CCARDESA

Centre for Coordination of Agricultural Research and Development for Southern Africa

STATUS REPORT

STATUS REPORT ON INCLUSION OF RELEVANT CLIMATE STI IN THE SADC REGIONAL COUNTRIES' AGRICULTURAL SECTOR

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IFAD Investing in rural people

CAADP XP4 PROGRAMME

Executive Summary

Introduction

Policy makers at national level have been attempting to mainstream climate change into their agricultural policies to increase the agricultural industry's resilience against climate change and variability. In the absence of a clear understanding of the status of inclusion of relevant climate STI in the SADC regional countries' agricultural sector, mainstreaming climate change into the agricultural policies becomes difficult. The status report therefore presents an Agricultural Innovation System (AIS) conceptual framework. The AIS framework was used to develop an estimation methodology for tracking the status of inclusion of relevant climate STI in the SADC regional countries' agricultural sector.

Key highlights

The following domains were used to track the status of inclusion of relevant climate STI in the SADC regional countries' agricultural sector. Domain 1: Agricultural innovation outcomes and sectoral performance. Domain 2: Climate smart agricultural research and education system. Domain 3: Climate smart agricultural value chains. Domain 4: Climate and innovation smart bridging institutions. Domain 5: Agricultural climate change and innovation policies, agricultural informal institutions and rural infrastructure. Domain 6: External environment to the agricultural industry. Estimates at domain level for all the seven countries revealed a low (≤ 50%) inclusion of climate STI in Domain 1, 2 and 4 and a moderate inclusion in Domain 5 and 6 (with the exception of Mozambique for Domain 5 and Eswatini for Domain 6). Domain 3 also indicated a low inclusion of climate STI for most of the seven countries with the exception of Zimbabwe and Tanzania as illustrated in Figure 1.

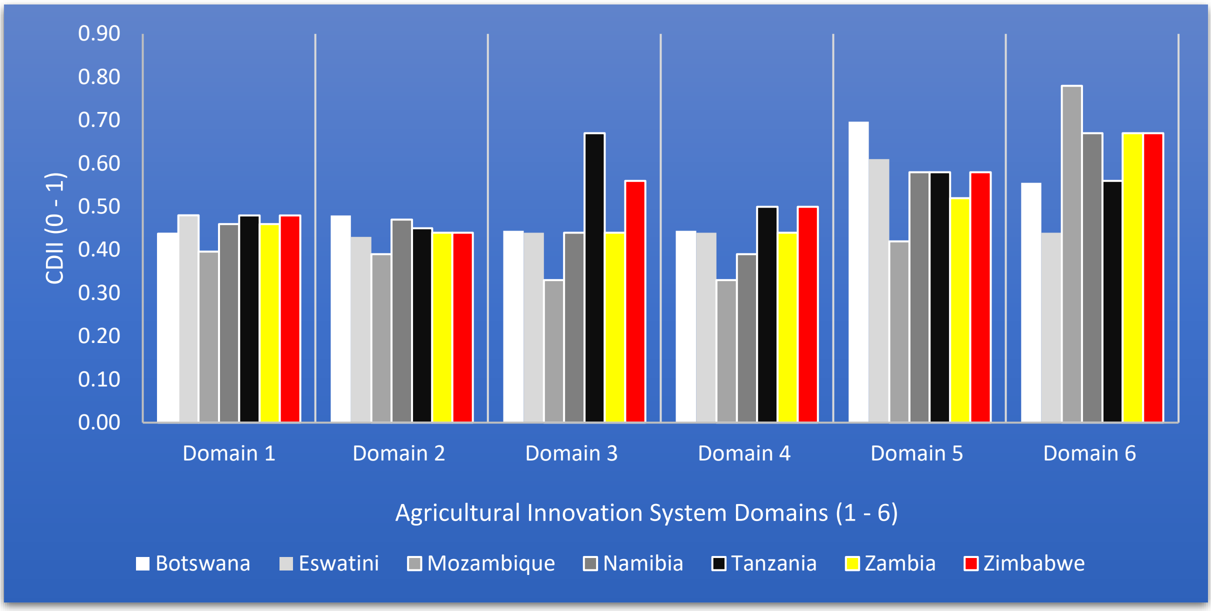

Figure 1: Status of inclusion of relevant climate STI in the SADC regional countries' agricultural sector at domain level

Conclusion

The report therefore concludes that there is a moderate inclusion of climate STI in the agricultural sectors of the following countries; Botswana (51%), Tanzania (53%) and Zimbabwe (53%) and a low inclusion in the following countries; Eswatini (47%), Mozambique (43%), Namibia (49%) and Zambia (49%) as summarised in Figure 2.

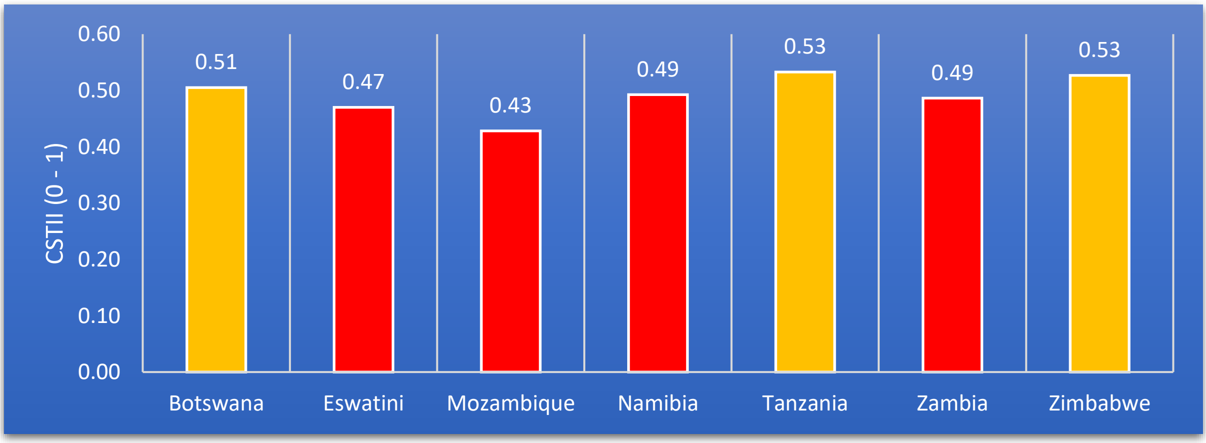

Figure 2: Status of inclusion of relevant climate STI in the SADC regional countries' agricultural sector.

Contents

Acronyms

AFAAS	African Forum for Agricultural Advisory Services
AIS	Agricultural Innovation System
AKIS	Agricultural Knowledge and Information System
AR4D	Agricultural Research for Development
ASARECA	Association for Strengthening Agricultural Research in Eastern and Central Africa
CAADP-XP4	Comprehensive Africa Agriculture Development Programme ex-Pillar 4 Programme
CCARDESA	Centre for Coordination of Agricultural Research and Development for Southern Africa
CDII	Climate Domain Innovation Index
CORAF	Council for Agricultural Research and Development in West and Central Africa
CSTII	Climate Science Technology Innovation Index
DeSIRA	Development Smart Innovation through Research in Agriculture initiative
EU	European Union
FAO	Food and Agricultural Organization of the United Nations
FARA	Forum for Agricultural Research in Africa
IFAD	International Fund for Agricultural Development

IFPRI	International Food Policy Research Institute
NAIPs	National Agricultural Investment Plans
NARES	National Agricultural Research and Extension Systems
NARS	National Agricultural Research System
NGO	Non-Governmental Organization
R&D	Research and Development
SADC	Southern Africa Development Community
SDGs	Sustainable Development Goals
STI	Science, Technology and Innovation
TOR	Terms of Reference
UN	United Nations
WB	World Bank

1.0 Introduction and Background

The Centre for Coordination of Agricultural Research and Development for Southern Africa (CCARDESA) is a SADC subsidiary mandated by Members States to coordinate regional cooperation in agricultural research and development. The Centre for Coordination of Agricultural Research and Development for Southern Africa (CCARDESA) is currently implementing the Comprehensive Africa Agriculture Development Programme EX Pillar 4 (CAADP-XP4) Programme on Agricultural Research and Innovation. This programme is being implemented under the EU's "Development Smart Innovation through Research in Agriculture" (DeSIRA) initiative.

CCARDESA is implementing this programme in partnership with other Ex-CAADP Pillar 4 (CAADP-XP4) Africa institutions comprising; African Forum for Agricultural Advisory Services (AFAAS), the Forum for Agricultural Research in Africa (FARA), the West and Central African Council for Agricultural Research and Development (CORAF) and the Association for Strengthening Agricultural Research in East and Central Africa (ASARECA). The CAADP-XP4 Programme is financed by the European Union (EU) and administered by the International Fund for Agricultural Development (IFAD) over a period of four (4) years. CCARDESA is implementing the programme in the SADC region with focus in seven countries (i.e. Botswana, Eswatini, Mozambique, Namibia, Tanzania, Zambia and Zimbabwe).

The aim of the programme is to link research and innovation with development initiatives to boost innovation in agriculture and food systems to make them more resilient to climate change and better responsive to development demands. Its objective is to enable agricultural research and innovation, including extension services, to contribute effectively to food and nutrition security, economic development and climate mitigation in Africa. The programme seeks to achieve five outputs which are;

(i) Capacity Strengthening;

(ii) Multi-stakeholder Partnerships for innovation established and in Operation;

(iii) Policy, cross country market access and improved investment;

(iv) Knowledge Management and

(v) Effective Planning, Coordination, Partnership, Monitoring, Evaluation Learning (MEL) and Reporting.

In support of quality policy formulation and planning that will enhance the region's scientific and technological development, CCARDESA with the assistance of a Consultant seeks to develop guidelines that will promote the inclusion of relevant climate Science, Technology and Innovation (STI) indicators into National Agricultural Investment Plans (NAIPs). The indicators are expected to facilitate agricultural transformation and to aid the tracking of progress of STI at national, regional and continental level. This is expected to contribute towards national, regional and continental development agenda, as well as attainment of the Sustainable Development Goals (SDGs) at a global level.

1.2 Rationale

Policy makers at national level have been attempting to mainstream climate change into their agricultural policies. One of the challenges have been incoherence between existing climate and agricultural policies. Science, Technology, and Innovation (STI) is therefore a catalyst for sustainable economic and social development hence the importance of integration of STI indicators into national development strategies. Science, Technology, and Innovation indicators are the developmental pillars that facilitate increased productivity, improve competitiveness, foster growth, and ensure improved livelihoods. It is against this background that CCARDESA realizes the need to build capacity to identify, conceptualize and define specific STI indicators that are measurable at all levels for the promotion of climate smart agriculture in the region.

These indicators are expected to address technical and institutional dimensions of science, technological advancements and innovations. The absence of guidelines that facilitate and promote the inclusion of relevant climate STI indicators, into NAIPs hampers the adoption of climate smart agriculture. This leads to poor agricultural productivity vulnerable to climate change and shocks with multiple negative welfare implications (poverty, inequality, food and nutritional insecurity) to the citizens of the region that highly depend on agriculture and natural resources for their livelihoods. Against this background, it is crucial that countries are supported to identify innovative approaches to stimulate the uptake of climate resilient technology solutions with a view to providing policy recommendations on this issue.

The challenges faced by policymakers towards mainstreaming climate change into agricultural policies leveraging science, technology and innovation are not surprising given the broadness of the agricultural system, ever-changing goals and often competing environmental and economic targets (Läpple, Renwick and Thorne, 2015). Besides increasing agricultural outputs and yields, policies that transform the agricultural sector to produce outputs that are sensitive to nutrition, responsive to cultural needs, resilient and dynamic to climate shocks and still remain competitive are now more than required. World Bank (2006) acknowledges this complexity attributing it to the structural changes in the global food and agricultural system. Leveraging science, technology and innovation in mainstreaming climate change into agricultural policies is therefore not obvious and straight forward given that agricultural innovation is more complex and less linear than once believed (Spielman and Birner, 2008).

1.3 Scope and Deliverables of the Assignment

In recognition of the complex and non-linear nature of agricultural innovation, Spielman and Birner, (2008) suggested the need to refine the conceptual and analytical tools for guidelines that will promote the inclusion of relevant climate Science, Technology and Innovation (STI) indicators into National Agricultural Investment Plans (NAIPs) for developing countries. Therefore, the consultancy work commenced with the design of a holistic conceptual framework that views agricultural innovation from a system perspective. The idea was to capture changing realities of the developing countries' agriculture system, where farmers are part of a complex network of heterogonous players engaged in the innovation process together with formal and informal rules, norms and values of engagement operating in different policy environments (Läpple, Renwick and Thorne, 2015; Spielman and Birner, 2008).

