described essentially as a comprehensive illustration that links outcomes with activities to establish of how and why a desired impact or change is expected to happen in a specific context (Clark and Anderson, 2004).

The ESPA Guide to working with Theory of Change for Research Projects (Vogel, 2012) defines Theory of change as dialogue-based process intended to describe a series of events that are expected to lead to a particular desired outcome. A working illustration of this is provided in the figure below:

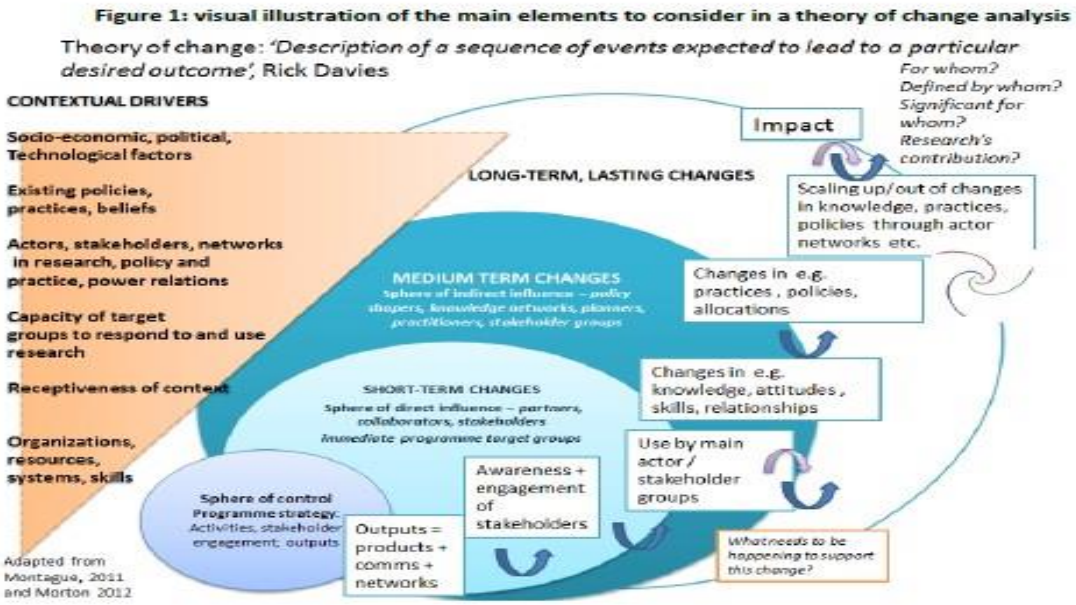

Figure 2Figure 2 Elements of Theory of change [EPSA Guide) [Vogel., 2012]

SCOPE AND EFFICIENCY:

Theory of change starts with a desired goal and then tailored down to specific inputs required to lead up to outcomes that brings about the realisation of results. The ESPA guide offers a tailored approach to developing the theory of change model and gives practical tips and resources for general knowledge on Theory of Change. (Vogel, 2012) This method most effective when it is used throughout the project cycle as it helps to guide stakeholder engagement, communication, co-production strategies and Monitoring & Evaluation progress towards impact within the lifetime of the project - also used to support discussions and decision-making with funders, communities and other stakeholders. (Vogel, 2012) It also helps research/project team respond to changes which is part of adaptive management (Vogel, 2012). Developing a Theory of Change requires discussion between research team and stakeholders of the context, desired long-term change, anticipated sequence of events to result in desired long-term change, assumptions of how these changes might happen, which includes key questions that should be considered when analysing.

The theory of change approach can be used for different purposes, by different users, and at different moments in the cycle of developing, monitoring, reviewing or evaluating a program or strategy. (vanEs., et. al, 2015) This literature provides comprehensive guidelines which

include concepts and definition (including utility), stepwise Theory of Change development, and additional resources. This is an excellent comprehensive overview of the tool, includes concepts of spheres from outcome mapping.

The eight key features of the proposed stepwise Theory of Change process are, in turn, represented in a virtuous circle, include the following: (vanEs et. al., 2015)

1) Clearly Specify the purpose of the Theory of Change process
2) Describe the desired change
3) Analyse the current situation
4) Identification of Domains of Change.
5) Identifying strategic priorities
6) Map pathways of change
7) Defining Monitoring Evaluation and Learning Priorities and Process
8) Use and adaptation of a Theory of Change.

Each step is presented as a dynamic, participatory and interactive process, which builds onto and provides feedback on previous steps.

The theory of change is outcomes based following a causal model which clearly articulates underlying assumptions. Sometimes the term is used generally to refer to any version of this process, including a results chain, which shows a series of boxes from inputs to outputs, outcomes and impacts, or a log frame, which represents the same information in a matrix (Rogers, 2014)

KEY TERMINOLOGIES:

Goal

This is used interchangeably with the term '**Impact',** and it simply refers to the overall purpose and desired impact of the project. It is born out of the problem statement design, which subsequently aids in producing a broad impact statement of what the project seeks to addresses. Goal or Impact is usually broad in nature, hence appears unmeasurable. In the Theory, some impact indicators can be highlighted to somewhat ease the broad generalisations to more specific impact areas. (Rogers, 2014)

Objectives

These are precise, measurable, specific, and tangible landmark steps towards the achievement of the overarching goal or desired impact. They take the form of goals breakdown, to help define what is planned to be achieved.

Outcome

Outcomes are the changes, learnings, benefits or other effects that happen as a result of your project. They are the consequences (intended and unintended) of the project. They ought to be comprehensive enough to reflect the complexity of the project as their aim is to elucidate intimately all of the changes that happen to beneficiaries during the programme. (Rogers, P. 2014). The outcomes are often immediate or short term, intermediate or for the long run. It is likely that you simply will have variety of outcomes along a sequence to urge to your final aim. you'll got to make sure that the sooner outcomes on the chain happen before it's possible that the later ones can do. Outcomes should be specific and measurable, typically using language like ‘greater’, ‘improved’ or ‘increased’. they ought to be phrased as if they need been achieved already.

Output

These are the series of events, products or services that reach the participants or beneficiaries of the project.

Activities

Like the term implies, these are simply the things you do during the project in order to achieve the goal, for instance, the services, trainings carried out, or skills acquisitions gotten through your project. They should be detailed sufficiently in order to guarantee ease of understanding to anyone unfamiliar with the project or programme. (Rogers, 2014)

Assumptions

Assumptions help to elucidate the TOC process and therefore the connections between the measurable effects, wider benefits and therefore the longer-term goal, also as how and why proposed activities are expected to bring these changes about.

The purpose of assumptions is to proactively identify reasons why a number of your causal links might not hold true in practice. Ask yourself, for every activity-outcome pair: What assumptions are made in determining this relationship? Assumptions should specialise in your

most contestable causal links i.e. the sections of your Theory of Change that somebody might challenge as being less plausible or convincing. (Rogers, 2014)

Indicators

The success of any Theory of Change depends on the succinct ability to demonstrate progress on the achievement of outcomes. Therefore, the outcomes during a Theory of Change must be including indicators that allow measurement to work out the extent to which progress has been made. Indicators operationalize the outcomes in the sense that they reduce the outcomes to concrete, observable and/or measurable terms. Ideally, every outcome should have an indicator, but available resources often make that difficult to try to achieve them.

Narrative

This refers to the summary of the TOC, which illustrates the general logic, highlights the assumptions, and presents a convincing case as to how and why the initiative is expected to work. (Rogers, 2014) There are two main purpose of the narrative: (1) is to communicate the major elements of the theory in a quick and easy manner to other; (2) to convey the message of how the elements of the theory works. The narrative is closely linked to the visual elements of the theory seeing that they complement each other.

CHAPTER THREE

3.0 METHODOLOGY

3.1 SITUATING THE STUDY IN THE FIELD

3.1.1 PRESENSATION OF WATER RESOURCES SITUATION IN AFRICA

There are many water problems in Africa which are varied in nature. Several socio-economic factors like overpopulation, poverty, and the unavailability or shortage of hydrological data, are root causes of these problems. Climate change impacts worsen the situation rendering the continent more vulnerable, leaving sustainable water resource development a more tedious goal. Inadequate and unsustainable water supply infrastructure and services both in urban and rural communities poses a huge treat to the health and well-being of the populace. The current problems of water resources vary from diminishing per capita freshwater resources, poor management and inefficient utilization of existing resources. (Oyebande, 2001). Some of the complex and many water problems in Africa include the following:

- Water scarcity: this is particularly due to the increasing population and water stress. Africa is found to actually suffer more from Economic Water Scarcity (Sub-Saharan Africa), rather than physical Water scarcity (Majorly North Africa).
- Climate and runoff variability:
- Low coverage and poor water services and infrastructure development for domestic and industrial water supply,
- pollution of water (rivers, streams and lakes) and Groundwater aquifers, especially receiving water bodies in urban areas resulting in numerous health risks
- Problems of water resources management
- Unsustainable policies and approaches
- Conflicts and unsettled disputes in many shared river basins
- Lack of water resource data and information;
- Capacity deficit arising from inadequate training and education in water technologies and management.

