Greenhouse Gas Observation
& Climate-Smart Agriculture

ICOS Integrated Carbon Observation System

SEACRIFOG Deliverable 7.1.

An integrated strategy for sustainable Africa-Europe research cooperation on greenhouse gas observations and food security

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Executive Summary

An integrated strategy for an African greenhouse gas (GHG) observation infrastructure is proposed in this final deliverable 7.1 of the SEACRIFOG (Supporting European and African Cooperation on Research Infrastructures for Food Security and GHG Observations) project. The strategy considers the main results of the project and significant steps made in designing an infrastructure for GHG observation in Africa. National, regional and international collaborative frameworks have been considered, for integration in climate and weather service provision. Partnership with organisations like the World Meteorological Organisation (WMO) are relevant for the proposed infrastructure. Particularly to the WMO Integrated Global Observation System (WIGOS), and the WMO Information System (WIS). Resulting data should be usable across different sectors and not only globally but nationally. The WMO Global Data Processing and Forecasting System (GDPFS) has a goal to provide integrated, seamless (from different observation systems) predictions. This is in order to have the highest return on investment through holistic systems.

On a national scale, such integrated data and expected return would have a direct correlation to Africa's economic growth. Therefore, to exclude the African national and regional economic communities at the core of any development of the infrastructure would be a big disservice to continental-driven growth. The African Science Technology Innovation Indicators initiative (ASTII) in their 3rd Africa Innovation Outlook (AOI) report had 43 countries carry out research development measurement in 2019 from only 19 countries in 2007. Such a network should be built on, in the engagement of African national ministries in conjunction with the African Union specialised technical office of the African Observatory of STI (AOSTI) whose objective is to support nations in STI indicator development (AUDA-NEPAD, 2019). This is a time (2019), when the WMO Global Observation Network (GBON) is requiring developing countries to establish a minimum requirement of surface-based observation infrastructure[1]. Political research has found that national funding correlates to national output in science and even though this is not equated to impact, science and technology remains central to economic growth (Wagner et al., 2015). The integral funding proposition in this report therefore considers African nations in the provision of basic as well as special services. A look at African public expenditure on Research and Development (PUBERD) data from the AOI III report shows a willingness that is a basis for engagement. The development of this concept for the proposed infrastructure with all the possible prospects for collaboration could not be more relevant now, and would contribute to the 17 Sustainable Development Goals of the UN 2030, which all have STI embedded in them, in addition to supporting national goals of adaptation and mitigation planning (AUDA-NEPAD, 2019).

A WMO strategy for service delivery approved in 2011 considered necessary: 1) the evaluation of user needs and decisions, 2) the linking of service development to user needs, 3) the monitoring and evaluation of service performance, 4) the sustenance of improved service delivery, 5) development of skills for service delivery and 6) the sharing of best practise and knowledge. Its implementation plan was later published by the WMO in 2014 (WMO 2015). The proposed GHG

[1] The systematic Observations Financing Facility aims to support countries in the generation and exchange of basic observational data

system concept is likewise planned here through the Programme and Innovation Management Cycle which considers the WMO needs above in time relevant phases of 1) prioritisation, 2) investment, 3) valorisation, 4) application and system improvement. Additionally, we consider the United Nations Consultative Group of Experts (CGE) recommendations for institutional arrangements in support of Measurement, Reporting and Verification (MRV) services for the national plans for mitigation and adaptation[2].

[2] UN CGE Toolbox reference.

1 Introduction

Africa is increasingly affected by but also causing climate change. Transformation of natural ecosystems to arable land, necessary for meeting 21st century food demands (Ramankutty et al., 2018) will change the continental carbon cycle and weaken the currently strong African carbon sink. African economic growth is proceeding at unprecedented rapidity since the major part of the global population growth in the 21st century is projected to occur in Africa (Cervantes-Godoy et al., 2014). It can be expected that industrialisation, transport and power generation emission will follow suit (Liousse et al., 2014). For all these reasons, Africa can be expected to go from a footnote (~4%) to the global anthropogenic GHG emission inventories, to a major item (20%) over the next three decades while it is already strongly affected by climate change and its vulnerability to extreme weather and climate conditions may increase during its further development.