Guided by a holistic Agricultural Innovation System (AIS) framework national level climate STI indicators that are capable of measuring climate smart innovation inputs, processes and outcomes were designed and constructed. These indicators were used to gauge and benchmark national performances in terms of level of inclusion of relevant climate STI indicators in National Agricultural Investment Plans (NAIPs). The indicators shall further be used to develop national and regional action plans that promote the inclusion and mainstreaming of relevant climate STI indicators into NAIPs. Lastly, the national actions plans shall be harmonized into a regional plan for use at regional level and provide technical guidelines for agenda setting to enhance mainstreaming STI indicators into NAIPS by national institutions.

Key Deliverables of this Consultancy include the following:

(i) Inception report;

(ii) Brief report on the status of inclusion of relevant climate STI in the SADC regional countries' agricultural sector based on the 7 target countries;

(iii) Generic national and regional technical guidelines and their associated generic national and regional action plans for agenda setting that promotes the inclusion and mainstreaming of relevant climate STI indicators into National Agricultural Investment Plans (NAIPs);

(iv) A knowledge product (policy brief) on the inclusion of relevant climate STI in the NAIPs;

(v) Regional status report on the prevailing level of inclusion of such indicators at national and regional level NAIPs and Regional Investment Plan;

(vi) Guidelines and their associated action plans for inclusion of climate relevant STI in the National Investment Plans for use each at National and Regional level and

(vii) A Policy Brief on the inclusion of climate-relevant STI in the NAIPs.

2.0 Conceptual Framework

A systems approach was used for this report as the conceptual framework for estimating the level of inclusion of relevant climate Science Technology and Innovation (STI) indicators in National Agricultural Investment Plans (NAIPs) for the targeted SADC countries. The framework also shall guide the development of generic national and regional actions plans and policies that shall promote the inclusion and mainstreaming of relevant climate STI indicators into NAIPs for SADC countries to foster climate smart agriculture in the region.

The systems approach views agricultural innovation as a process with a set of interrelated actors interacting in the production, exchange and use of agriculture related knowledge in processes of socio-economic relevance including the institutional (formal and informal) context that conditions their actions and interactions (Spielman and Birner, 2008). The framework builds on previous linear based approaches like the National Agricultural Research System (NARS) and the Agricultural Knowledge and Information System (AKIS) framework. These previous approaches (NARS & AKIS) focused primarily on the role of education, research and extension in supplying knowledge and technology to farmers. The Agricultural Innovation System (AIS) conceptual framework includes farmers as part of a complex network of heterogeneous actors engaged on innovation processes along with the formal and informal institutions and policies environments that influences these processes.

The point of departure from previous approaches is the recognition of innovation as a complex web of related individuals and organizations rather than viewing innovation as a linear sequence of research, development and dissemination. Figure 3 presents the conceptual framework that captures relevant elements of a national agricultural innovation system including several linkages between components, institutions and policies that creates a supporting environment for innovation. The following domains are suggested as the essential elements of an innovation system following Spielman and Birner, (2008): (a) business and enterprise domain, (b) knowledge and education domain and (c) bridging institutions that connects the first two domains. The knowledge and education domain (agricultural research and education) co-create and/or independently generate agricultural knowledge and technologies, while the business and enterprise domain (value chain actors and organizations) uses outputs from the knowledge and education domain and also innovate independently. The two domains are connected by the bridging domain (extension, services and stakeholder platforms) that facilitate transfer of information.

The conceptual framework also include the frame conditions that impede or enhance innovation (these include public policies of innovation and agriculture, informal institutions that dictate norms, values, rules, cultural attributes, behaviours, perceptions and attitudes that influence the way in which individuals and organizations act and interact within each domain). Lastly, external influencing factors such as linkages to other sectors of the economy (manufacturing and service) international actors, political system and general science and technology policy are also in-cooperated in the framework. The framework therefore suggests that, to identify types of indicators that can be used to measure climate smart agricultural innovation inputs processes and outcomes, a holistic systems approach is required given the spill-over effects of innovation.

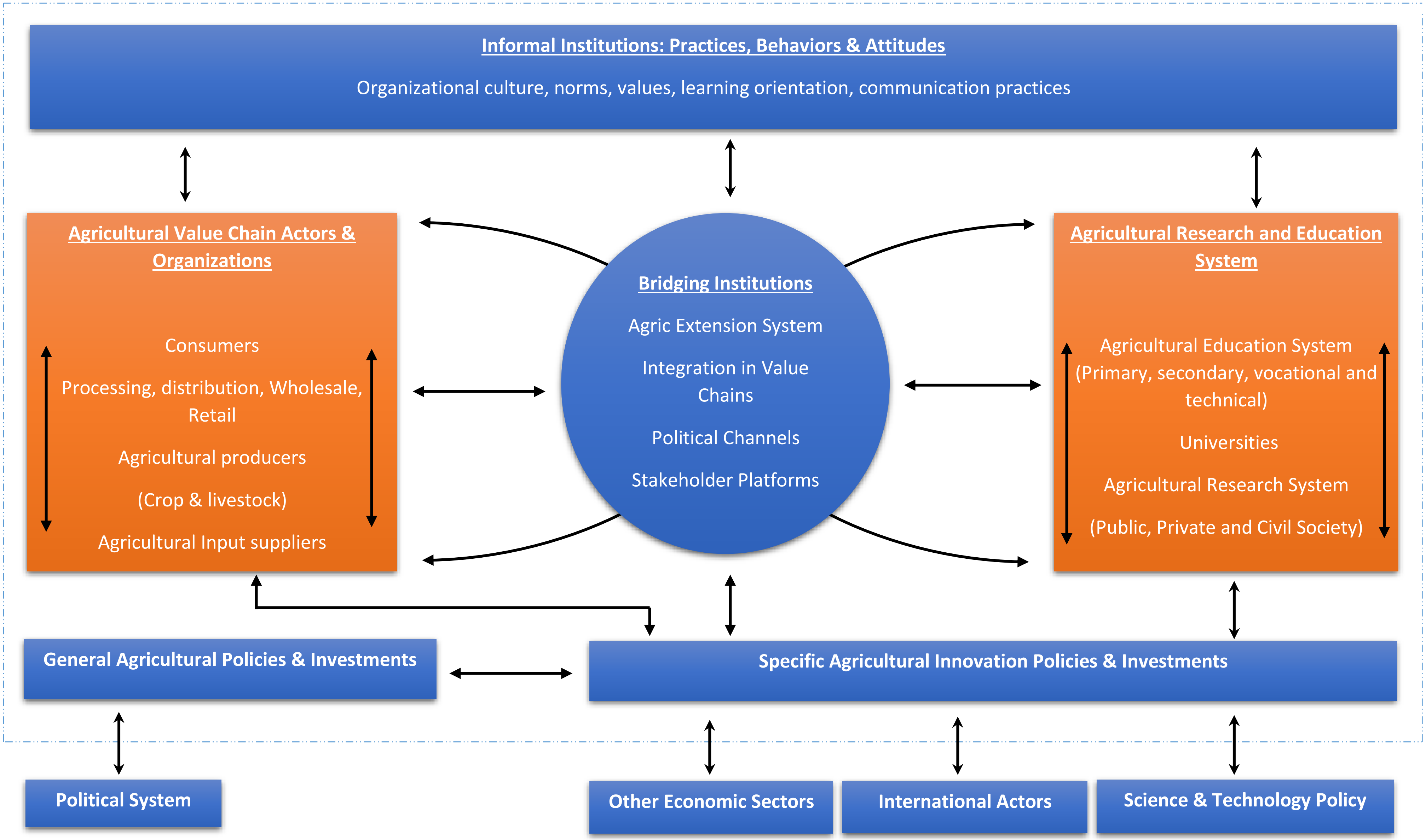

Figure 3: Conceptual Framework for a National Agricultural Innovation System: **Source:** Modified from Arnold & Bell (2001)

3.0 Methodology and Approach

This section presents the approach for designing climate STI indictors for the agricultural sector at national level. Building on previous approaches that focused more on measuring science, technology and innovation (Nin-Pratt, 2016), a composite measure that incorporates climate change, science, technology, innovation and country level expert opinions was used (Ariza et al., 2013; Läpple, Renwick and Thorne, 2015). Thus, climate STI were tracked in the following agricultural domains;

a) Climate smart agricultural innovation outcomes and sectoral performance;
b) Climate smart agricultural research and education system;
c) Climate smart agricultural value chains;
d) Climate smart bridging institutions;
e) Climate smart agricultural policies, institutions and frame conditions and
f) Beyond the system's borders (climate smart external environment).

The six domains broadly cover the concepts of innovation with respect to the agricultural industry that includes creation and/or adoption of innovations, where innovation can be in the form of a product, process, market, organizational and management techniques (Läpple, Renwick and Thorne, 2015). More importantly the degree to which climate change issues are embedded in these domains was the main focus. To avoid errors of omission, climate STI indicators were measured in two ways as illustrated below following Spielman and Birner (2008).

3.1 Classical Indicators

A set of commonly and widely accepted indicators as suggested by literature were used per domain to capture the status of climate STI. With respect to Domain ***"1"*** – "***agricultural innovation outcomes and sectoral performance"***, these indicators estimated availability of climate smart yield increasing technologies and incentives of farmers to adopt these technologies. With reference to Domain ***"2" – "agricultural research and education system"***, these indicators measured the strength of the agricultural research and education system and coverage of climate change and adaptation issues for purposes of enhancing individual and organizations' innovative capacity and creation of new products and processes. For Domain ***"3" – "agricultural value chains"***, the indicators estimated the resilience to climate change, structure, function and performance of value chain actors thus capturing contribution of technological, organisational and institutional innovation. With respect to Domain ***"4" – "bridging institutions"***, the indicators estimated the inclusivity of climate change and adaptation issues, diversity and capacity of bridging institutions to connect different domains of an innovation system. Under Domain ***"5" – policies institutions and frame conditions***, these indicators estimated the degree of enabling environment for agricultural innovation, climate change and adaptation. Lastly Domain ***"6" – beyond the system's borders (external environment)*** – these indicators measured the degree of external enabling environment capable of indirectly influencing agricultural innovation, climate change and adaptation.

3.2 AIS – Oriented Indicators

Indicators more oriented towards capturing aspects of the innovation system and climate change adaptation such as demand orientation, interactions, relationships, informal institutions and learning processes were also used to complement classical indicators. With respect to Domain ***"1" – "agricultural innovation outcomes and sectoral performance"***, these indicators measured processes that underline sectorial performance and the contribution of innovation to performance and resilience to climate change. With reference to Domain "***2" – "agricultural research and***

education system", indicators under this category focused more on the degree of integration or connectedness of climate smart agricultural research and education system. For Domain ***"3" – "agricultural value chains"***, indicators under this category focused more on how different value chain arrangements integrate actors and climate smart technologies within a given point along the chain. With respect to Domain ***"4" – "bridging institutions"***, the indicators under this category estimated the quality of climate smart linkages between bridging institutions and other system actors. Under Domain ***"5" – policies institutions and frame conditions***, these indicators estimated the quality of climate smart policies and their enforcement. Lastly, Domain ***"6" – beyond the system's borders (external environment)*** – these indicators measure quality of external enabling environment capable of indirectly influencing agricultural innovation and climate change adaptation.

3.3 Characteristics of Indicators

- The indicators referred to some measurable phenomenon of climate innovation from a classical (contribution of agriculture to GDP) and processes point of view (number of technological innovation adopted by rural farming households).
- Indicators were relevant to the analysis of climate agricultural innovation in the target SADC countries.
- Indicators relied on more than a recombination of existing data (government and institutional data sources, expert assessments and peer reviewed information).
- Indicators were measured using some simple type of common unit across all categories.

3.4 Data Sources

The following data sources presents a pool of databases that were used as sources of information towards the development and quantification of climate agricultural innovation indicators at country level.

- International and regional sources (World Bank, FAO, UN, SADC, IFPRI, CCARDESA);
- Government sources (Census, government expenditure);
- Industry sources (market and firm level analysis reports);
- Survey sources (survey data of say household income);
- Expert sources (expert opinion polls) and
- Peer reviewed publication sources (journal articles on adaptation of agricultural innovation).

3.5 Domain Indicators

This section presents indicators used per each domain for purposes of estimating the level of inclusion of relevant climate STI in the SADC region countries' agricultural sector. The indicators were according to the domains set forth in the conceptual framework (Spielman and Birner, 2008). Significant effort was put to make sure that all indicators complied with attributes below following several comparable studies (Spielman and Birner, 2008; Ariza et al., 2013; Läpple, Renwick and Thorne, 2015):

- Indicators should refer to some measurable phenomenon (both classical and process or throughput indicators);
- Indicators should be relevant to the analysis of climate STI in the target countries' agriculture;

- Indicators should rely on more than a recombination of existing data (published data and data drawn from country level expert opinion across the agricultural subsectors);
- Indicators should be measured using some type of common unit across all categories.