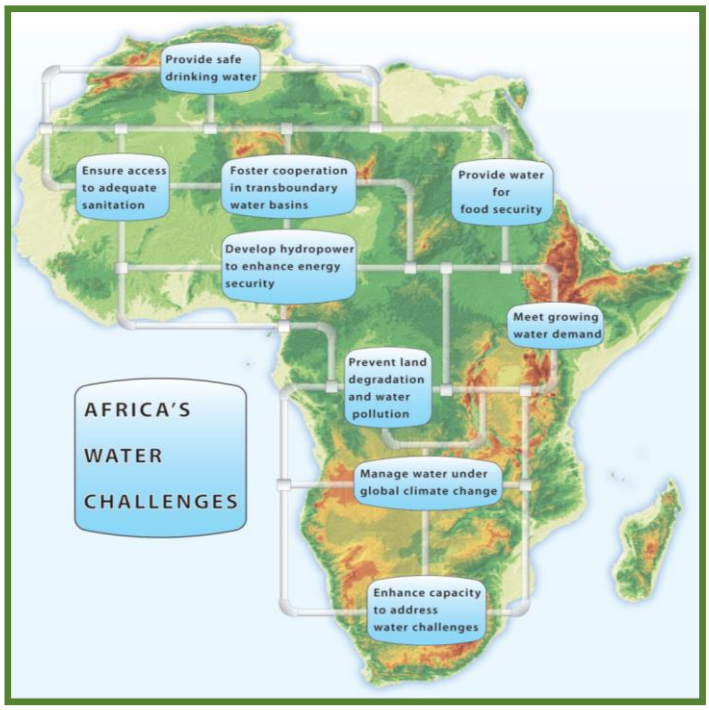

Figure 3 Africa's Water Challenges Atlas (UNEP, 2006)

WATER SITUATION IN AFRICA

1) **Access to Water**:

About 66% of Africa is arid or semi-arid and more than 300 of the 800 million people in sub-Saharan Africa live in a water-scarce environment which means that they have less than 1,000 m3 per capita per year. (UNDESA, 2015). The statistics of progress in access to water differs between Northern Africa and Sub-Saharan Africa even though they are both in the African continent. As at 2013, under the Millennium Development Goals Water targets, North Africa had achieved a 92% coverage and was steadily on track to meet the 94% target it set for its water sector before 2015, despite the physical water scarcity challenge the region faces, due to its climate conditions. Sub-Saharan Africa, on the other hand, which suffers more from Economic Water Scarcity, experienced a more contrasting case with about 40% of the 783 million population as at 2012, lacking access to an improved source of drinking water. (MDGs Report, 2012)

Results from a United Nations analysis of data from 35 countries in sub-Saharan Africa (forming up 84% of the region's population) reveals a striking difference between the poorest and richest fifths of the population in both rural and urban areas. (UNDESA, 2015) In urban areas, it is revealed that over 60% have piped water on premises and over 90% of

the richest quintile in urban areas use improved water sources. While in rural areas, piped-in water is almost a myth as they are found to be non-existent in the poorest 40% of rural households and improved source of water is utilised by just less than half of its rural population. From the analysis, it is evident that Rural water sources are mostly unimproved sources which generally poses major health risks and affects productivity.

The drinking water coverage in urban and rural households from 35 countries (percentage) of sub-Saharan Africa, analysed by wealth quintiles, are presented below:

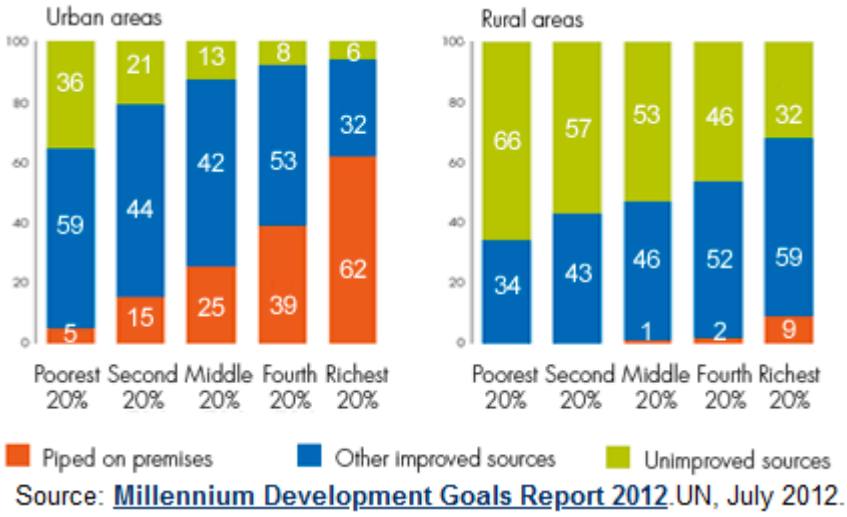

Figure 4 Africa's Urban and Rural Water Coverage (MDG Report, 2012)

In solving of Africa's water problems, Science, Technology and Innovation, hydrological studies, engineering and social sciences play important roles.

2) <u>Access to Sanitation:</u>

With the least improvement statistics in sanitation to achieve the 2015 Millennium Development Goals, Africa is one major regions with higher health risks and challenges resulting from unimproved sanitation facilities across the continent. Sub-Saharan Africa has only 30% sanitation coverage with only a 4% increase from 1990. (UN Water, (GlAAS) 2012) This presents serious concerns of health burden because lack of these basic sanitation facilities, subsequently leads to unhealthy unsanitary factors like Solid was disposal, Open defecation and indiscriminate waste water disposal. Children are the most vulnerable to faecal oral disease transmission which is directly connected to open defecation practices (UN Water, (GlAAS),

2012). An overview of the statistics of sanitation coverage in Africa, also when considering the urban and rural areas sanitation coverage.

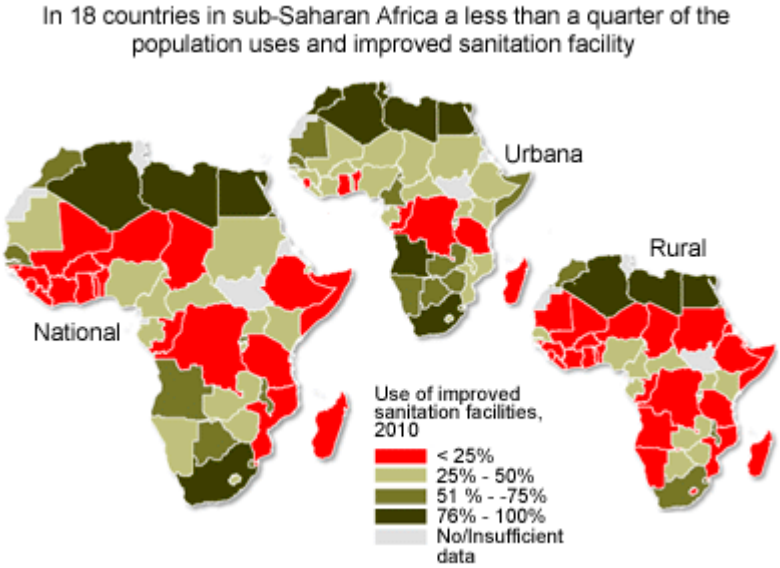

Figure 5 Drinking Water Coverage in Africa (AMCOW et. al. 2012)

SOURCE: A snapshot of Drinking Water and Sanitation in Africa-2012 Update. AMCOW, WHO/UNICEF JMP, 2012

3.1.2 Presentation of the African Union Strategies (AOSTI and PAU) and Its Vision for Water Innovation in Africa

The African Union has launched several policies and programme strategies to undertake activities which will in turn produce outputs and outcomes that aids the realisation of its African Water Vision. (AU Agenda 2025). The AOSTI institution is one of the institutional frameworks of the African Union to house the policy on Science, Technology and Innovation with the STISA 2024 strategy program for Africa, and Pan African University research programmes in water resources, which relates specifically to PAUWES, are both of strategies for water sector development in Africa. They both fall under the auspices of the African union. This research explores the policy documents and ancillary documents available to analyse how they are dedicated to solving water resource challenges in water sector through research.