Infrastructure for environmental observation in general and – more specifically - quantifying the GHG sources and sinks as well as the climate feedbacks on the carbon cycle in Africa is of urgent necessity to generate knowledge that informs decision making at global, regional, national and sub-national level and guides strategic plans for sustainable development and investment. At present, the infrastructure for quantifying the GHG sources and sinks in Africa is inadequate, due to the diversity of land cover, climate, management intensity and investment in capacity development, making this one of the weakest links in the global observation system (Ballantyne et al., 2015). The need for such an infrastructure has been apparent for more than a decade.

This final deliverable of the SEACRIFOG (Supporting European and African Cooperation on Research Infrastructures for Food Security and GHG Observations) project provides an integrated concept and an implementation strategy. It borrows from consortium reports and peer reviewed articles that have been crucial in preparing ground for the proposed infrastructure for GHG observations. A situational analysis was done through consultation to find essential variables that are relevant to GHG observation for agricultural mitigation and adaptation in Africa. Cost and feasibility of their measurement in Africa was considered. Separately, a design study to attain the most uncertainty reduction in the overall system through evidence-based locations concluded 10 atmospheric composition measurement station locations. Further, a framework for data collection, storage and transmission to allow for federated but interoperable GHG observation data was proposed.

Experiences from similar infrastructure have shown that it is crucial to provide an implementation plan with a long-term financial sustainability perspective from the beginning. A costing exercise for a 30-year cycle concluded that 542.76 M€ (on average 18.09 M€ annually) will be needed for all components. The exercise allocated more than half of the estimated total cost for human and institutional capacity building with the ambitious goal to build a strong independent scientific capacity on GHG and climate-carbon feedbacks in Africa.

This integrated strategy holistically considers these project conclusions alongside both technical and governance requirements for a sustainable GHG observation system with relevance to climate-smart agriculture, and other sectors in Africa. To build on the SEACRIFOG project results, ways for sustainable cooperation between African and European partners in research and innovation have been reflected on in this report. The target is to compliment and to consolidate existing global GHG data with scientific assessment and services for evidence-based political and entrepreneurial decision making, in meaningful partnerships.

This deliverable first reflects on the highlights of WP2 of the project whose goal was to develop a common research agenda to promote food and nutrition security in mixed crop-livestock systems in Africa. A resulting Eastern African study (Hunt et al. 2019) on the scope of climate-smart agriculture (CSA) and food security pointed to the relevance of GHG observation data for sustainable agricultural productivity.

Following is an overview of the SEACRIFOG project's main results in a long-term perspective, a first step in the implementation plan using the Programme and Innovation Management Cycle (PIMC) model. The PIMC Model describes four functions in a collaboration cycle. Data and observation related considerations are first listed in impact pathways together with a monitoring and evaluation concept as part of the function called *prioritisation* which proposes that a situational analysis is done and indicators are agreed on right at the start of the programme. This is first function of the PIMC Model that allows for finding value and setting agendas and budgeting accordingly before funding is sought.

The next function in the PIMC model promotes dialogues for action in research and innovation, and solicits funders for *investment* decisions. Funding decisions have been found by the WMO 2015 report to be influenced by a clear demonstration of benefit of the infrastructure especially if it involves long-term commitment. Socio-economic valuation studies would be carried out in the actual lifetime of the infrastructure in this phase, funds would be sought and put to use. In this report, we summarise the demonstrated value, cost and inclusive funding propositions. Inclusion of the private sector through transnational relations could be a breakthrough solution for a funding model of the proposed African greenhouse gas (GHG) observation system, given Africa's economic growth which is influenced by a dynamic informal sector, barely captured by the Gross Domestic Product indicator (GDP), (Fioramonti, 2014). We nevertheless use a GDP indicator to estimate government expenditure in research and development and to compare with private sector expenditure in research and development for now (AUDA-NEPAD, 2019). We find that gross domestic expenditure of GDP by both government and private sector is considerable even in countries with very low GDP, see section 4.3.3.1, showing willingness and a possibility to reach the 1% GDP investment in research and development recommendation to African countries by the AU Heads of State Assembly. Contrary to the rhetoric that Africa is not investing in research and development, this start could go a long way in ownership, participation, further capacity and economic growth and more stable research and development.

The *valorisation* function in the model ensures that data is translated into knowledge and recommendations which must be strategically communicated with end-users, in this case policy makers and farmers. A knowledge and communication framework would support this work. This function also further reflects on the relevant users and on value addition strategies so that relevance to the user is at the centre of service provision. Lessons can be learnt from developments by the European Integrated Carbon Observation System (ICOS) and other data and service providers. This function is relevant in already established institutions for evidence-based decision making.