All indicators were then collapsed into an ordered categorical Climate Innovation Indicator Rating Score [(0 to 3): 0 = absent; 1 = poor; 2 = moderate; 3 = good]. For classical indicators, this was benchmarked against expected industry standards (yields based on genetic potential of common varieties and breeds used in the subsector under consideration). A weighted aggregate of these indicators was therefore used to calculate the Climate Domain Innovation Index (CDII) as detailed in section 4.0.

3.5.1 Domain 1: Agricultural Innovation Outcomes and Sectoral Performance

With reference to Domain 1, the following 16 indicators with equal weights of 6.25% were used.

- Agricultural GDP;
- Total agricultural factor productivity;
- Average yields per hectare of major staple food crops among the commercial agriculture sub-sector;
- Average yields per hectare of major staple food crops among the smallholder agriculture sub-sector;
- Average yields per hectare of major horticultural crops among the commercial agriculture sub-sector;

- Average yields per hectare of major horticultural crops among the smallholder agriculture sub-sector;
- Average yields per hectare of major cash crops among the commercial agriculture sub-sector;
- Average yields per hectare of major cash crops among the smallholder agriculture sub-sector;
- Off-take rate of the commercial livestock sub-sector;
- Off-take rate of the smallholder livestock sub-sector;
- Adoption/trial rate of climate smart new crop varieties among the commercial agriculture sub-sector;
- Adoption/trial rate of climate smart new crop varieties among the smallholder agriculture sub-sector;
- Adoption/trial rate of climate smart livestock breeds among the smallholder agriculture sub-sector;
- adoption/trial rate of climate smart livestock breeds among the commercial agriculture sub-sector;
- adoption/trial rate of climate smart natural resources management techniques (conservation agriculture, water harvesting, soil erosion) among the smallholder agriculture sub-sector and;
- Adoption/trial rate of climate smart natural resources management techniques (conservation agriculture, water harvesting, and soil erosion) among the commercial agriculture sub-sector.

3.5.2 Domain 2: Climate smart agricultural research and education system

For Domain 2, the following 25 indicators with equal weights of 4% were used.

- Agricultural research intensity;
- R&D spending allocation – salaries;
- R&D spending allocation - Operations / programs;
- R&D spending allocation - capital investments;
- Level of expenditure on agricultural research and education;
- Level of qualification of agricultural researchers and educators;
- Total agricultural researchers per capita;
- BSc holders (agricultural researchers) per capita;
- MSc holders (agricultural researchers) per capita;
- PhD holders (agricultural researchers) per capita;
- BSc male agricultural researchers per capita;
- BSc female agricultural researchers per capita;
- MSc male agricultural researchers per capita;
- MSc female agricultural researchers per capita;
- PhD male agricultural researchers per capita;
- PhD female agricultural researchers per capita;
- Number of new climate smart plant varieties and livestock breeds released in the past 5 years;
- Level of publication (peer reviewed journals and textbooks) in climate change and innovation by agricultural researchers;
- Level of secondary and tertiary enrolments in agricultural education;
- Level of plant variety protection and patents approval for commercialization in the past 5 years;
- Quality of ICT devices and services available to the research and education system;

- Level of inclusion of climate change, science, technology and innovation issues in the research and education system;
- Share of agricultural students sent abroad for advanced training in climate change, science and technology;
- Extent of agricultural researchers or organizational membership in regional and international research bodies and;
- Quality of climate smart, science and technology related collaborations between academia and value chain actors.

3.5.3 Domain 3: Climate smart agricultural value chains

Domain 3 had 3 indicators with equal weights of 33.33% as summarized below.

- Share and growth rate of agricultural value chains in the country;
- Participation of commercial farmers in climate smart value chains;
- Participation of smallholder farmers in climate smart value chains.

3.5.4 Domain 4: Climate and innovation smart bridging institutions (extension system)

Six (6) indicators with equal weights of 16.67% were used for Domain 4 as summarized below.

- Ratio of farmers to extension agents;
- Qualifications (certificate, diploma, degree) and area of specialization (crop, animal, agribusiness) of extension agents;
- Frequency of training and skills upgrades related to climate change for agricultural extension agents;
- Quality of extension services with respect to enhancing climate smart agriculture and natural resources management;

- Level of agricultural extension services that are based on climate smart collaborations with other value chain actors;
- Level of expenditure on agricultural extension.

3.5.5 Domain 5: Agricultural climate change and innovation policies, agricultural informal institutions and rural infrastructure

With regards to Domain 5, the following 11 indicators with equal weights of 9.09% were used as summarized below.

- Digital/ICT literacy level;
- Country's poverty level;
- Country's food and nutritional security at household level;
- Country's income inequality level;
- Country's agricultural climate change, innovation and investment policies;
- Country's membership in regional and international treaties, conventions and protocol related to climate change, science, technology and innovation;
- Level of enforcement of these agricultural policies and regulations that promote climate change, science, technology and innovation in agriculture;
- Country's rural infrastructure (road networks, communication services - internet, mobile telephone services and access to cell phones);
- Country's share of rural population to total population;
- Country's rural education level? (its ability to equip learners with climate smart agricultural knowledge) and;
- Country's level of openness to indigenous or foreign agricultural climate change and innovation knowledge.

3.5.6 Domain 6: External environment to the agricultural industry

Lastly, Domain 6, had 3 indicators with equal weights of 33.33% as summarized below.

- Political system of a country with respect to supporting climate smart innovative agriculture;
- Country's general policies on science and technology for innovation and;
- Linkage between the agricultural sub-sector and other economic sectors (manufacturing, service).

4.0 National Climate STI Index for the Agriculture Sector

The six climate smart agricultural innovation domain indicators (based on data availability) were considered for the development of a national climate STI index (CSTII). The index was based on essential elements of an innovation systems domain and a number of innovation indicators per domain as detailed in the next sections.

4.1 Climate Innovation Indicator Score

Each domain had a series of classical and AIS-oriented innovation indicators herein referred to as the Climate Innovation Indicator Score (CIIS). The score per each innovation indicator was calculated as illustrated below:

$$CIIS = \left(\left(\frac{ciiw}{100}\right)\left(\frac{ciirs}{tciirs}\right)\right)$$

Where:

- CIIS = Climate Innovation Indicator Score (ranging 0 to 1);
- ciirs = Climate Innovation Indicator Rating Score ranging from 0 to 3 (0 = absent; 1 = poor; 2 = moderate; 3 = good);
- tciirs = Total Climate Innovation Indicator Rating Score (with a maximum value of 3) and
- ciiw/100 = Climate Innovation Indicator Weight (ranging from 0 – 100% as suggested by country experts).

4.2 Climate Domain Innovation Index

The Climate Innovation Indicator Score (CIIS) was used to calculate the Climate Domain Innovation Index (CDII) as illustrated below:

$$CDII = \sum_{ciis=1/n}^{n} \left((ciis_1) + \cdots + (ciis_n)\right)$$

Where:

- CDII = Climate Domain Innovation Index (ranging from 0 to 1);
- n = total number of innovation indicators in the analyzed domain;
- $ciis_1$ = 1st Climate Innovation Indicator Score in the analyzed domain and
- $ciis_n$ = last Climate Innovation Indicator Score in the analyzed domain.

4.3 National Climate Science Technology and Innovation Index for the Agriculture Sector

The weighted summation of all the Climate Domain Innovation Indices were used as the proxy Climate STI Index at country level as illustrated below:

$$CSTII = \sum_{cdii=1/n}^{n} \left(\left(\left(\frac{cdiw}{100} \right) (cdii) \right)_1 + \cdots + \left(\left(\frac{cdiw}{100} \right) (cdii) \right)_n \right)$$

Where:

- CSTII = Climate Science Technology Innovation Index at national level for country x (ranging from 0 to 1);
- n = total number of innovation domains considered in the agricultural sector in country x;
- $cdiw/100_1$ = 1st Climate Domain Indicator Weight (ranging from 0 – 100% as suggested by country x experts);
- $cdiw/100_n$ = last Climate Domain Indicator Weight (ranging from 0 – 100% as suggested by country x experts);
- $cdii_1$ = 1st Climate Domain Innovation Index for country x (0 – 1) and
- $cdii_n$ = last Climate Domain Innovation Index for country X (0 – 1).

5.0 Interpretation and Implied use of Generated Indices

5.1 Climate Domain Innovation Index (CDII)

The CDII is linear in nature ranging from 0 to 1 (0% to 100%), where figures close to 1(100%) implied highest level of climate STI inclusion in a specific agricultural domain and figures close to 0 (0%) implied otherwise. The CDII can also be grouped into an ordered categorical version as follows: poor CDII: 0 – 0.5 (0 – 50%): moderate CDII: 0.51 – 0.74 (51% - 74%): good CDII: 0.75 – 1 (75% - 100%). Domains with poor, moderate and good climate STI inclusion can therefore be easily identified at national level for strategic targeting through research, investment and policy.

5.2 Climate Science Technology Innovation Index (CSTII)

The CSTII is linear in nature ranging between 0 and 1 (0% and 100%). Figures close to 100% (1) implied the highest level of CSTI inclusion in the agriculture sector of a country and figure close o% (0) mean otherwise. An ordered categorical version of the CSTII is also possible as follows; poor CSTI inclusion: 0 – 0.5 (0 – 50%): moderate CSTI inclusion: 0.51 – 0.74 (51% - 74%): good CSTI inclusion: 0.75 – 1 (75% - 100%). A country's CSTI inclusion in the agricultural sector can therefore be easily identified and compared to other regional countries for strategic targeting through research, investment and policy.

6.0 Inclusion of Relevant climate STI in the SADC Regional Countries' Agricultural Sector

This section presents the estimated status of inclusion of relevant climate STI in the SADC regional countries' agricultural sector based on the 7 target countries listed in Figure 4. Initially the report presents statistics on country level experts who were consulted to select appropriate indicators and to provide guidance in determining their relative weight in terms of inclusion of climate STI in the agricultural sector (thus validating the index), based on their expert opinion as illustrated in Figure 4.

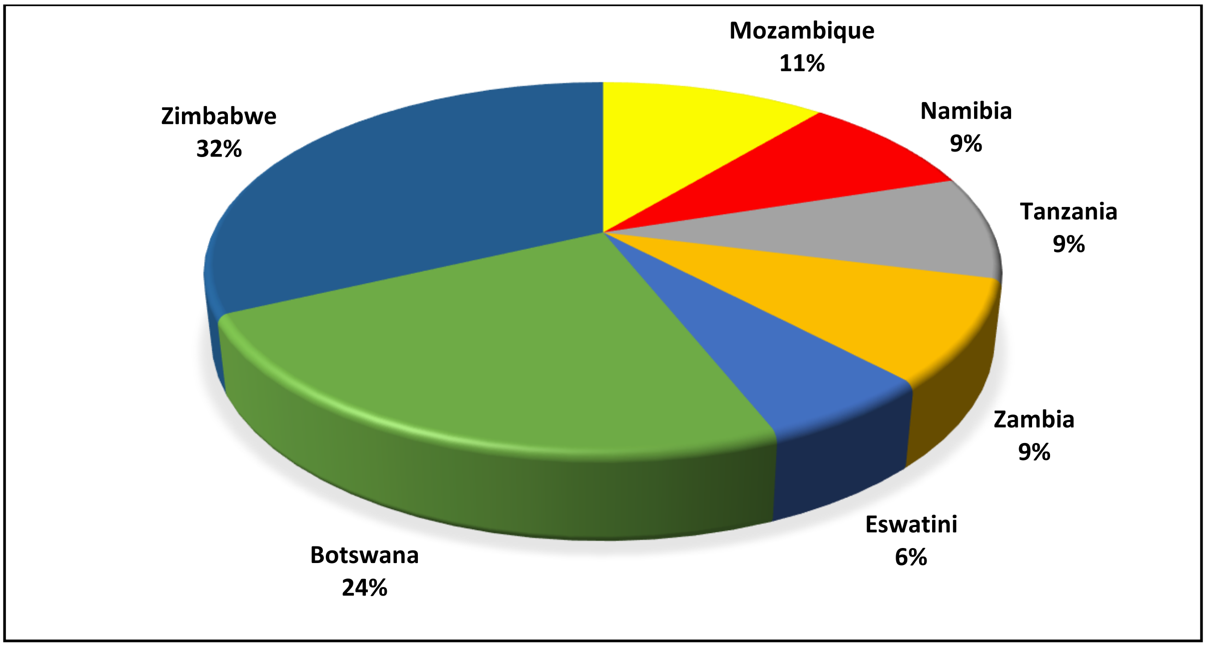

Figure 4: Distribution of experts by country

A majority of the experts consulted were from Zimbabwe (32%), Botswana (24%) and Mozambique (11%). Eswatini had the least number of experts (6%) consulted mainly because of the current political challenges in the country. Thus far, most of the information used for Eswatini for this report was obtained from secondary literature.