Research in Sciences, technology and innovation for water development across Africa's water sector is the result of a juxtaposition of the STISA 2024 Policy and PAUWES Water research program. The PAUWES Agenda (PAUWES,2017) gives the priority areas for the analysis of

thesis conducted within the institution. The document, was developed to strategically highlight the research Agenda in the context of the African Union strategies. It highlights that The African Union (AU) deems that research and innovation are key tools for leveraging its human capital in order to further benefit from the region's resources.(PAUWES, 2017) Additionally, it highlights that PAUWES has an opportunity to inform and support regional agencies such as the Intergovernmental Agency for Water and Sanitation for Africa (WSA) in achieving their goals for research and training whilst advising the Member States to promote appropriate technologies, participatory, operational and financial strategies in water access, hygiene and sanitation. These vision and highlighted goals of the PAUWES agenda document shows that the R&D program has clear commitments to seeing to the realisation of the STISA 2024 policy on Science, Technology and Innovation (STI) research for water sector development.

3.2 RESEARCH METHODS

3.2.1 QUALITATIVE DOCUMENTARY ANALYSIS

The Qualitative Documentary Analysis is being adopted to achieve the objective of establishing the link between the PAU Research in Water sector development and the STISA-24 Policy objectives and priority areas. This method establishes the links through connections of deduced policy and programmes focus or priority areas in Policy statements, technical reports, reports, conferences discussion reports, speeches and relevant institutional publications of the two institutions in question.

DATA COLLECTION*:*

To obtain qualitative data sets to carry out this objective, contents of the STISA 24 policy documents are analysed in an exploratory manner to deduce what forms the crux of its innovation and development goals. In this case, the four (4) pillars of the STISA-24 Policy and the Six (6) Priority Areas with clearly spelt out indicators for optimised innovation in each priority areas deduced as data for carrying out this linkage documentary Analysis. (STISA., 2014)

PAU Research in Water sector on the other hand, was exploratively analysed through its PAUWES Research Agenda on Water ZEF Presentation Paper (Bernhard / ZEF**,** 2018), as well as the Institution's Recommendation Research Agenda Document (PAUWES., 2017) and a conference paper presentation by the Director, Abdelatif Zerga and the head of Research

department, Dr. Eric Tambo. (Zerga and Tambo., 2018) A combined document analysis of these papers, produced the data sets tagged as 'PAUWES Water Research Priorities' for the purpose of analysis. These research priorities are five (5) Main Water sector Research and Development Priorities of the institution, which is used to determine its relevance to the STISA 24 policy program. Each of these five research priority agendas are being pegged to several other indicators.

3.2.1.1 SIX (6) STISA-24 PRIORITITY AREAS:

The priority action areas have been identified and validated by African and International Research and Innovation Stakeholders from different sectors such as Agriculture and Food Security, Biosciences, Governance and African Integration, Information and Communication Technologies (ICT), Natural Resources, Public Health, and Human Studies – to provide the necessary foundation to achieve a sustainable African Renaissance. Each of them is further expanded into innovation and research indices which are all being presented in the summary below.

	Priorities	Research and/or innovation areas
1	Eradicate Hunger and ensure Food and Nutrition Security	- Agriculture/Agronomy in terms of cultivation technique, seeds, soil and climate - Industrial chain in terms of conservation and/or transformation and distribution infrastructure and techniques
2	Prevent and Control Diseases and ensure Well-being	- Better understanding of endemic diseases - HIV/AIDS, Malaria Hemoglobinopathie - Maternal and Child Health - Traditional Medicine
3	Communication (Physical & Intellectual Mobility)	- Physical communication in terms of land, air, river and maritime routes equipment and infrastructure and energy - Promoting local materials - Intellectual communications in terms of ICT
4	Protect our Space	- Environmental Protection including climate change studies - Biodiversity and Atmospheric Physics - Space technologies, maritime and sub-maritime exploration - Knowledge of the water cycle and river systems as well as river basin management
5	Live Together – Build the Society	- Citizenship, History and Shared values - Pan Africanism and Regional integration - Governance and Democracy, City Management, Mobility - Urban Hydrology and Hydraulics - Urban waste management
6	Create Wealth	- Education and Human Resource Development - Exploitation and management of mineral resources, forests, aquatics, marines etc - Management of water resources

Table 1: STISA Priorities (6) and Research/Innovation Areas [STISA, 2014]

3.2.1.2 Four (4) STISA-24 PILLARS:

On the development of STISA-2024, four prerequisite pillars were defined to ensure the achievement of its mission "Accelerate Africa's transition to an innovation-led, Knowledge-based Economy" and the realization of its goals and objectives. These pillars are:

- Upgrading/Building Research Infrastructure;
- Technical and Professional Competencies;
- Innovation and Entrepreneurship; and
- Providing an Enabling Environment for STI Development in the African Continent.

Using finite element analysis and problem tree methodology, the AU/STRC analysed each of the STISA pillars and identified the needed foundation (sub-pillars), to ensure they are in place or to be in place to achieve the STISA outputs and mission. The Figure below contains an exert of the table prepared by the institution showing the analysed sub-pillars.

PILLARS	1. Research Infrastructure	2. Technical/Professional Competence	3. Innovation and Entrepreneurship	4. STI Enabling Environment
SUB-PILLARS	1.1 Strengthen existing National R&D Institutions 1.2 Establish new National R&D Institutions in the Priority Sectors 1.3 Encourage Private Sector to establish new R&D Institutions/Facilities 1.4 Encourage Private Sector to establish Universities/ Higher Education Institutions 1.5 Promote Science Parks 1.6 Promote Community Innovation Hubs	2.1 Build critical mass of MSes & PhDs with emphasis to industry 2.2 Promote Technology transfer & Acquisition 2.3 Promote Professional membership of regulatory bodies 2.4 Build lifelong learning 2.5 Promote Knowledge exchange and brain circulation 2.6 Develop advocacy programs and outreach at all AU levels	3.1 Technology Acquisition, transfer and commercialization 3.2 Commercialization of research outputs 3.3 Entrepreneurship capacity building 3.4 Local market protection 3.5 Financial instruments for entrepreneurship establishment 3.6 Inclusive Innovation (Community Innovation) 3.7 Green Innovation 3.8 Innovation capacity building	4.1 Development of Integrated market across all AU levels 4.2 Financial mechanisms to support STISA implementation 4.3 Enabling Infrastructure (ICT, Railways, roads etc.) 4.4 Advocacy & Communication 4.5 STI policies

STISA Pillars and its Sub-Pillars

Table 2: STISA 4 pillars and Sub-Pillars (STISA, 2014)

3.2.1.3 5 PRIORITY AREAS OF WATER RESEARCH (PAUWES WATER RESEARCH)

Based on the priority areas of research defined in the PAUWES research agenda, this research checks it against all the above mentioned STISA priorities and pillars to establish the link between the policy and program. The research agenda has been developed by the PAUWES institutional partners and stakeholders to serve as key guides to produce the expected research outcomes for the institution in relation to Water, Energy and Climate Change. Flowing from conference presentation by the ZEF institution, Germany, (Berhnad /ZEF, 2018) these Five priority areas have been broadly expressed to show their specific targets. These five priority areas and deduced indicators by this research are presented below:

PAUWES FIVE (5) RESEARCH IN WATER PRIORITY AREAS		INDICATORS
1.	Water and Food Security	Long-term food production; Sustainable livelihoods; Water management and efficient irrigation and agricultural productivity; water information systems / meteo-hydrodatabases; Water footprints; water (right) trade; Remote sensing techniques for forecasting, upscaling and analyses.
2.	Water Management	Water demand and supply; Urban water supply; Water qualities and quantities; Water & sanitation systems; Circular systems and Water re-use; Water treatment; forecasting tools; Risks (floods) and its health impact; Flood management; Transboundary and national water management (groundwater aquifers and surface water); IWRM (Integrated Water Resource Management).
3.	Water and Environment	Water cycle and healthy ecosystems, food security; Industrial chemical discharge and urban waste management, Healthy population; Solid waste management; floods; groundwater quality; Seawater intrusion management; Desalination technologies; Hydrological and matter flow models; SMART monitoring systems in analysing and modelling
4.	Water Economics and Governance	Water Efficiency; Effective Water Allocation; Integrated Economic tools; Implementing Water Management strategies; Institutional arrangements; Efficient Water Pricing tariff systems.
5.	Water-Climate Nexus	Hydrological/Water Management Systems; Livelihoods; Rain-fed, Supplementary and full irrigation systems;

		Water Conservation Infrastructures and strategies; Best practices and approaches to climate-smart water utilisation; Strategic meteo-hydro series stationing; Strengthened Science-Practice-Policy interface.