System improvement measures are proposed and implemented as a final function in the cycle which gives way to another prioritisation phase for further activities in following cycles. Strategic services for policy recommendation uptake and for societal *application* are proposed and implemented, then the whole system is reviewed through an impact analysis using earlier set indicators.

2 List of objectives

A general objective beyond the SEACRIFOG project is to establish a sustainable African infrastructure in the provision of environmental observation data to complement remote sensing and modelling data products in atmospheric, terrestrial and ocean domains. Sustainability is pursued through stable funding and a long-term collaboration model that contextualises functions and services for transparent GHG data provision. As the consortium works to attract future investment that would make the 30-year plan feasible, the immediate plan is to engage African national governments in sustaining this infrastructure with support of the international community.

The ultimate goal is to impact national, regional and global climate adaptation and mitigation measures in the agricultural, energy, health and other sectors. This integrative concept lays the ground for the continuous inclusive cooperation of partners in GHG research and innovation activities, providing concepts to guide dialogue for agenda setting, funding, data provision and for the translation of data into knowledge for end users: decision makers and entrepreneurs and/or farmers. The strategy should enable the GHG infrastructure to continue activities according to need, with continual monitoring and evaluation of activities.

3 Value propositions

An African observation, data and research infrastructure for greenhouse gases and climate-carbon feedbacks would be a much-needed achievement in services for the continent to support decision making for agricultural productivity, adaptation and mitigation both at country and international levels. The case of the Eastern African study[3] in an agricultural production review against climate change and food security by Hunt et al. 2019, has brought to evidence and affirmed previous research that data on precipitation is uncertain as per planetary climatic events[4] but more certain is a consensus on rising temperature and increasing carbon dioxide (CO_2). Real-time data and science for society on the consequences of these changes are needed. The value of the proposed GHG infrastructure is that it would complement existing knowledge on GHG emissions to guide decisions on resilience and productivity.

3.1 Greenhouse gas data provision

There is a clear need for the link between agricultural productivity and climate resilience. Several efforts have been mapped externally of the project. The ERA database, for CSA decision support for Africa was launched in October 2019, managed by the Consultative Group on International Agricultural Research (CGIAR) to link datasets with projects to compare productivity and resilience that would both account to climate-smart agriculture. "*The Evidence for Resilient Agriculture database contains more than 75,000 data points from about 1,400 scientific studies conducted in Africa that describe the impacts of more than 100 agricultural technologies on more than 50 indicators of productivity and resilience (e.g., net returns, yield stability, soil carbon, resource use efficiency*" (Hunt at al. 2019: 32). The Global Research Alliance on agricultural greenhouse gases,

[3] List of countries in the study: Eritrea, Djibouti, Somalia, Somaliland, Ethiopia, Kenya, Uganda, Rwanda, Tanzania.

[4] The Inter-tropical Convergence Zone, El-Nino Southern Oscillation and the Indian Ocean Dipole.

(GRA) is another network with member countries aiming at increased agricultural production without increasing GHG emissions. It proposes the Measuring, Reporting and Verifying (MRV) platform for agriculture database called SAMPLES (Standard Assessment of Agricultural Mitigation and Potential Livelihoods), which is a hub for GHG emission factors and associated metadata for different agricultural systems. This MRV platform was also recommended by the United Nations Consultative Group of Experts for climate change as a technical resource in their toolbox for better institutional arrangement[5]. Several other knowledge repositories exist or are being developed in the context of EU-AU partnership for climate change and for food and nutrition security like the GMES Africa coordinated by the African Union, and SEACRIFOG will continually consolidate these efforts with the SEACRIFOG collaborative tool for the continental grand challenge of food and nutrition security.

The Eastern African study reviewed the contribution of selected countries to world GHG emission totals. The report confirmed an already established gap for climate forcing observation data from Africa. *"Many of the reviewed countries are lacking in quality data regarding livestock numbers, types and production systems, this is especially true for Somalia, Somaliland, Eritrea and Ethiopia in its lowland region. Meteorological stations are spartan across the countries making historic trend analysis difficult and undermining potentials for accurate future monitoring*." As part of the solution, the SEACRIFOG project established 58 essential variables, with direct or indirect relevance to the agricultural mitigation and adaptation needs. Relevant examples are *surface temperature, precipitation, above and below ground biomass, burnt area, fertilizer application, human population, livestock distribution and manure management, plant species traits* among others (Beck et al. 2019). As becomes evident in the next section, further modelling and region-specific analysis are necessary for detailed assessments to find trends in future water availability for crops and livestock (Tierney et al.2015, Shongwe at al. 2011). On this basis, the SEACRIFOG project has foreseen remote sensing and meteorological data modelling as part of the GHG infrastructure components to be developed.