The next section presents the distribution of country experts consulted across the agricultural innovation system as illustrated in Figure 5.

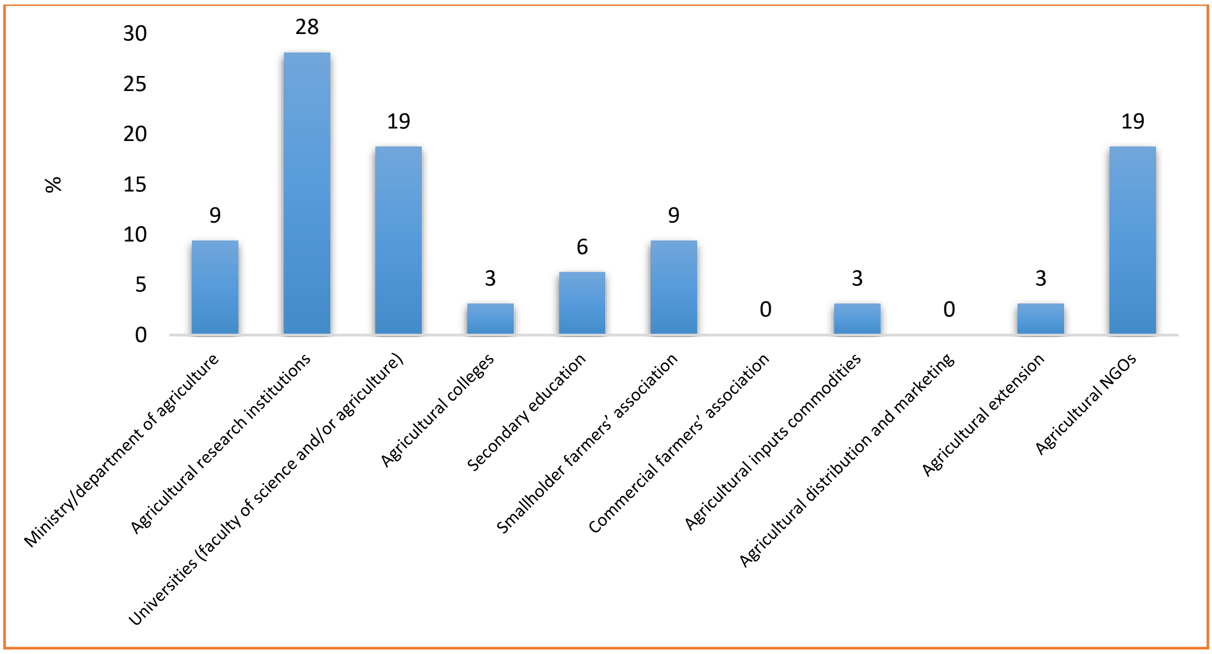

Figure 5: Distribution of country experts across the agricultural innovation system

For purposes of capturing the climate smart agricultural innovation system and bearing in mind that different agricultural stakeholders may perceive climate smart innovation differently, the country experts were selected from different agricultural subsectors (Läpple, Renwick and Thorne, 2015). These included; ministries of agriculture (9%), research institutions (28%), universities (19%), agricultural colleges (3%), secondary education (6%), smallholder farmers associations (9%), commercial farmers associations (0%), agricultural inputs and commodities (3%), agricultural distribution and marketing (0%), agricultural extension (3%) and agricultural NGOs (19%).

6.1 Climate Domain Innovation Indicators

The following domains were considered for the purposes of estimating the status of inclusion of relevant climate STI in the SADC regional countries' agricultural sector.

- Domain 1: Agricultural innovation outcomes and sectoral performance (16 indicators, both classical and AIS – oriented indicators with equal weights).
- Domain 2: Climate smart agricultural research and education system (25 indicators, both classical and AIS – oriented indicators with equal weights).
- Domain 3: Climate smart agricultural value chains (3 indicators, both classical and AIS – oriented indicators with equal weights).
- Domain 4: Climate and innovation smart bridging institutions (extension system) (6 indicators, both classical and AIS – oriented indicators with equal weights).
- Domain 5: Agricultural climate change and innovation policies, agricultural informal institutions and rural infrastructure (11 indicators, both classical and AIS – oriented indicators with equal weights).
- Domain 6: External environment to the agricultural industry (3 indicators, both classical and AIS – oriented indicators with equal weights).

Guided by country experts' opinions, the following weights were given to different domains as illustrated in Figure 6. The performance of an agricultural system is expected to influence the overall performance of the agricultural sector (Spielman and Birner, 2008). Thus far, sectorial performance is a good proxy measure of an agricultural innovation system that include climate STI. Against this background and guided by opinions of country experts, a weight of 19% was given for Domain 1.

Climate smart agricultural research and education system of a country is expected to generate knowledge and technology that enhance agricultural yields and outputs as well as promoting the agricultural value chain (inbound logistics, operations, outbound logistics, marketing & sales, and services). Thus far, a weight of 20% was given for Domain 2.

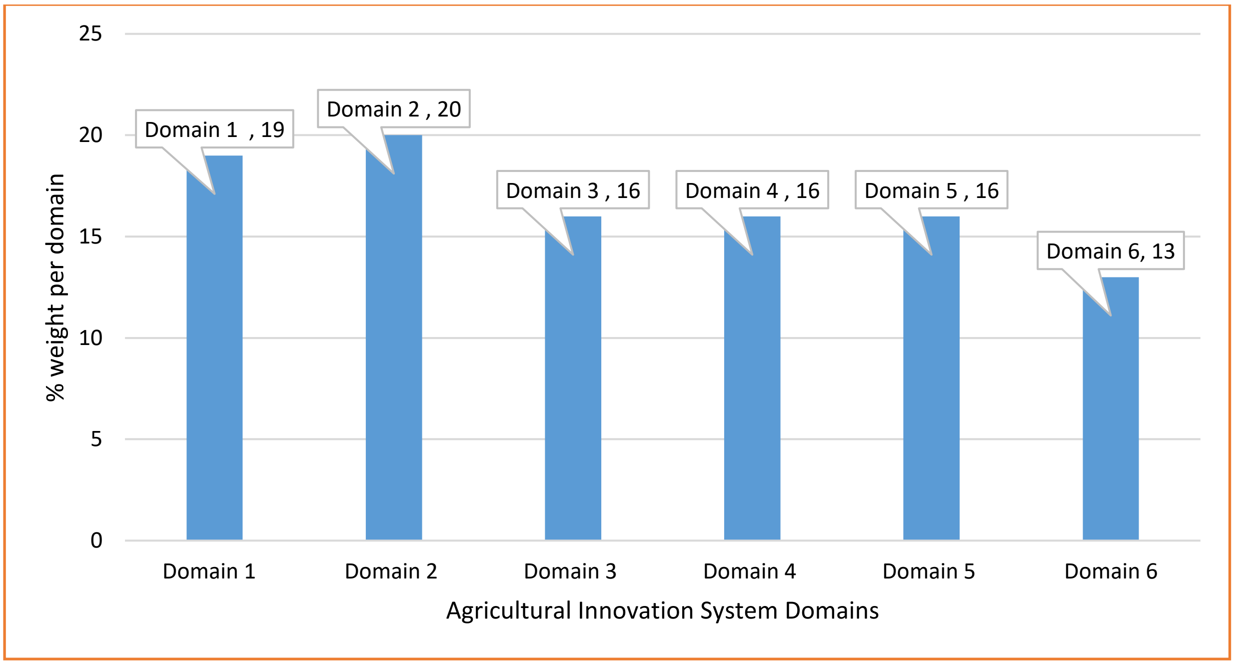

Figure 6: Agricultural Innovation System Domains and Weights

Climate smart agricultural value chains represents the business domain of the agricultural innovation system (Kaplinsky and Morris, 2001) driven by the research and education system of a country as well as its innovative capacity (Spielman and Birner, 2008). Growth of a country's climate smart agricultural value chains, especially among the smallholder farming subsector is expected to trigger multiple socio-economic, environmental and productivity benefits worth promoting. A weight of 16% was therefore given for Domain 3.

Climate and innovation smart bridging institutions (extension system) presents critical networks for supporting farmers and rural farming households. A weight of 16% was also given for Domain 4. Climate smart agricultural policies, formal institutions, rural infrastructure, informal institutions and frame conditions provides enabling environment for agricultural innovation and growth (Spielman and Birner, 2008). Herein, a weight of 16% was given for Domain 5.

Lastly, external environment to the agricultural industry also plays a significant role in a country's agricultural innovation system (Spielman and Birner, 2008). Linkages with other economic sectors like manufacturing and services create demand and new knowledge (Spielman and Birner, 2008) capable of sending positive signals to the agricultural process and innovation. General science and technology policies of a country also derive formulation of specific agricultural climate and innovation policies. Also, the political system of a country influences the degree to which a country is integrated to regional and international organizations, treaties and conventions (Spielman and Birner, 2008). A weight of 13% was therefore given for Domain 6.

6.2 Climate Domain Innovation Index

This section presents the estimated climate domain innovation indices based on the domain innovation indicators (classical and AIS – oriented indicators).

6.2.1 Estimated climate domain innovation indicator indices for Botswana

This section summarizes the estimated climate domain innovation indicator indices for Botswana as illustrated in Figure 7.

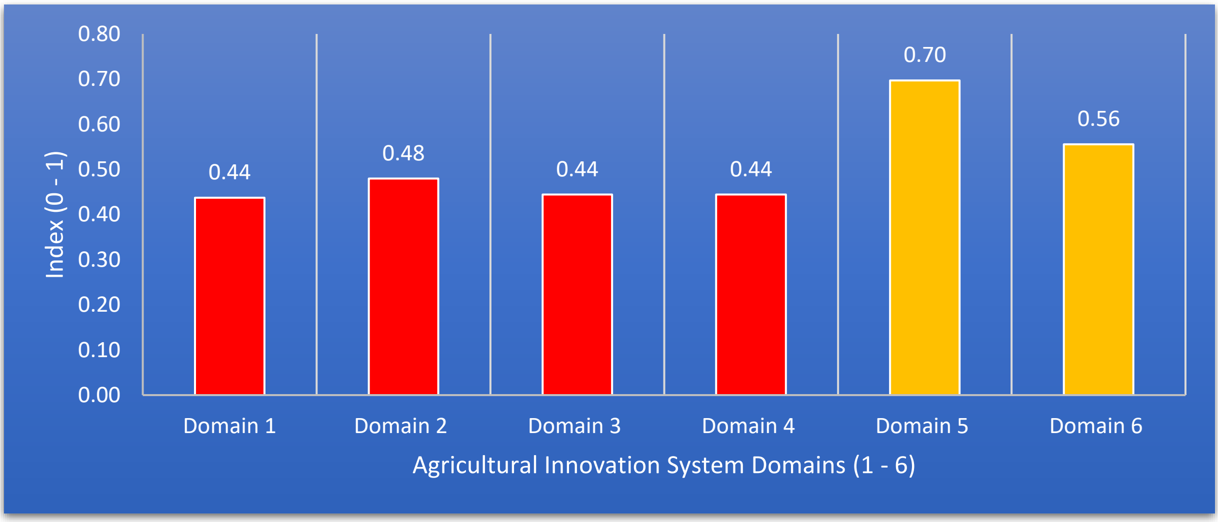

Figure 7: Estimated domain innovation indicator indices for Botswana

The results reveal low indices in Domains; 1 to 4 and moderate indices in Domains 5 and 6. With reference to "Domain 1: Agricultural innovation outcomes and sectoral performance", a climate domain innovation index of 44% was estimated. This was mainly attributed to a low agricultural GDP (2.14%), low total agricultural factor productivity (2.2%), low crop yields (0.1t/ha) and a low livestock off take (6.6%) especially among smallholder farming households.

For Domain 2, a climate Domain innovation index of 48% was estimated. This was influenced by the following variables;

- Low agricultural research intensity (2.27%),
- Low female agricultural researchers per capita (0.00137%),
- Poor ICT devices and services for the research and education system of the country,
- Poor collaboration between academia and agricultural value chains actors,
- Poor research and development expenditure of capital investments and
- Low inclusion of climate change, science, technology and innovation issues in the research and education system.

The revealed index of 48% suggests a general agricultural research and education system that poorly accommodates climate smart knowledge and technology creation leading to the poor agricultural sectoral performance as revealed in Domain 1.

Results for Domain 3 reveal a climate domain innovation index of 44% mainly caused by a low share and growth rate of agricultural value chains especially among smallholder farmers. The findings suggests low climate smart value chain integration in the country.

A climate domain innovation index of 44% was estimated for Domain 4, possibly explained by several factors. Such factors as that the country has low expenditure on agricultural extension services, poor frequency of training and skills upgrades related to climate change for agricultural extension agents and low level of agricultural extension services that are based on climate smart collaborations with other value chain actors. Despite a good farmer to extension agent ratio estimates reported in country, a generic agricultural research and education system that poorly accommodate climate smart knowledge and technology constantly supply the agricultural extension system with graduates who are poorly equipped to handle climate smart agricultural extension services.