Table 3: PAUWES (5) Research Priority Areas (Original Contribution)

3.2.1.4 DOCUMENTARY ANALYSIS METHODOLOGY:

Upon obtaining the data sets, a comparison mode of establishing links is adopted to connect the PAUWES Water Sector Research Priorities with the first, the Six (6) STISA-24 Priorities, and then, the four (4) Pillars of STISA-24. This takes the form of a cross section comparison takes, with qualitative data inputs to determine connectedness of objectives. On the upper Vertical Y-axis are the PAUWES Water Sector Research Priorities, and on the Horizontal X-axis are the STISA-24 six priorities (in one table) and the Four (4) STISA Pillars (in another table). Using the indicators of all the various priorities and pillars, the data sets are checked against each other to determine the measure of connectedness of purpose and objectives.

3.3 ANALYSIS OF PAU WATER RESEARCH 2016-2019 (STATISTICAL TREND)

This research work would carry out analysis of the research in Water sector from the existing PAUWES Student thesis in water sector development between the years 2016-2019. These theses are made publicly available on the PAU repository website where all of the research was obtained. (PAU, 2020) Search engine was used to obtain results of water research conducted by students admitted between 2016-2019 past four cohorts and this analysis results present the statistical trend regarding three main criteria assessed. These include: the **orientation** (Form and Structure) of the theses and the **case study location** studied and most importantly; the **research/thematic focus** (based on Water research priority areas) of the theses.

3.3.1 QUESTIONNAIRE AND DOCUMENT DATA COLLECTION:

To collate relevant data necessary for conducting this analysis and presenting statistical results that would aid discussions establishing PAU Water research relevance to the STISA 24 vision for Africa, the system of a document analysis questionnaire is being utilised. This system is simply reliant on the use of a research specific designed questionnaire which is used to analyse

the contents of the currently available master thesis of the Pan African University Institute for Water and Energy Sciences, between the years 2016 and 2019 (Four Cohorts).

Contents of the questionnaire are structured to reflect certain indicators that will ultimately help in determining the specific priority area each of the master thesis research falls under. The questions help to extract relevant data sets like;

- the year the research was conducted
- the department under which the research was conducted (Water/Energy)
- The Case Study Location
- The practical orientation of the research (form and structure of thesis)
- The main goal of the research
- The research objectives of the research
- The specific sector the research influences

The results of each thesis following the questionnaire data collection steps, helps to successfully categories the theses into the five PAUWES Water research Priority areas as established under the PAU research agenda and discussed in the documentary analysis methodology (3.2.1.4), which are:

i. Water and Food Security
ii. Water Management
iii. Water and Environment
iv. Water Economics and Governance
v. Water-Climate Nexus

It also results in successfully categorising the thesis according to its form which is basically showing whether the research:

i. Focuses on developing a new water innovation technology or solution or adapting an existing water innovation to solve an African water challenge.
ii. Projects a simulation or modelling caried out by the researcher to water challenge in Africa.
iii. Conducts and Assessment, Evaluation or Monitoring of existing situations or solutions across Africa's water sector.

Statistical results from the above category analysis are further presented in the fourth chapter of this thesis and deduced inferences of results are further discussed to answer the second research question and third research objective of this work which bothers on the current positioning and contributions of PAU research in Water towards the realisation of STISA-24 vision for water innovation and development in Africa

3.4 THEORY OF CHANGE FOR WATER AND ENVIRONMENT INNOVATION RESEARCH IN AFRICA

Having concluded the link between the PAU research in water sector and STISA-24 policy, this research proceeds to develop a theory of change for one of the thematic priority areas of water research for Africa. This segment of the research fills in one of the major gaps that exists in the industry currently, which is the lack of foundational frameworks to access the impacts and contributions of research in water to the realisation of the STISA-24 policy targets for Science, Technology and Innovation for Africa. Theory of change as discussed in the literature review, forms a foundation for any program seeking to measure impact and evaluate or access contributions of its activities towards the realisation of the programme objectives and policy goals. In this case, one of the goals of water development for Africa is centred and a theory of change is developed with outcome indicators as well as output indicators. The format that would be utilized in presenting this theory of change is shown in this fig.

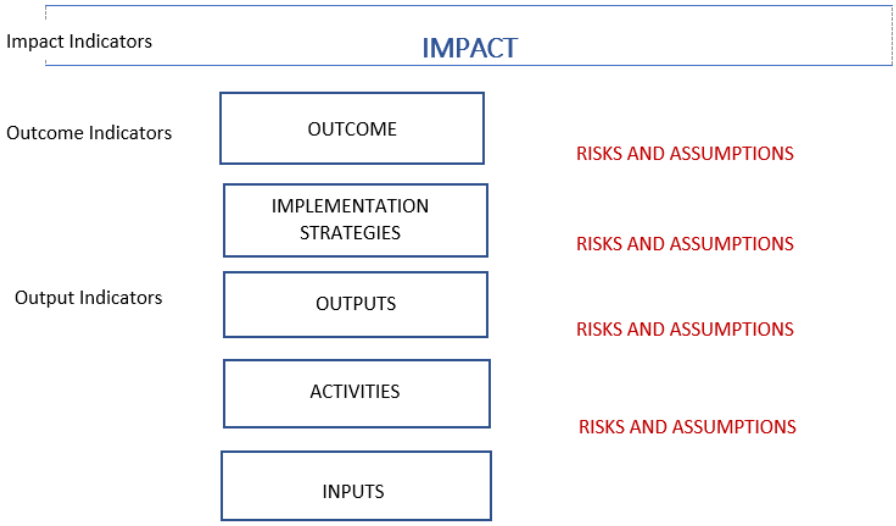

Figure 6: Theory of Change Framework (Open University, 2020)

The impact reflects the overall goal that is to achieved and the impact indicators will project the objectives of the main goal, which would indicate an achievement of the proposed impact. The outcome contains specific and measurable change that is sought after, which ultimately produces the proposed impact. The activities and inputs are action oriented, relating to the things that are being done to realise the desired outcomes and impact expected. In this case, the framework that would be designed for the water resource challenge of poor access to water, would channel its activities to mainly research and development actions.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

4.1 LINKING STISA-24 AND PAUWES WATER RESEARCH PRIORITIES

The key priority areas as well as the four pillars of the STISA-24 policy when matched and analysed alongside the PAUWES Priority Areas reflected in its research agenda developed through documentary analysis of relevant policy documents, showed the following results;

4.1.1 6 PRIORITY AREAS OF STISA vs. 5 PAUWES WATER SECTOR RESEARCH PRIORITIES

6 PRIORITIES OF STISA-24 POLICY	5 PAUWES WATER SECTOR RESEARCH PRIORITY AREAS				
	Water & Food Security	Water Management	Water & Environment	Water Economics& Governance	Water-Climate Nexus
Eradicate Hunger & Food and Nutrition Security	✔	✔	✔	✔	✔
Prevent and Control Diseases & Ensure Well-being	✔	✔	✔	✘	✔
Communication (Physical & Intellectual Mobility)	✔	✔	✘	✔	✔
Protect our Space	✘	✔	✔	✘	✔
Live Together, Build the Society	✔	✔	✔	✔	✘
Create Wealth	✔	✔	✔	✔	✘

Table 4: PAUWES Priority Areas vs. STISA priorities (original compilation)

Findings and Discussions:

Results as displayed in the table above presents a **25/30** result of connectedness between the water research priority areas of PAUWES and the Priority Areas of STISA -24 Policy. From

the given results, the deduced interpretation shows that continuous realisation of successful research in:

1. Water and Food security would lead to Eradication of Hunger & Food and Nutrition Security, Communication and information (water information systems / meteo-hydrodatabases); Prevention and Control Diseases & Ensure Well-being, Build the Society and creating wealth.
2. Water management would aid in the direct realisation of Ensuring the Well-being of people (Water quality control eradicates risks of water borne diseases), water and food security assured for the populace, communication technology for advance water infrastructure (Drought and flood forecast and management tools/ technologies), Protection of our environment, Building a sustainable societies and cities (in terms of urban water management, wate water management etc.], creating wealth (Water availability creates an enabling environment for businesses to thrive and encourages global investments).
3. Water and Environment would invariably directly help to eradicate hunger & food and nutrition security (Better soil quality and reduced water risks to agricultural practices); prevent and control diseases & ensure well-being (Water and Sanitation as well as availability of portable drinking water); Protect our space (environment protection of water resources); Build our society (Water rights and inclusiveness and accessibility of basic resources to all)
4. Water Economics and Governance aids in Eradicate Hunger & Food and Nutrition Security (Equitable water allocations for availability of water resources); Prevent and Control Diseases & Ensure Well-being (Urban water quality control, waster water disposal and sewage-ground water regulations) Communication (Physical & Intellectual Mobility- Water Infrastructure); Protect our Space (Governance and Water Policies); Live Together (Rural water management, Inclusiveness of water policies and infrastructure developments); Create Wealth (Water Economics, Utilities and Water trade, water rights policies).
5. Water-Climate Nexus successful management aids in achieving sustainable food security (Mitigate agricultural waste); Prevention and Control of diseases & Ensure Well-being (Mitigating the chances of unforeseen disasters as a result of climate change

threats); Communication (Physical & Intellectual Mobility) (Development of adaptation tools and water-climate information tools); Protect our Space; Create Wealth (Reduce the water-climate change effects on the economy and economic activities).

It is worthy of note that all of the five (5) PAUWES Research Priority areas in Water research for Africa is directly linked with **at least FOUR (4)** of the STISA 2024 Policy Priority areas.

4.1.2 4 PILLARS OF STISA vs. 5 PAUWES WATER SECTOR RESEARCH PRIORITIES

4 PILLARS OF STTISA	5 PAUWES WATER SECTOR RESEARCH PRIORITY AREAS				
	Water & Food Security	Water Management	Water & Environment	Water Economics& Governance	Water-Climate Nexus
Infrastructure Development	✔	✔	✔	✔	✔
Technical Competencies	✔	✔	✔	✔	✔
Innovation and Entrepreneurship	✔	✔	✔	✔	✘
Enabling Environment	✔	✔	✔	✔	✔

Table 5: PAUWES Priority Areas vs. STISA 4 pillars (original compilation)

Discussion:

The findings above reflect the distinguished connection of the PAU Water Research Program priorities to the STISA policy pillars. Each of the indicator clusters matched using its sub-pillars and priorities breakdown.

Whilst the pillars of STISA-24 are broadly centred around the overall vision which the policy seeks to achieve, a connection to specific water research priorities of PAUWES is still possible and correct in its validity. This is because, successful research in each of these areas of water sector development aids in the realisation of those STISA pillars, especially when it is streamlined to Water innovation and development for Africa.

The PAUWES Research areas in Water and Food security, Water Management, Water and Environment, Water Economics and Governance as well as Water-Climate Nexus, are well channelled and driven towards realisation of the Four (4) STISA Pillar of Infrastructure Development, technical competencies, innovation and entrepreneurship, and enabling environment which all comprise of sub-pillars that are centred around its highlighted indicators of progress. Hence, a connection of these two cluster priorities, shows its linkage in achieving;

- The development of research infrastructures for a better developed water sector;
- A sustainable water sector development knowledge bank and sustainable knowledge exchange of water technology solutions for Africa's Water Sector;
- Sustainable and viable water innovations and social enterprises, championing creative solutions to water challenges across Africa; and
- Policy dynamics that allow for enabling environment for the success of new innovations in water in Africa

Invariably, it is worthy of note to emphasize that a continuous development of the PAU research in Water, aids the continuous realisation of the pillar of STISA-24 Policy, with specific impact on Water sector innovation and Development for Africa.

4.2 ANALYSIS OF PAU WATER RESEARCH 2016-2019 (STATISTICAL TREND)

Within the first four years (2016-2019) of the commencement of the Pan African University Institute for Water and Energy Sciences (including Climate Change) [PAUWES], there has been four cohorts. Students in these cohorts that had undergone water engineering and water policy programmes, had conducted research to be applied in the water sector of Africa's development fronts. Soft copies are provided on the institutions' online repository (**CITATION)** and results of detailed search of the research conducted between 2016 and 2019 shows that about 93 research were centred around the water sector.

Out of the 93 total research number, we have 8 of them conducted in the year 2016, 19 in the year 2017, 32 in the year 2018 and 34 in the year 2019. The statistical representation of this result is presented in the chart below:

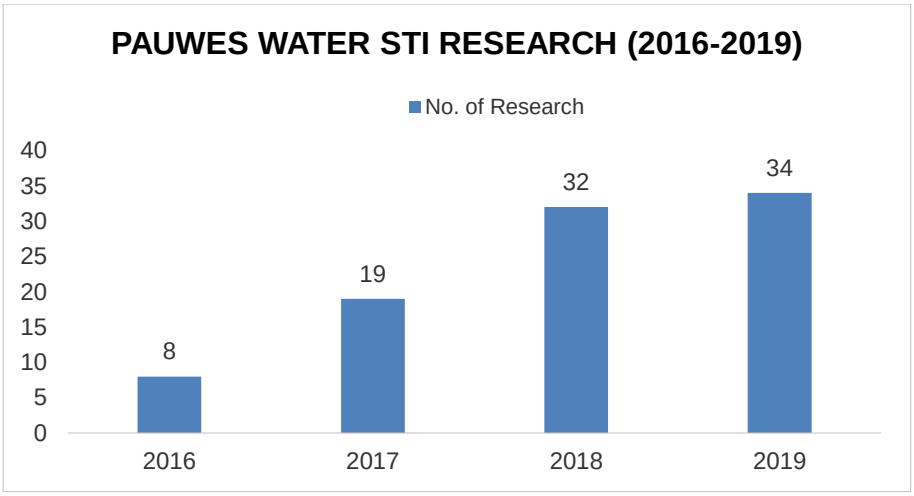

Figure 7: Statistical illustration of PAUWES Water STI Research (2016-2019) Analysis (original)

4.2.1 STATISTICAL TREND OF PAUWES WATER RESEARCH IN CATEGORY OF FORM:

As expressed in the methodology, this classification analysis if based on form and structure categorisation. The results below show the number of researches that were centred around the development of a new innovation for water or an adaption of existing ones to Africa, number of simulations and core modelling research exercises, and number of researches that did evaluations, assessment and monitoring of established situations and existing situations. The results of the statistic are displayed in the table as this:

PAUWES WATER RESEARCH BY ORIENTATION (FORM)					
	Year 2016	Year 2017	Year 2018	Year 2019	Total
Water Innovation Research (New& Adaptations)	0	4	2	4	**10**
Simulations and Modelling	6	5	5	9	**25**
Evaluations, Assessments, and Monitoring	2	10	25	21	**58**
TOTAL	**8**	**19**	**32**	**34**	**93**

Table 6: PAUWES Water Research per orientation/Form Statistics (original)

A cluster bar is further utilised in presenting the statistics clearer, to highlight the details of the research thesis structure analysis. From the Cluster chat below, water innovation research focus has shown to be the least researched type amongst the students of the first four (4) cohorts, and the years 2017 and 2019 had the highest and equal number of water innovation research which is 4. On the other hand, the highest researched type as revealed in the results of analysis, is the

category of evaluations, Assessments and monitoring researches. This research type has been on a rise form the inception of the institute and rose to taking more than 80% of the total water related research conducted in the year 2018, however it dropped slightly in 2019 but still remained the highest researched type in that year. The discussed cluster chart is presented below Fig.

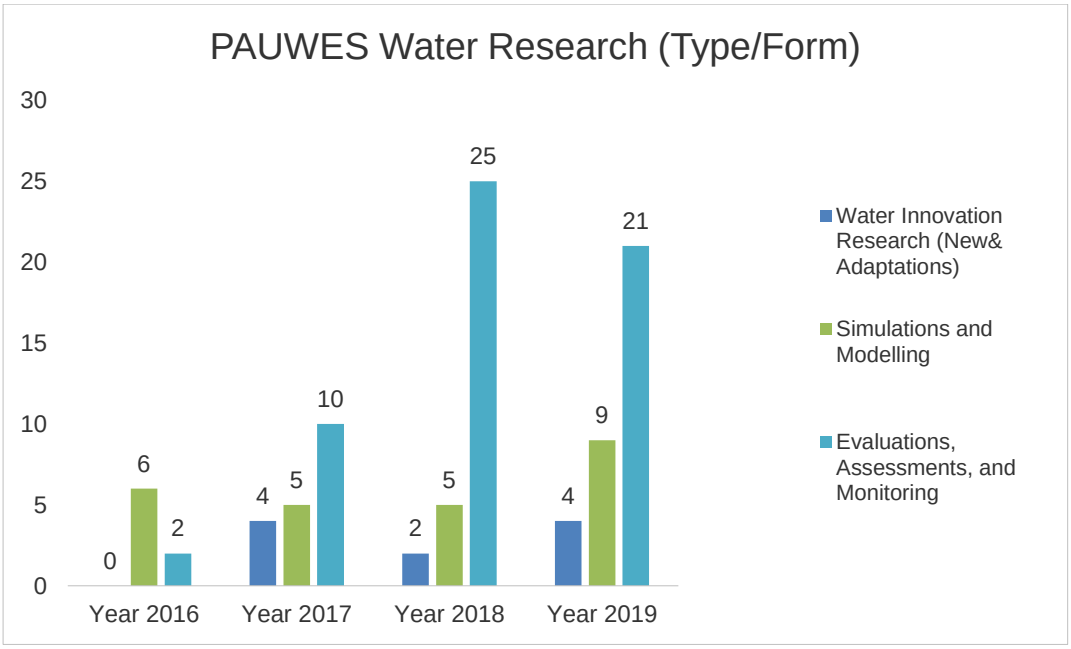

Figure 8: Statistical trends of Water research by orientation (2016-2019) [original]

4.2.2 STASTICS BASED ON CASE STUDY LOCATIONS:

This presents an overview result of the case study locations of the 93 thesis that were covered in this analysis. Results presented in the bar chart below with figures, display the total numbers of thesis focused on various African countries. Nine of the research works on water were regional case studies, and it is important to note that these thesis touch on areas like transboundary surface water, groundwater aquifers crossing borders, cluster of regional water regulatory boards, and general African policies for the continent.