With respect to Domain 5, a climate domain innovation index of 70% was estimated for Botswana. The country has moderate agricultural climate change, innovation and investment policies, moderate rural infrastructure, low rural population (29%), high literacy level (87%), low food insecurity level (22.2%), high Gini Index (53,3) and a fair level of openness to indigenous or foreign agricultural climate change and innovation knowledge.

A climate domain innovation index of 56% was estimated for Domain 6. Moderate political system and general policies on science and technology for innovation possibly explain the moderate index. These policies provide a fair integration of the country to regional and international organisations as well as formulation of climate smart agricultural innovation policies.

6.2.2 Estimated climate domain innovation indicator indices for Eswatini

This section summarizes the estimated climate domain innovation indicator indices for Eswatini as summarised in Figure 8. The results reveal low indices in Domains 1, 2, 3, 4, 6 and moderate index in Domains 5. A climate domain innovation index of 48% was estimated for Domain 1. This is mainly attributed to a low agricultural GDP (9.1%), low total agricultural factor productivity (0.4%), low crop yields (1.1t/ha) and low livestock off-take especially among smallholder farming households.

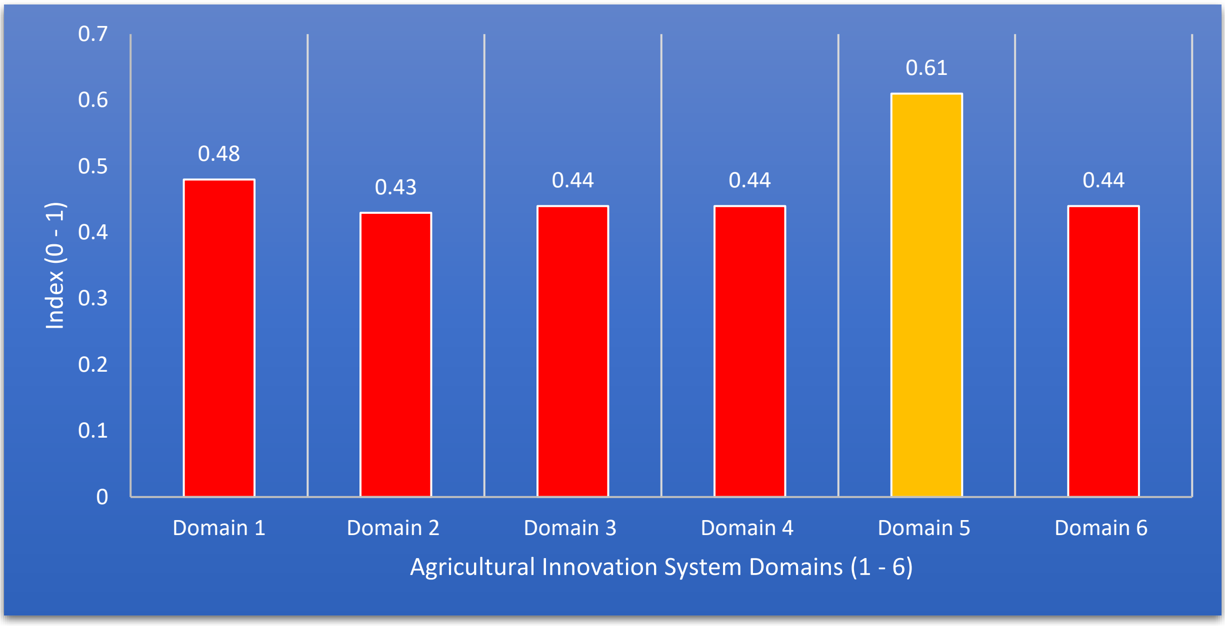

Figure 8: Estimated domain innovation indicators indices for Eswatini

For Domain 2, a climate domain innovation index of 43% was estimated mainly influenced by; low agricultural research intensity (0.7%), low agricultural researchers per capita (0.002%), poor ICT devices and services for the research and education system of the country, poor collaboration between academia and agricultural value chains actors, poor research and development expenditure of capital investments and low inclusion of climate change, science, technology and innovation issues in the research and education system.

Results for Domain 3 reveal a climate domain innovation index of 44% mainly caused by a low share and growth rate of agricultural value chains especially among smallholder farmers. These findings suggests low climate smart value chain integration in the country. A climate domain innovation index of 44% was estimated for Domain 4. The country has low expenditure on agricultural extension services, poor frequency of training and skills upgrades related to climate change for agricultural extension agents and low level of agricultural extension services that are based on climate smart collaborations with other value chain actors.

With respect to Domain 5, a climate domain innovation index of 61% was estimated. The country has moderate agricultural climate change, innovation and investment policies, moderate rural infrastructure, high literacy level (88%), low poverty level (29,2%) and a fair level of openness to indigenous or foreign agricultural climate change and innovation knowledge. A climate domain innovation index of 44% was estimated for Domain 6. Poor linkage between the agricultural sub-sector and other economic sectors (manufacturing, service) in the country limits the growth of the agricultural sector.

6.2.3 Estimated climate domain innovation indicator indices for Mozambique

A summary of the estimated climate domain innovation indicator indices for Mozambique is presented in this section as illustrated in Figure 9. Mozambique had low indices in Domains 1 to 5 and a moderate index for Domain 6. A climate domain innovation indicator index of 40% was estimated for Domain 1. Possible drivers include a moderate agricultural GDP (26.03%), negative total agricultural factor productivity (-5,4%), low major cereal crop yields (0.8t/ha) and a low livestock off take (8.5%) especially among smallholder farming households.

For Domain 2, a climate domain innovation indicator index of 39% was estimated. Possible triggers include; low agricultural research intensity (0.43%), low agricultural researchers per capita, poor ICT devices and services for the research and education system of the country and poor collaboration between academia and agricultural value chains actors. The country's agricultural research and education system therefore poorly accommodates climate smart knowledge and technology creation, a possible reason why the agricultural sectoral performance is also low.

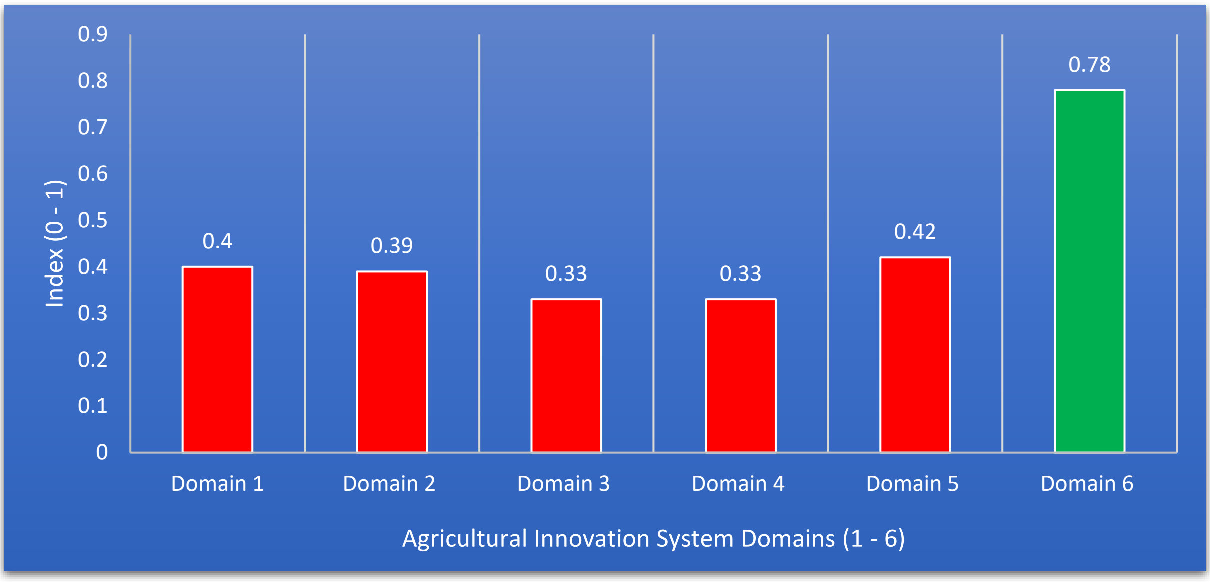

Figure 9: Estimated domain innovation indicators indices for Mozambique

The climate smart agricultural value chains (Domain 3) domain innovation indicator index of 33% was estimated for the country. Possible drivers of the low index include a low share and growth rate of the agricultural value chains for both commercial and smallholder farmers. The climate and innovation smart bridging institutions (extension system) domain innovation indicator index was estimated at 33%. The country has low expenditure on agricultural extension services, poor farmer to extension ratio, poor frequency of training and skills upgrades related to climate change for agricultural extension agents and low level of agricultural extension services that are based on climate smart collaborations with other value chain actors.

With respect to Domain 5 (Climate smart agricultural policies, formal institutions, rural infrastructure, informal institutions and frame conditions), a climate domain innovation index of 42% was estimated for Mozambique. The country has a low level of enforcement of agricultural policies and regulations that promote climate change, science, technology and innovation in agriculture, poor rural infrastructure (road networks, communication services - internet, mobile telephone services and access to cell phones), high rural population (63%), moderate literacy level (61%), moderate food insecurity level (40.5%) and a high Gini Index (54).

External environment to the agricultural industry for Mozambique was very good as revealed by a climate domain innovation index of 78%. The political system of Mozambique supports climate smart innovative agriculture and the agriculture industry is well linked with other economic sectors like manufacturing and services.

6.2.4 Estimated climate domain innovation indicator indices for Namibia

This section presents climate domain innovation indicator indices for Namibia as summarised in Figure 10.

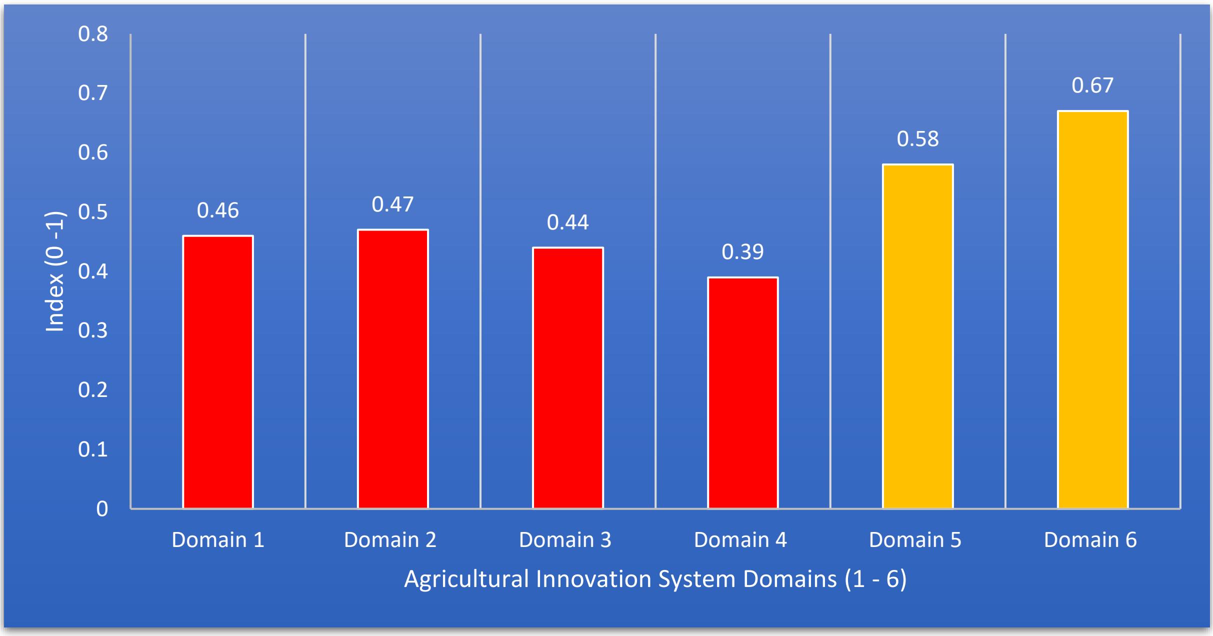

Figure 10: Estimated domain innovation indicators indices for Namibia

Results reveal that Namibia has low indices in Domains 1 to 4 and moderate indices in Domain 5 and 6. The agricultural innovation outcomes and sectoral performance, for Namibia had an estimated climate domain innovation indicator index of 46%. Contributing factors include; a low agricultural GDP (9.03%), low agricultural factor productivity (0.6%) and a low livestock off take (7%) especially among smallholder farming households.

Namibia's climate smart agricultural research and education system had an estimated climate domain innovation indicator index of 47%. Low agricultural research intensity (3,09%), low agricultural researchers per capita, poor ICT devices and services for the research and education system of the country and poor collaboration between academia and agricultural value chains actors explains the low domain index.