Kenya, of all the countries involved, has the highest number of research case study location point, with 18 total number of thesis conducted by the four cohorts of PAUWES focusing on tackling water challenges and developing innovations for Kenya's water sector. This is followed by Rwanda with 12 total research case study points, and Algeria as well as Regional case studies, come third place with 9 equal research theses.

21 out of 54 African countries, have been posited as case study locations for Water research under the PAUWES water research programme between 2016-2019 (the past four cohorts) and about 9 were focused on regional studies. It is noteworthy to highlight some factors that influence the result of this finding, which include;

- Number of students admitted to the Water department of the institution;
- Home countries of the water research students: This factor is a huge influence that determines most of the statistics presented. Most of the students carrying out water research were from Kenya, East Africa in general, and quite a number from Algeria, which goes to show why these areas had more research in these areas.

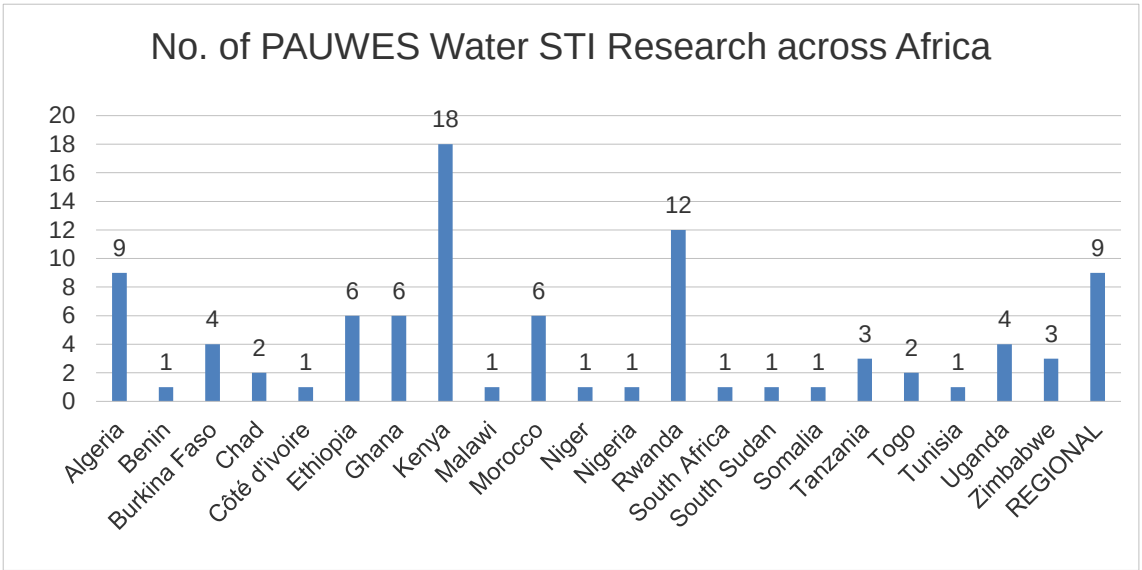

Figure 9: Statistical trends of Water research by Case study locations (2016-2019) [original]

4.2.2 WATER RESEARCH ANALYSIS PER PRIORITY AREAS

This section stands as the most important and safe to say, the main body of analysis of this research work. As discussed in the methodology (3.2.1.5), an analysis of the 93-research theses across the priority areas of PAU research in Water (which has been found to have an established link and connectedness with the STISA 2024 Policy objectives) has been conducted. The results as shown in the table below;

PAUWES WATER RESEARCH ANALYSIS (2016-2019)					
	Year 2016	Year 2017	Year 2018	Year 2019	Total
Water & Food Security	2	1	7	6	**16**
Water Management	0	4	8	9	**21**
Water & Environment	3	8	6	8	**25**
Water Economics & Governance	1	2	7	4	**14**
Water-Climate Nexus	2	4	4	7	**17**
TOTAL=	**8**	**19**	**32**	**34**	**93**

Table 7: PAUWES WATER Research Analysis (2016-2019) [original]

From the table, a breakdown of how many research theses were conducted along the thematic areas of priority is presented. The highest and most focused priority area of the PAUWES Water research theses in the past four cohorts is **Water and Environment** with 25 total theses, followed by **Water Management** with 21 total research.

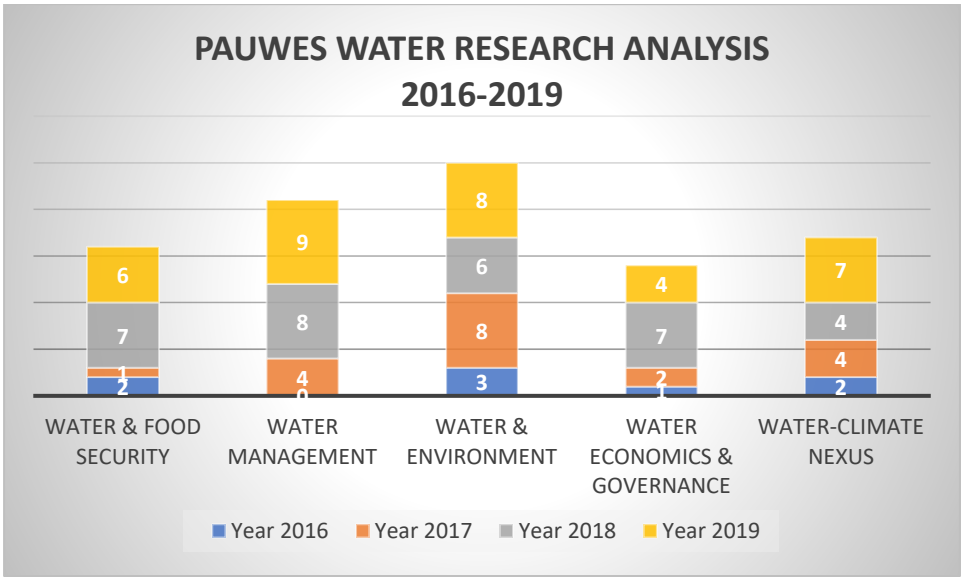

Figure 10: Statistical illustration of PAUWES Water research trends by priority Areas Analysis (original)

From the questionnaire used to gather data, we see that many factors bring about this classification. The content of each of the 93 theses were critically analysed and double checked with the indicators developed for each of the PAUWES Priority Areas (As discussed in Methodology 3.2.1.3).

The illustrated Bar chart clearly shows the least researched thematic areas in the past four cohorts to be Water Economics and Governance. This is of course influenced by the actual number of water students in water policy and economics focus, as a higher number of the 93 students' researches were enrolled under the Water Engineering department and a number of policy students still carried out research in other thematic areas as background degrees play a determining role in most students' choice of thesis research area.

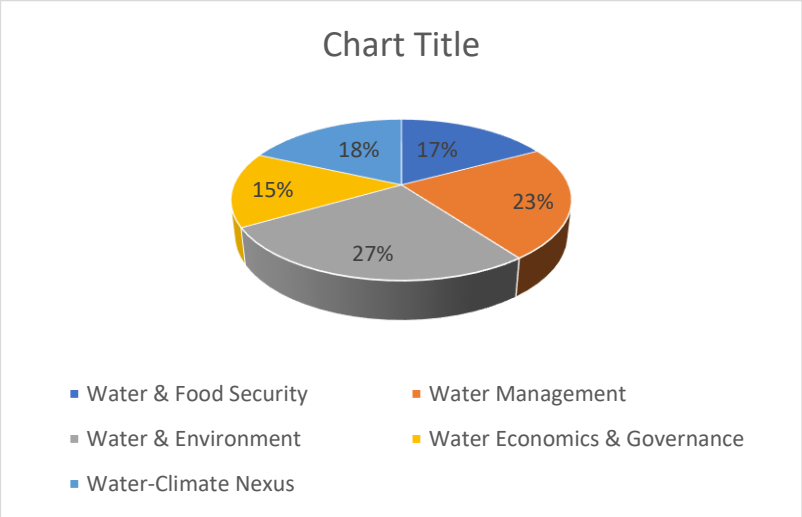

Figure 11: Pie chart percentage illustration of Water research (2016-2019) across water thematic area

From the above Pie chart (Fig.11), Commendably, the difference in the portions of research done across all of the five thematic areas are not too wide in terms of margin, which projects a recorded effort in diversification. The pie chart shows the percentage divisions across all the priority areas, and out of 93 total research thesis, 15% Water Economics and Governance Thesis, 17% focus on Water and Food Security, 18% are Water-Climate Nexus centred, 23% are on Water Management and finally 27% focus on Water and Environment.