The climate smart agricultural value chains for Namibia had an estimated climate domain innovation indicator index of 44%. Possible drivers of the low index include a low share and growth rate of the agricultural value chains in the country and more importantly among smallholder farmers.

Namibia's climate and innovation smart bridging institutions (extension system) had an estimated climate domain innovation index of 39%. Namibia has low expenditure on agricultural extension services, poor farmer to extension ratio, poor frequency of training and skills upgrades related to climate change for agricultural extension agents and low level of agricultural extension services that are based on climate smart collaborations with other value chain actors.

Climate smart agricultural policies, formal institutions, rural infrastructure, informal institutions and frame conditions for Namibia had an estimated climate domain innovation indicator index of 58%. This is explained by the country's good membership to regional and international treaties that promote climate change, science, technology and innovation, low share of rural population to total population (48%), high literacy level (92%) and low food insecurity level (32.1%).

Namibia's external environment to the agricultural industry is moderate with an estimated climate domain innovation indicator index of 67%. The political system of the country supports climate smart innovative agriculture and the country's general policies on science and technology for innovation are fairly good.

6.2.5 Estimated climate domain innovation indicator indices for Tanzania

This section summarizes the estimated climate domain innovation indicator indices for Tanzania as illustrated in Figure 11.

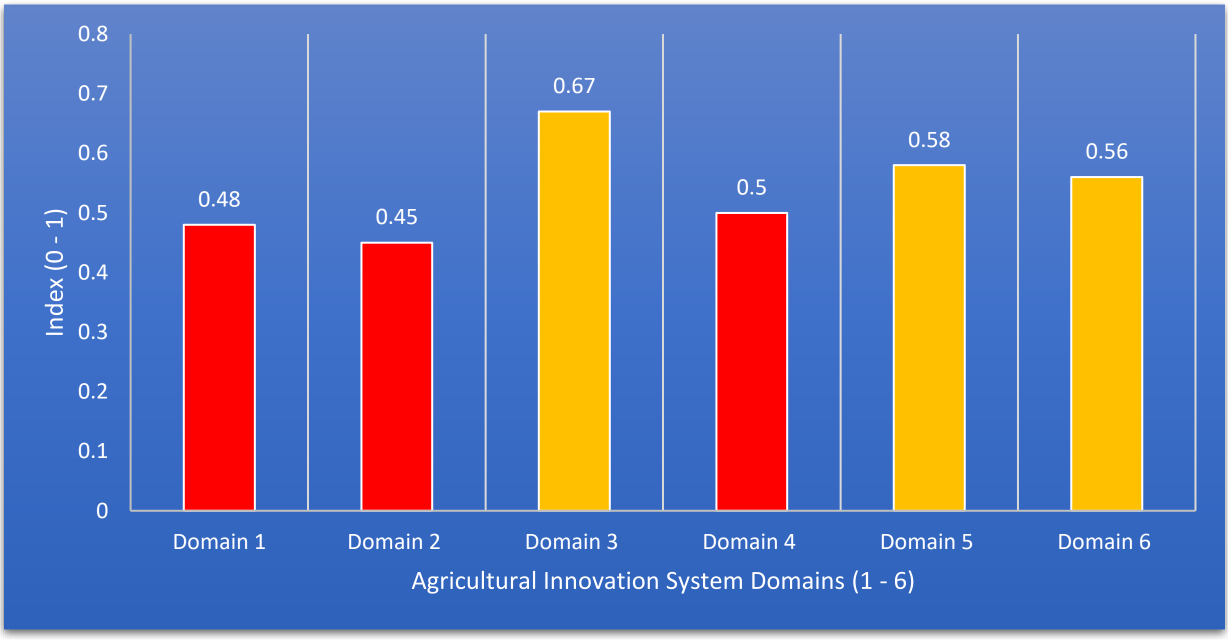

Figure 11: Estimated domain innovation indicators indices for Tanzania

Tanzania has moderate indices in almost all domains with the exception of Domain 1 and 2. The agricultural innovation outcomes and sectoral performance, for the country had an estimated index of 48%. Contributing factors include low agricultural factor productivity (1.6%) and a low livestock off-take (8-13%) especially among smallholder farming households.

The country's climate smart agricultural research and education system had an estimated index of 45%. Factors like low agricultural research intensity (0.17%), low agricultural researchers per capita, low publications (peer reviewed journals and textbooks) in climate change and innovation by agricultural researchers and low agricultural students sent abroad for advanced training in climate change explains the low domain index.

The climate smart agricultural value chains for Tanzania had an estimated index of 67%. The country has a moderate growth rate of the agricultural value chains for both commercial and smallholder farmers. Tanzania's climate and innovation smart bridging institutions (extension system) had an estimated index of 50%. The country has a moderate farmer to extension ratio and the extension agents have fairly good qualifications. This is also supported by extension services which enhance climate smart agriculture and natural resources management.

Climate smart agricultural policies, formal institutions, rural infrastructure, informal institutions and frame conditions for Tanzania had an estimated index of 58%. This is explained by the country's good membership to regional and international treaties that promote climate change, science, technology and innovation, high literacy level (78%) and low food insecurity level (24.7%).

The external environment to the agricultural industry of Tanzania was moderate with an estimated index of 56%. The political system of the country fairly supports climate smart innovative agriculture and the country's general policies on science and technology for innovation are fairly good.

6.2.6 Estimated climate domain innovation indicator indices for Zambia

A summary of the estimated climate domain innovation indicator indices for Zambia is presented in this section as illustrated in Figure 12.

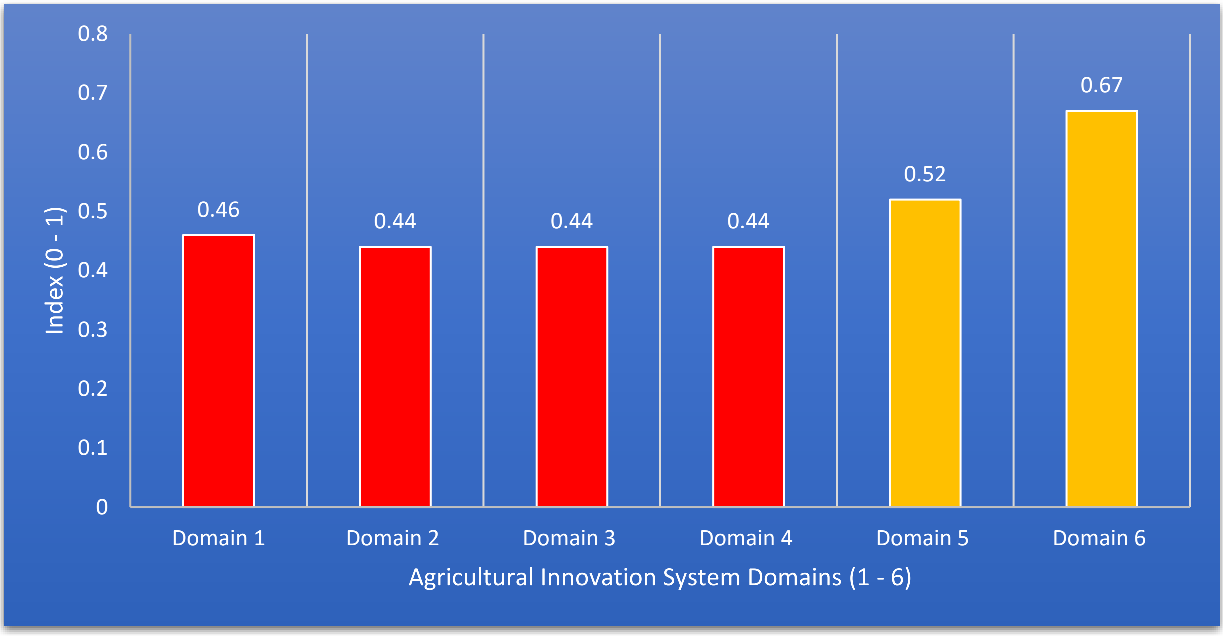

Figure 12: Estimated domain innovation indicators indices for Zambia

Zambia had low indices in almost all domains with the exception of Domain 4 and 5. The agricultural innovation outcomes and sectoral performance, for the country had an estimated index of 46%. Contributing factors include low agricultural factor productivity (2.73%), negative total agriculture factor productivity (- 6.2%), low average cereal yields per hectare (1.5t/ha) and a low livestock off take (5-10%) especially among smallholder farming households.

The country's climate smart agricultural research and education system had an estimated index of 44%. Factors like low agricultural research intensity (0.51%), low agricultural researchers per capita, low publications (peer reviewed journals and textbooks) in climate change and innovation by agricultural researchers, low R&D spending allocation in capital investments, and low climate smart, science and technology related collaborations between academia and value chain actors explains the low domain index.

The climate smart agricultural value chains for Zambia had an estimated index of 44%. The country has a low growth rate of the agricultural value chains for the commercial agriculture subsector. Zambia's climate and innovation smart bridging institutions (extension system) has an estimated index of 44%. The country has a low expenditure on agricultural extension, low farmer to extension ratio and the extension agents' frequency of training and skills upgrades related to climate change is also very low.

Climate smart agricultural policies, formal institutions, rural infrastructure, informal institutions and frame conditions for Zambia had an estimated index of 52%. These findings may be explained by the country's moderate membership to regional and international treaties that promote climate change, science, technology and innovation, high literacy level (87%) and low food insecurity level (23.2%).

The external environment to the agricultural industry of Zambia was moderate with an estimated index of 67%. The political system of the country fairly supports climate smart innovative agriculture and the country's general policies on science and technology for innovation are fairly good. This is further complemented by a moderate linkage between the agricultural sub-sector and other economic sectors (manufacturing, service).

6.2.7 Estimated climate domain innovation indicator indices for Zimbabwe

This section summarizes the estimated climate domain innovation indicator indices for Zimbabwe as illustrated in Figure 13. Zimbabwe has low indices in the first two Domains and moderate indices in the third, fourth and fifth Domains. The agricultural innovation outcomes and sectoral performance, for the country had an estimated index of 48%. Contributing factors include a negative total agricultural factor productivity (-5.5%), low average cereal yields per hectare (1.15t/ha) and a low livestock off take rate (9%) especially among smallholder farming households.

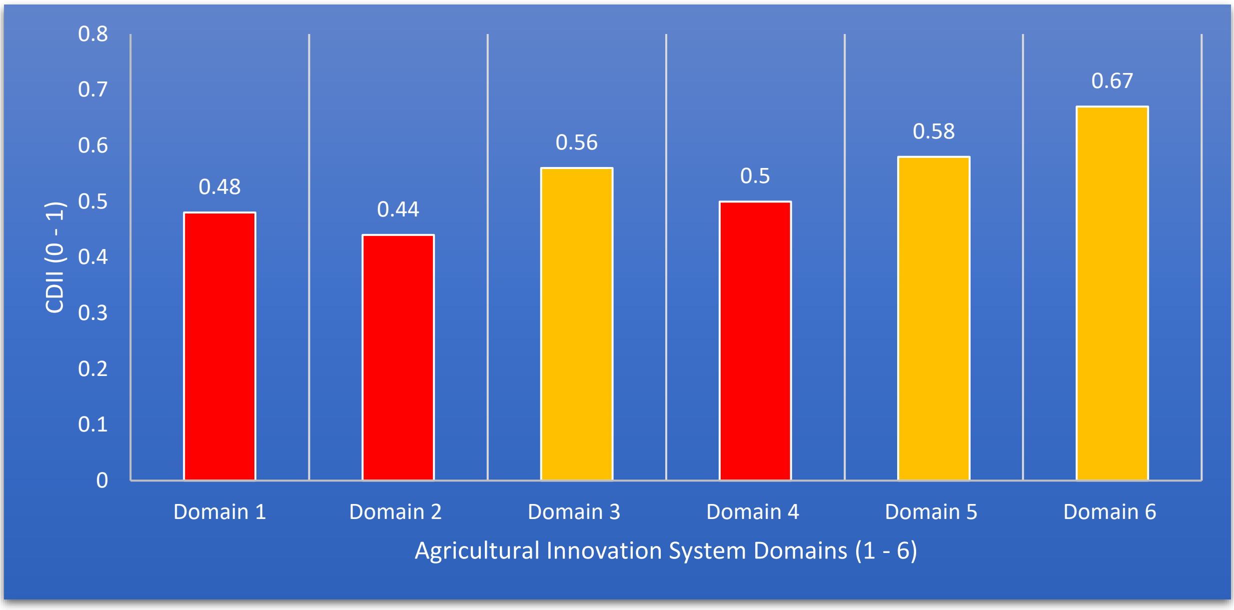

Figure 13: Estimated domain innovation indicators indices for Zimbabwe

The country's climate smart agricultural research and education system had an estimated index of 44%. Factors like low agricultural research intensity (1.39%), low agricultural researchers per capita, low publications (peer reviewed journals and textbooks) in climate change and innovation by agricultural researchers, low R&D spending allocation in capital investments, low ICT devices and services available to the research and education system and low climate smart, science and technology related collaborations between academia and value chain actors explains the low domain index. The climate smart agricultural value chains for Zimbabwe had an estimated index of 56%. The country has a moderate growth rate of the agricultural value chains especially among the commercial agriculture subsector.

Zimbabwe’s climate and innovation smart bridging institutions (extension system) had an estimated index of 50%. The country’s extension agents have moderate qualifications (certificate, diploma, degree) broadly spread in strategic agricultural areas (crop, animal, agribusiness). This is supported by a supportive agricultural extension services that are based on climate smart collaborations with other value chain actors.

Climate smart agricultural policies, formal institutions, rural infrastructure, informal institutions and frame conditions for Zimbabwe had an estimated index of 58%. These findings may be explained by the country’s moderate membership to regional and international treaties that promote climate change, science, technology and innovation, high literacy level (89%), moderate rural education capable of equipping learners with climate smart agricultural knowledge, moderate poverty level (33.9%) and moderate food insecurity level (32.1%).

The external environment to the agricultural industry of Zimbabwe was moderate with an estimated index of 67%. The political system of the country fairly support climate smart innovative agriculture and the country's general policies on science and technology for innovation are fairly good. This is complemented by a moderate linkage between the agricultural sub-sector and other economic sectors (manufacturing, service).

6.3 Domain innovation indicator comparison across countries

Figure 14 summaries performance of all domains innovation indicators (1 - 6) across the 7 SADC countries. Domain 1 (Agricultural Innovation Outcomes and Sectoral Performance) and 2 (Climate smart agricultural research and education system) had the lowest indices for all countries. These findings suggests low climate smart innovations in the agricultural industry of all the country negatively affecting the performance of their agricultural industry. The revealed low index for Domain 2 further suggest a general agricultural research and education system in all countries that poorly accommodates climate smart knowledge and technology creation leading to the poor agricultural sectoral performance as revealed in Domain 1.

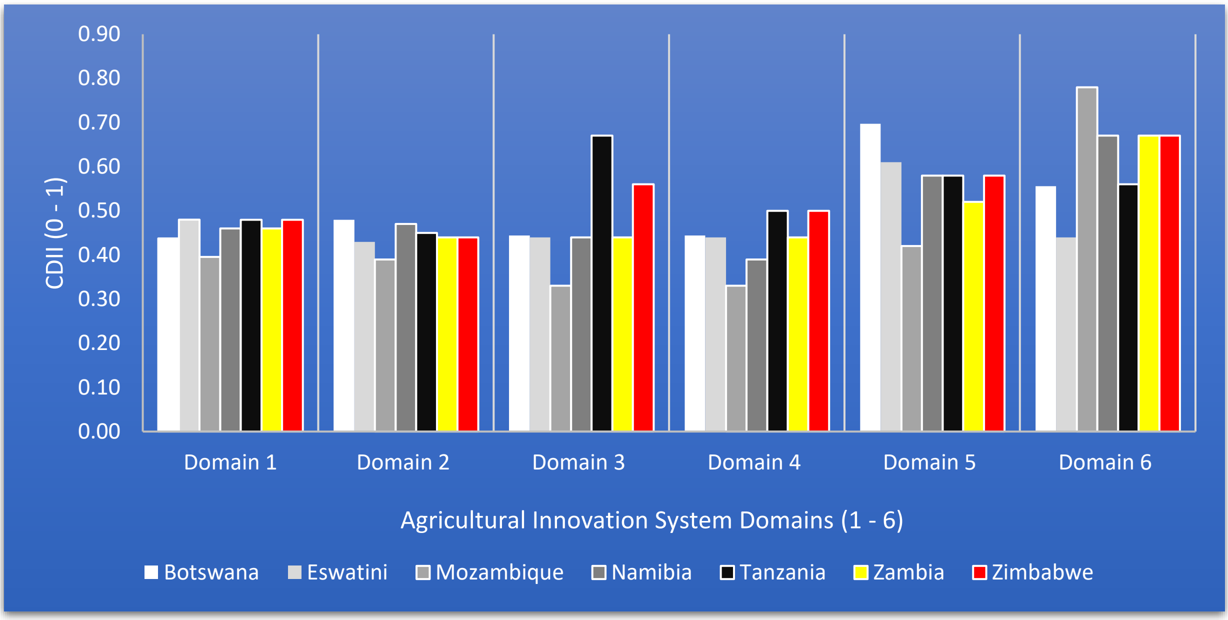

Figure 14: Agricultural Innovation System Domains innovation indicators country comparisons

Domain 3 (Climate smart agricultural value chains) also had the lowest indices for the majority of the countries with the exception of Tanzania and Zimbabwe. For countries with indices below 50%, this is mainly triggered by low participation of smallholder farmers in climate smart value chains and a low share and growth rate of agricultural value chains at country level.

All countries also had low indices for Domain 4 (Climate and innovation smart bridging institutions (extension system)). Several triggers of this low index include low expenditure on agricultural extension services, high ratio of farmers to extension agents, poor frequency of training and skills upgrades related to climate change for agricultural extension agents and limited agricultural extension services that are based on climate smart collaborations with other value chain actors.

All countries had moderate indices for Domain 5 (Agricultural climate change and innovation policies, agricultural informal institutions and rural infrastructure) with the exception of Mozambique. Poor rural infrastructure (road networks, communication services - internet, mobile telephone services and access to cell phones) and enforcement of agricultural policies and regulations that promote climate change, science, technology and innovation in agriculture are possible challenges faced by a majority of these countries.

Lastly, all countries had moderate to good indices for Domain 6 (Climate smart external enabling environment). The political systems of all countries and general policies on science and technology for innovation are highly supportive with respect to supporting climate smart innovative agriculture with good linkage between the agricultural sub-sector and other economic sectors (manufacturing, service).

6.4 Climate Science Technology Innovation Index

This section presents the estimated Climate Science Technology Innovation Index (CSTII) for all countries (Figure 15) for the purpose of estimating the status of inclusion of relevant climate STI in the SADC regional countries' agricultural sector. Results indicate an estimated index of 51% for Botswana possibly driven by its moderate agricultural climate change and innovation policies, agricultural informal institutions and rural infrastructure (Domain 5: Index = 0.70) and a moderate climate smart external enabling environment (Domain 6: Index = 0.56). These moderate domains are however negatively affected by Domains 1 (Index = 0.44), 3 (Index = 0.44) and 4

(Index = 0.44) with the lowest indices. Botswana therefore had a moderate (51%) inclusion of climate STI in its agricultural sector.

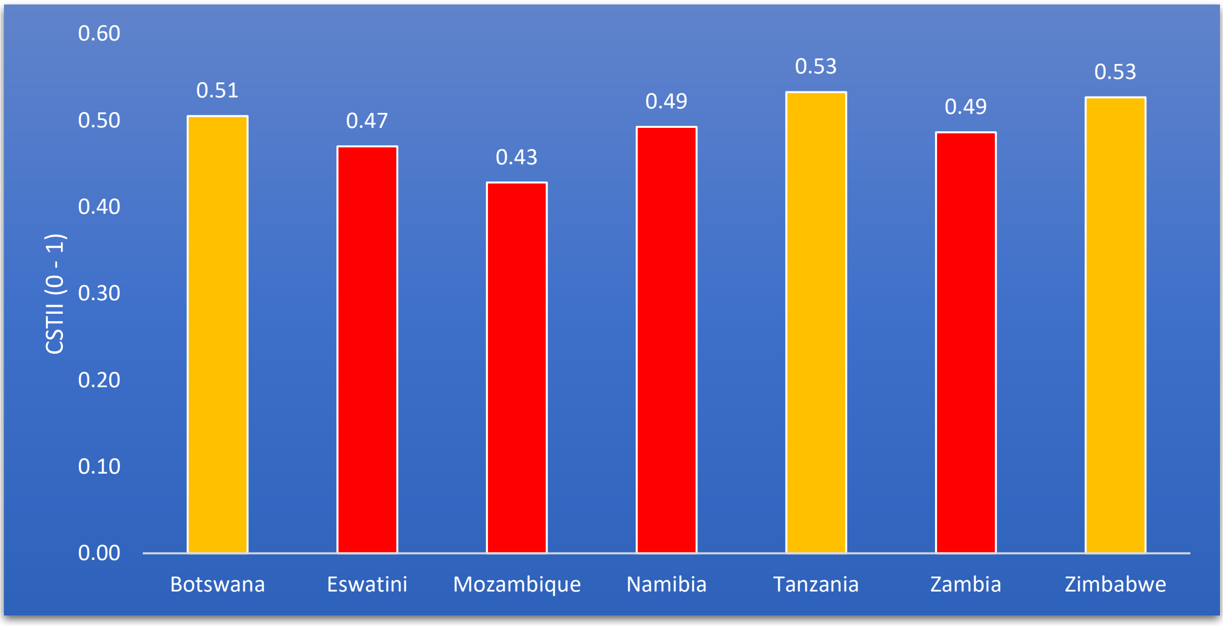

Figure 15: Estimated Climate Science Technology Innovation Index (CSTII) for all countries

Estimates for Eswatini reveal an estimated index of 47% explained by a moderate agricultural climate change and innovation policies, agricultural informal institutions and rural infrastructure (Domain 5: Index = 0.61). This is however negatively affected by all other domains with low indices. Against this background, Eswatini had a low (47%) inclusion of climate STI in its agricultural sector.

Mozambique had an estimated index of 43%. The country has good climate smart external enabling environment (Domain 6: Index = 0.78). This is however negatively affected by all other domains with low indices especially Domains 3 (Index = 0.33) and 4 (Index = 0.33). Thus far, Mozambique had a low (43%) inclusion of climate STI in its agricultural sector.

Estimates for Namibia reveal an estimated index of 49% explained by a moderate agricultural climate change and innovation policies, agricultural informal institutions and rural infrastructure (Domain 5: Index = 0.52) and a moderate climate smart external enabling environment (Domain 6: Index = 0.67). These are however negatively affected by Domain 4 with the lowest index (0.39). Namibia therefore had a low (49%) inclusion of climate STI in its agricultural sector.

Tanzania had an estimated index of 53%. The country has moderate climate smart agricultural value chains (Domain 3: Index = 0.67), moderate climate and innovation smart bridging institutions (extension system) (Domain 4: Index = 0.50), moderate agricultural climate change and innovation policies, agricultural informal institutions and rural infrastructure (Domain 5: Index = 0.58) and a moderate climate smart external enabling environment (Domain 6: Index = 0.56). This is however negatively affected by Domain 2 with a low index (0.45) and Domain 1 (Index = 0.48). Tanzania therefore had a moderate (53%) inclusion of climate STI in its agricultural sector.

Estimates for Zambia indicate an estimated index of 49% explained by a moderate agricultural climate change and innovation policies, agricultural informal institutions and rural infrastructure (Domain 5: Index = 0.52) and a moderate climate smart external enabling environment (Domain 6: Index = 0.67). These are however negatively affected by Domain 2 (Index = 0.44) and Domain 3 (Index = 0.44) with the lowest indices. Zambia therefore had a low (49%) inclusion of climate STI in its agricultural sector.

Lastly, Zimbabwe had an estimated index of 53%. The country has moderate climate smart agricultural value chains (Domain 3: Index = 0.56), moderate climate and innovation smart bridging institutions (extension system) (Domain 4: Index = 0.50), moderate agricultural climate change and innovation policies, agricultural informal institutions and rural infrastructure (Domain 5: Index = 0.58) and a moderate climate smart external enabling environment (Domain 6: Index = 0.67). This is however negatively affected by Domain 1 with a low index of 0.48 and Domain 2 (Index = 0.44). Zimbabwe had therefore a moderate (53%) inclusion of climate STI in its agricultural sector.

7.0 Correlation between Climate STI Index and Country Level Agricultural Sectorial Performance (Domain 1)

This section presents an assessment of the correlation between a good CSTI index with sectoral performance (resilience) as illustrated in Table 1, 2 and 3. The analysis estimates the potential of the climate STI index to predict resilience as measured by the agricultural sectorial performance at country level. Table 1 presents the correlation between CSTI index and agricultural sectorial performance (resilience).

Table 1: Correlation between CSTI Index and Domain 1 (Agricultural Sectorial Performance) for the seven SADC countries

Correlations			
		Climate STI Index	Agricultural Sectorial Performance (Domain 1)
Climate STI Index	Pearson Correlation	--	
	N	7	
Agricultural Sectorial Performance (Domain 1)	Pearson Correlation	.716*	--
	Sig. (1-tailed)	.035	
	N	7	7
*. Correlation is significant at 5% significance level (1-tailed).			