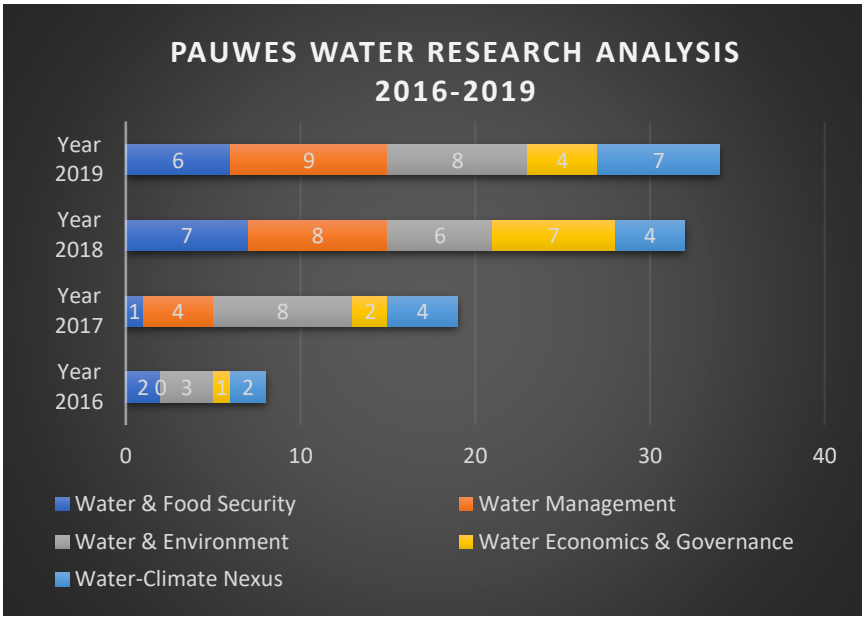

Figure 12:PAUWES Water Research Analysis (2016-2019) from a yealy perspective [original]

The above bar chart presents the yearly view of the theses across the five thematic areas. This result ultimately presents upward progression in general research in water for Africa, as the scale is seen to be on the increase since the year 2016. Looking specifically into the chart, we see a somewhat scattered progression of all of the thematic areas across the years, in the sense that none of the priority area is kept on a steady increase. For instance, Water Economics and Governance which shows a steady increase in the first 3 years, from 1 to 2 and to 7, is seen to have witnessed a drop in the year 2019 to a number of 4 theses. This scattered progression as it is called by the researcher, is definitely nothing near negative, rather it depicts the efforts to balance and spread out research to cover all of the priority areas. Hence, the fairly distributed margin across all of the PAU water Research Priority areas which have been earlier established to be strongly linked to the realisation of the STISA-2024 Policy Objectives for Water sector innovation and development for Africa.

4.3 THEORY OF CHANGE FOR CLEAN WATER ACCESS IN RURAL COMMUNITIES

As part of the objectives of this research is to establish a sustainable model that links and helps to continuously measure the impact of the PAUWES Water research to the STISA-24 Policy, this section of the research work develops a theory of change model for one of the major water challenges across Africa which is fundamental to life, good health and productivity. The developed theory of change shows the chronology of goals to outcome down to inputs, wherein the activities of the PAUWES R&D Programme for is linked to Water Innovation Solutions for Africa which stems from evidence -based research.

The problem sought to be addressed is the challenge of "Limited evidence-based sustainable water innovations for Africa". This problem statement births the **goal/ impact expected** which is "Evidence-based Technical and Innovative Water solutions for African states". The framework designed below covers all the outcomes, outputs, their indicators, activities, inputs required, as well as the risks and assumption.

The designed theory of change framework is presented thus:

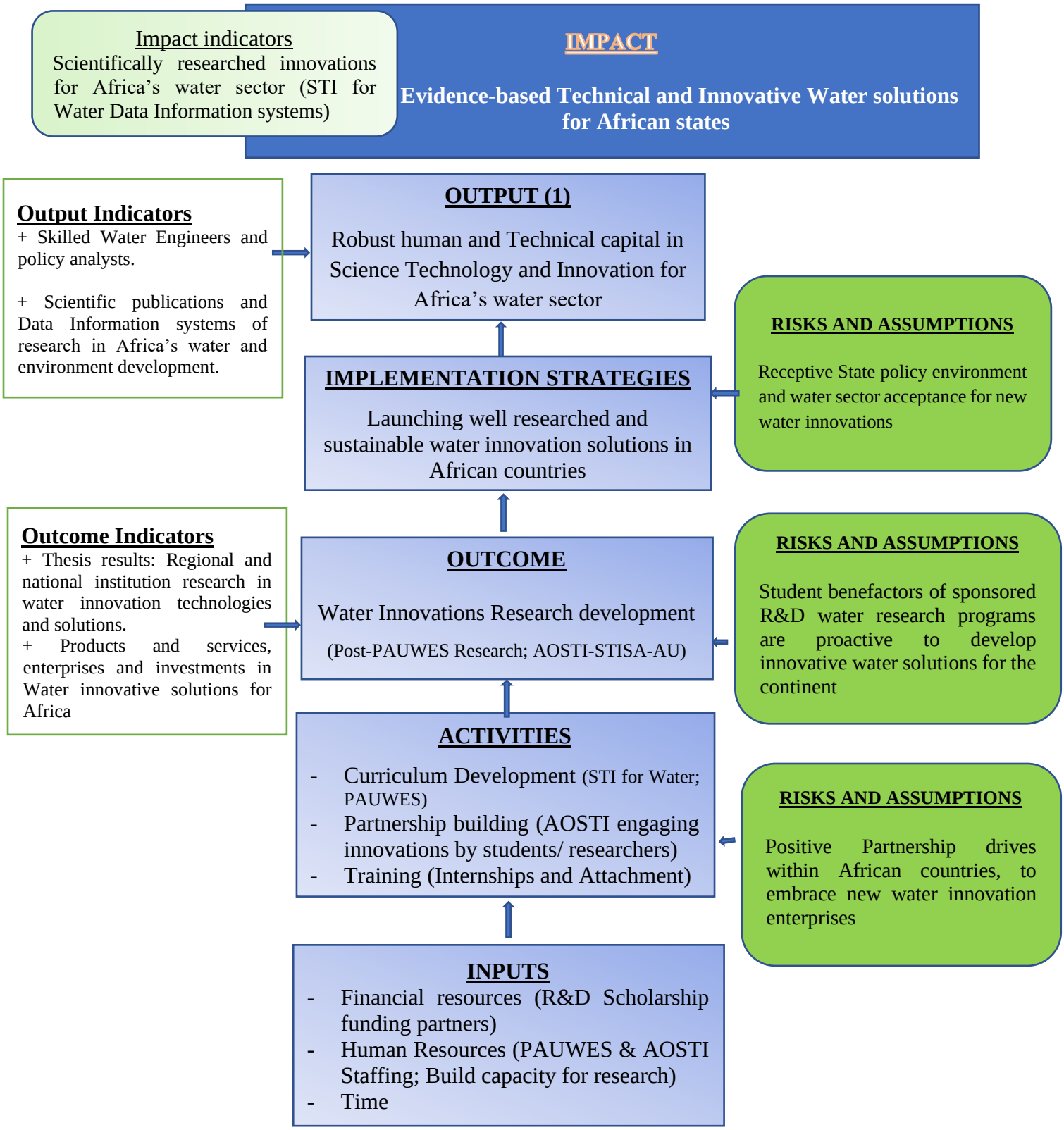

Figure 13: Theory of Change for Water Access in Africa (lined to innovation and Research) [original]

CHAPTER FIVE

5.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 POLICY AND PROGRAMME CONNECTEDNESS FOR WATER SECTOR DEVELOPMENT IN AFRICA

This research establishes a measurable and concrete analysed link between the STISA-2024 Policy for STI for Africa water sector development (from a policy interference angle) and the PAU R&D in Water sector research. Documentary analysis is utilised in data collation from the relevant worksheets, conference papers, agenda documents and policy documents applicable to both institutions. The five (5) PAUWES priority Areas are successfully check across the six (6) STISA-24 Priority areas, and also the Four (4) STISA pillars. The result shows a high level of connectedness between the water research priority areas of PAUWES and the Priority Areas of STISA -24 Policy. Most importantly, the thematic areas of Water and Food security; Water management; Water and Environment; Water Economics and Governance; Water-Climate Nexus, all work hand in hand to the improvement of innovations and technologies for Africa's water sector development.