Results indicate a statistically significant (p-value = 0.35) and positive strong correlation (coefficient = 0.716) between climate STI index and the agricultural sectorial performance at 5% significance level. These findings suggests that an increase in climate STI index is associated with an increase in Agricultural Sectorial Performance of a country. This may imply that an increase in climate STI at country level is more likely to boost the agricultural sectorial performance. This could possibly be explained by the resilience of the agricultural sector to climate change necessitated by climate smart agricultural innovations.

To complement the above correlation results, given that correlations provides a systematic relationship which doesn't necessarily imply causation (Daniel, 1990; Abdi, 2007), a linear regression analysis was conducted as detailed in Table 2. With reference to the overall fit of the linear regression model, the obtained R^2 (0.512) suggests that the predictor variable (climate STI index) is significant to explain the dependent variable (Agricultural Sectorial Performance - Domain 1). Regression estimates reveal that a positive unit change in climate STI index at country level, increases a country's Agricultural Sectorial Performance (resilience) by 0.591 units. These results suggest that increasing a country's climate STI positively influences the probability of a country to increase its Agricultural Sectorial Performance, possibly as a result of increased productivity through innovative technologies and resilience of the agricultural sector to climate change as a result of climate smart technologies.

Table 2: Linear Regression Estimates

Linear Regression					
	Unstandardized Coefficients		Standardized Coefficients		
Model	B	Std. Error	Beta	t	Sig.
(Constant)	.166	.127		1.302	.250
Climate STI Index	.591	.258	.716	2.291	.071*

a. Dependent Variable: Domain1
b. $R^2 = 0.512$
c. *, Significant at 10% level

Lastly, an assessment of the top performing country (Tanzania) and the low performing country (Mozambique) in terms of the inclusion of climate STI as estimated by the climate STI index was done. This was done to confirm the premise that a high climate STI index is consistent with high agricultural sectorial performance (resilience) of a country. Tanzania had the highest climate STI index (0.53) and an agricultural sectorial performance (Domain 1) index of 0.48. Mozambique had the lowest climate STI index (0.43) and an agricultural sectorial performance (Domain 1) index of 0.40. The variation in Domain levels (0.48 and 0.40) was assessed, its statistical significance targeting four main agricultural sectorial performance indicators from these two countries (Agricultural GDP, total agricultural factor productivity, average staple crop yields under smallholder agriculture and livestock off-take rate under smallholder agriculture).

Null hypothesis (H_0): Tanzania and Mozambique's agricultural sectorial performance indicators are different (they are not the same).

Table 3: Hypothesis test summary

Indictors	**Countries**		**T-Test Analysis**		**Decision**
	Tanzania	**Mozambique**	**t**	**Sig. (2-tailed)**	
Agriculture GDP	26.7	26.03	78.701	.008*	Reject H_0
Total agriculture factor productivity	1.6	-5.4	-.543	.683	Retain H_0
Yields (maize)	1.5	0.8	3.286	.188	Retain H_0
Livestock off take rate	10.5	8.5	9.500	.067	Retain H_0
*. Significant at 1% level (1-tailed).					

Results indicate that agricultural GDP for the two countries is not statistically different (reject null hypothesis), while total agriculture factor productivity, yields and livestock off-take rate are statistically different (accept the null hypothesis). These findings provide sufficient evidence to suggest that there is a significant difference in the agricultural sectorial performance (Domain 1) indices for the two countries (Tanzania = 0.48 and Mozambique = 0.40). This could be explained by several factors to include the difference in the inclusion of climate STI in the agricultural sectors of these two countries as supported by a strong positive correlation between climate STI index and the agricultural sectorial performance (Domain 1) index. Thus far, correlation, regression and T-Test results support the premise that a high climate STI index is consistent with high agricultural sectorial performance (resilience) of a country.

8.0 Unique Characteristics of the Approach Used

This section presents a summary of unique characteristics of the hybrid approach used in this report to estimate the inclusion of climate STI in the agricultural sector. The hybrid approach was necessitated by the broadness of the agriculture industry and the fact that climate change and adaptation issues may be embedded in some STI commonly used in the agricultural industry.

8.1 Climate Smart Agricultural Innovation System Approach

Several previous studies have estimated the level of inclusion of STI in various agricultural subsectors at different levels (Spielman and Birner, 2008; Ariza et al., 2013; Läpple, Renwick and Thorne, 2015; Nin-Pratt, 2016). A linear approach is dominant in these studies focusing more on classical input and output indicators.

The hybrid approach used in this study departed from the linear approach and adopted a systems approach. STI in agriculture was therefore viewed as a complex web of related individuals and organizations with several linkages between components, formal and informal institutions and policies environments that influences this complex web. This created strategic agricultural innovation system domains (1 – 6) fully representing all the agricultural value chain actors. The idea was to holistically scan the level of STI inclusion in these domains rather than focusing only on classical measures normally confined in one or two subsystem of the agricultural value chain.

Bearing in mind that not all STI in agriculture are climate smart, a deliberate effort was put in place to include quantitative and qualitative estimate measures of climate change and adaptation issues in all the six domains. In some cases this was in the form of probing the level of climate change inclusion in current STI used by the agricultural value chain actors. For each of the domains, classical quantitative indicators were blended with agricultural innovation systems oriented indicators, assessing how climate STI is included in the whole agricultural value chain and various agricultural processes.

Given the challenge of data limitation, all indicators were based on more than a recombination of existing data (published data and data drawn from country level expert opinion across the agricultural subsectors). To limit expert opinion bias, country level experts were drawn from various subsectors of the agricultural value chain (ministries of agriculture, research institutions, universities, agricultural colleges, secondary education, smallholder farmers associations, agricultural inputs and commodities, agricultural extension, and agricultural NGOs) to enhance a balanced expert opinion.

To this end, the climate STI index if compared with generic STI indices a lower value should be expected because of;

- The deliberate inclusion of the climate variable (normally absent in most STI indices);
- The systems approach (that focused on classical and agricultural innovation system oriented indicators across the agricultural value chain actors) and;
- The use of country level expert opinion (who provided qualitative estimates and also acted as moderators to some published statistics for classical indicators normally absent in most generic STI indices).

9.0 Conclusion

The report presents a framework and an analytical estimation tool for assessing the level of inclusion of relevant climate STI in the agricultural sectors of the targeted 7 SADC countries. The following six domains can be used to estimate the inclusion of climate STI in the agricultural sectors of SADC countries. Domain 1: Agricultural innovation outcomes and sectoral performance. Domain 2: Climate smart agricultural research and education system. Domain 3: Climate smart agricultural value chains. Domain 4: Climate and innovation smart bridging institutions. Domain 5: Agricultural climate change and innovation policies, agricultural informal institutions and rural infrastructure. Domain 6: External environment to the agricultural industry.

Estimates at domain level for all the seven countries revealed a low (≤ 50%) inclusion of climate STI in Domain 1, 2 and 4 and a moderate inclusion in Domain 5 and 6 (with the exception of Mozambique for Domain 5 and Eswatini for Domain 6). Domain 3 also indicated a low inclusion of climate STI for most of the countries with the exception of Zimbabwe and Tanzania. The report therefore concludes that there is a moderate inclusion of climate STI in the agricultural sectors of the following countries; Botswana (51%), Tanzania (53%) and Zimbabwe (53%) and a low inclusion in the following countries; Eswatini (47%), Mozambique (43%), Namibia (49%) and Zambia (49%).

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Annex 1: Questionnaire

Background Information:

The Centre for Coordination of Agricultural Research and Development for Southern Africa (CCARDESA) is a SADC subsidiary mandated by Members States to coordinate regional cooperation in agricultural research and development. The Centre for Coordination of Agricultural Research and Development for Southern Africa (CCARDESA) is currently implementing the Comprehensive Africa Agriculture Development Programme EX Pillar 4 (CAADP-XP4) Programme on Agricultural Research and Innovation. This programme is being implemented under the EU's "Development Smart Innovation through Research in Agriculture" (DeSIRA) initiative.

In support of quality policy formulation and planning that will enhance the region's scientific and technological development, CCARDESA with the assistance of a Consultant (Prof Amon Taruvinga) are developing guidelines that will promote the inclusion of relevant climate Science, Technology and Innovation (STI) indicators into National Agricultural Investment Plans (NAIPs). The indicators are expected to facilitate agricultural transformation and to aid in the tracking of progress of STI at national, regional and continental level. This is also expected to contribute towards national, regional and continental development agenda, as well as attainment of the Sustainable Development Goals (SDGs) at a global level.

For purposes of developing relevant climate Science, Technology and Innovation (STI) indicators in the agricultural industry and assessment of the level of inclusion of these climate STI in different agricultural innovation domains, CCARDESA is kindly requesting for your expert opinion on selection of key climate STI domains & indicators with relevance to agriculture and the degree of inclusion of climate change and adaptation issues in the agricultural innovation system of your country. Your responses to the survey shall be kept in strict confidentiality and the information that you are about to give shall help CCARDESA in the development of a national level Climate Science Technology and Innovation Index (CSTII) and a general understanding of the degree to which climate change and adaptation issues are included in the agricultural innovation system of your country. There are no right or wrong answers to the questions, only your honest expert opinion.

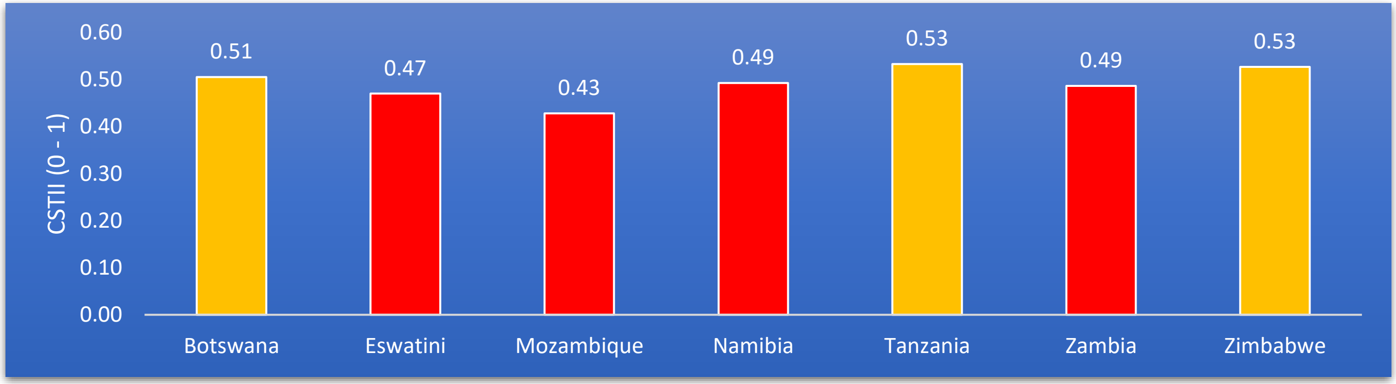
Below please find the google forms questionnaire link to use. Remember to submit the form after completing.

https://forms.gle/ZHkDJbyNsfSSdWk2A

Thank you so much for your time and responses.

Annex 2: Inclusion of relevant climate STI in the SADC regional countries' agricultural sector

Domains	Botswana			Eswatini			Mozambique			Namibia			Tanzania			Zambia			Zimbabwe		
	Low	Moderate	Good	Low	Moderate	Good	Low	Moderate	Good	Low	Moderate	Good	Low	Moderate	Good	Low	Moderate	Good	Low	Moderate	Good
Domain 1	.44			.48			.40			.46			.48			.46			.48		
Domain 2	.48			.43			.39			.47			.45			.44			.44		
Domain 3	.44			.44			.33			.44				.67		.44				.56	
Domain 4	.44			.44			.33			.39			.50			.44			.50		
Domain 5		.70			.61		.42				.58			.58			.52			.58	
Domain 6		.56		.44					.78		.67			.56			.67			.67	
Index	≤ 50	51 - 74	≥ 75	≤ 50	51 - 74	≥ 75	≤ 50	51 - 74	≥ 75	≤ 50	51 - 74	≥ 75	≤ 50	51 - 74	≥ 75	≤ 50	51 - 74	≥ 75	≤ 50	51 - 74	≥ 75



Domain 1: Agricultural innovation outcomes and sectoral performance (All countries had indices ≤ 50%)

Domain 2: Climate smart agricultural research and education system (All countries had indices ≤ 50%)

Domain 3: Climate smart agricultural value chains [All countries had indices ≤ 50% with the exception of Tanzania (67%) and Zimbabwe (56%)]

Domain 4: Climate and innovation smart bridging institutions (extension system) (All countries had indices ≤ 50%)

Domain 5: Agricultural climate change and innovation policies, agricultural informal institutions and rural infrastructure [All countries had indices between 51% and 74% with the exception of Mozambique (42%)]

Domain 6: External environment to the agricultural industry [All countries had indices between 51% and 74% with the exception of Eswatini (44%) and Mozambique (78%)]