LIMITATIONS AND RECOMMENDATION:

Ease of access to clearly identified indicators is essential to sustainable evaluation and monitoring of systems, projects, policies and programmes. The indicators were hidden under multiple objectives, desired impacts, and outputs. This analysis had to take each categories, pillars and priority areas to develop indicators which would be taken into consideration wen conducting the research thesis analysis. By way of recommendation, the relevant institutions can adopt some of the developed indicators or map out new ones, to allow for ease of monitoring and evaluation / assessment of the programmes and policies.

5.2 R&D IN SCIENCE, AND TECHNOLOGY FOR INNOVATION IN WATER SECTOR

There is an averagely balanced dynamics of research in water across the priority areas serving as pillars of focus for Africa water sector development, thus, innovation across all boards are achievable. The theory of changed developed for Water Access for all Africans in line with the SDG6 has research as its bedrock and foundation (inputs and activities) for success. Therefore, the existing R&D investment in the continent's research in water sector is towards the right direction to achieving the outcome of multiple sustainable water innovation solutions that can be available to all Africans, particularly the rural community dwellers.

Limitations and Suggestion:

Although the fraction of research across all the thematic areas of focus are fairly even, it is noteworthy to highlight that there are certain factors (potential limitations if not kept in check) that determine the analysed research thesis choice of thematic areas of focus, one of which is; the background of the researcher. The students coming from different backgrounds shows the diversification in thematic areas which is applaudable and continued development of strategies to diversify research areas will definitely keep the programme in check to achieving the STISA policy vision for water on a more wholistic level/ font.

At the commencement of the R&D program in water (mostly in 2016-2018 of the PAUWES Program), there existed a major imbalance in the case study dynamics of the water research. This is majorly as a result of factors like the home countries of the students admitted into the water research department. A perfect example here is the fact that before fifth cohort, which is 2020 set, only one Nigerian water student (2019) set (who was admitted in Water Engineering) which led to the obvious reason that only one (1) water research was developed with Nigerian case study specifically between the set 2016 and 2019 (4 cohorts). And Presently, the research author stands as the first Nigerian admitted as a water policy student (5th cohort, 2020 set).

To ease off these limitations, this research suggests that the scope of admission be broadened to achieve more regional balance of water research students, as this program goes beyond regular academia to a wholistic representation and influence in Africa's water sector development. Another suggestion is to develop a strategy of encouraging students to base their research not just in their home-based countries but other African countries, and as this research work has designed in the specific theory of change, internships, partnerships for innovative works and trainings helps to facilitate these goals.

5.3 IMPACT METRIC AND FRAMEWORKS

Theory change developed for measuring the impact and monitoring the achievement of one of the numerous water goals for Africa, has been developed in this research work. The impact of equitable access to portable water for rural community dwellers is succinct for global health challenge mitigation and the TOC framework established the link to its realisation with research inputs. Research birthing innovations, which subsequently generates outcomes such

as sustainable domestic water treatment technologies for every rural household in communities across Africa.

This model is used to channel and map out one of Africa's water challenges, and it is recommended that the relevant stakeholders and institution role players, such as AOSTI, prepare foundational theory of change frameworks for possibly every desired goal or impact in water sector, as this would propel actions and aid in continuous monitoring of progress to realisation of policy goals and vison.

6.0 REFERENCES

African Union Commission (AUC) (2015) *Agenda 2063: First ten-year implementation plan*. Retrieved and Accessed at 02/02/2020 www.un.org/en/africa/osaa/pdf/au/agenda2063-first10yearimplementation.pdf

AOSTI. (2014). *Science, Technology and Innovation Strategy for Africa 2024.* African Union Commission.

AMCOW, WHO/UNICEF JMP, (2012). A snapshot of Drinking Water and Sanitation in Africa-2012 Update.

AUSTRC, (2016)

Bernhard Tischbein (ZEF) (2018). PAUWES Research Agenda / Part on Water: Priorities and framework for engagement and actions. Presented for Zentrum für Entwicklungsforschung, Center for Development Research. University of Bonn. Accessed last; 27th September, 2020. http://pauwes-cop.net/res2prac/wp-content/uploads/2018/04/Bernard-Tischbein.pdf

Clark, H. and Anderson, A. 2004. *Theories of Change and Logic Models: Telling Them Apart*. https://www.theoryofchange.org/wp-content/uploads/toco_library/pdf/TOCs_and_Logic_Models_forAEA.pdf

EPA. (2014). *Promoting Technology Innovation for Clean and Safe Water*. USA: Water Technology Innovation Blueprint—Version 2. U.S. Environmental Protection Agency Office of Water.

Falkenmark, M., (1989). The Massive Water Scarcity Now Threatening Africa, Why Isn't It Being Addressed? *Ambio*, 18(2), p.112-118]

Oyebande L. (2001). Water problems in Africa—how can the sciences help? Hydrological Sciences Journal, 46:6, 947-962, DOI: 10.1080/02626660109492888

Martino JP. (1996). The Role of University Research Institutes in Technology Transfer. Industry and Higher Education. 1996;10(5):316-320. doi:10.1177/095042229601000508

MDG Report (2012). United Nations Millennium Development Goals Report (2012). https://www.un.org/millenniumgoals/pdf/MDG%20Report%202012.pdf

Morton, S. (2012). Exploring and Assessing Research Impact on Social Policy. *Edinburgh, University of Edinburgh.*

OECD. (2009). *Enhancing Research performance through Evaluation, Impact Assessment and Priority Setting.* Paris.: Directorate for Science, Technology and Innovation.

Open University Online site (2020). Retrieved from site and last accessed 19th September, 2020 https://www.open.edu/openlearncreate/pluginfile.php/324730/mod_page/content/3/toc3.PNG

PAU Repository Website. (2020) Last Accessed 15th September 2020 http://repository.pauwes-cop.net/handle/1/5

PAUWES. (2017). *PAUWES Recommendations for a Research Agenda at PAUWES: Scientific Contribution to Agenda 2063.* AU Pre-Final Draft.

PAUWES Recommendations for a Research Agenda at PAUWES: Scientific Contribution to Agenda 2063 of the AU (Oct. 18, 2017) Pre-Final Draft.

Poh, K., Ang, B., & Bai, F. (2001). A Comparative Analysis of R&D Project Evaluation Methods. *R&D Management. 31. 10.1111/1467-9310.00197.*

Rogers, P. 2014. *Theory of Change, Methodological Briefs: Impact Evaluation 2*. Available at: http://devinfolive.info/impact_evaluation/img/downloads/Theory_of_Change_ENG.pdf

Salasin, J. et al. (June 1980) The Evaluation of Federal Research Programs, MITRE Technical Report MTR-80W123.STISA-2024 (2014) *Science, Technology and Innovation Strategy for Africa 2024.*

UN-water global annual assessment of sanitation and drinking-water (GlAAS) 2012 report: The challenge of extending and sustaining services. Retrieved from: https://www.un.org/waterforlifedecade/pdf/glaas_report_2012_eng.pdf

UN/DESA, 2015. World Urbanization Prospects: The 2014 Revision. ST/ESA/SER.A/366. United Nations, Population Division, New York. http://esa.un.org/Unpd/Wup/. Accessed 10 April 2017

UNEP. (2006). Africa Environment Outlook 2: Our Environment Our Wealth. United Nations Environment Programme. Earthprint: UK. https://na.unep.net/atlas/africaWater/downloads/chapters/africa_water_atlas_123-174.pdf

United Nations World Water Assessment Programme (W/WAP). 2015. The United Nations World Water Development Report 2015: Water for a Sustainable World. Paris, UNESCO.

vanEs M., Gujit, I., and Vogel, I. (2015). *Hivos ToC Guidelines: Theory of Change Thinking in Practice: A stepwise approach.*

Vogel, I. (2012). ESPA guide to working with Theory of Change for research projects. LTS/ITAD.

Vogel, I. (2012). *Review of the use of 'Theory of Change' in international development*. https://assets.publishing.service.gov.uk/media/57a08a5ded915d3cfd00071a/DFID_ToC_Review_VogelV7.pdf

Zerga. A., Tambo E. (2018). A Pan African Research Agenda on Water, Energy and Climate Change RERIS 2018 Lesotho