In the same Eastern African study, GHG data which was mainly dating a few years back was sourced from the United States Agency for International Development (USAID) and the World Bank. Clear national research institution involvement in data provision was lacking in this case. To provide data that has temporal and spatial relevance is a strategy that has been addressed in the GHG infrastructure conception. The data came from USAID GHG emissions factsheet, East Africa 2015, which used the World Resources Institute, CAIT Climate Data Explorer 2011 data. Emission rates per capita review derived all country data from 2014 except for Eritrea, from 2011. Estimations of GHG emissions with agricultural methane (CH_4) and nitrous oxide (N_2O) sited the World Bank 2016. Data for Djibouti for its agricultural sector contribution to the total country GHG was derived from its 2001 nationally determined contributions (NDC), and all other countries data came from the USAID Greenhouse Gas fact sheets per country with some not available (40-41).

Tier 1 methodologies have been used so far in developing countries' Nationally Determined Contributions (NDC) reporting according to the Paris Agreement. 54 African countries have signed the agreement and submitted the Intended nationally determined contributions (INDC) according

[5] UN CGE Toolbox reference.

to the African Development Bank NDC Hub. Data on animals and fodder are often not available according to the Eastern African study. Additionally, detailed emission factors are mainly limited to work done on dairy value chains in Kenya, Ethiopia, Uganda and Tanzania. It is important to note that a SEACRIFOG consortium partner contributed to Tier 2 land management emission factor improvement for developing countries in the IPCC 2019 report on refinement to the 2006 IPCC Guidelines on National Greenhouse Gas Inventories, a major step to reduce uncertainty and improve methods for GHG exchange data measurement in Africa.

A main value proposition is a data technical and governance framework to guide data provision, to support an integrated GHG observation and data system. The report reiterated that the ability for households and nations to adapt especially livestock systems to climate change resilience needed *accessible, timely and actionable* information. These needs are similar to European open access data provision principles. These FAIR principles have been considered in the foundation of ICOS data as well as other European environmental infrastructures. That data and its policies ensure it is f*indable*, through common searchable metadata, *accessible* through a clear data use policy, *interoperable* and *reusable* through clear identification.

3.2 Impacting climate-smart agriculture (CSA) and food security

For livestock as well as crop production, the goal is to mitigate risk associated with climate change, to adapt to climate change and to increase agricultural productivity. "*CSA by definition needs to address issues of food security (the productivity pillar), the long-term viability of the household production and environment in the face of climate change (adaptation pillar), and where possible, help address countrywide GHG emissions (the mitigation pillar), (FAO 2013).*

The D2.1 report concluded that diversification and intensification of smallholder practices are possible productivity and mitigation strategies, but they are only viable if the livestock developments fit into household practices and all of the non-market values of the livestock continue to be met. A context specific data need arises coupled with smallholder farmer engagement in order to consider agroecological and socio-political realities. *Economic development* and *human population* are examples of SEACRIFOG essential variables that were considered and that could lead to this context specific data need. Access to these context specific recommendations would be through the SEACRIFOG dialogue platform that should enable engagement with users like farmers through representatives already working with them.

Improving livestock productivity and resilience pursues improved health, feeding and animal genetics which according to Hunt at al. 2019, can result from certain commonly referenced technologies that would need informed knowledge (Hunt et al. 2019: 44). Crop production according to the same report must consider changes in planting times, growing season length and local shifts in viable crop types. Temperature and rainfall patterns change and these might also shift potential growing areas. Adaptation plans must therefore consider that agricultural production zones could shift worldwide, hence both crop and livestock production need further data for these predictions. Food security and nutritional deficits are hard to measure and operationalize as per the report. Relevant pillars to be considered are *availability, accessibility, utilization and stability* of food and nutrition in the household. As these realities vary spatially and temporally, the observation system should be valuable in reducing uncertainty of the household data collected. Pathways to provide this needed data are included in the monitoring and evaluation concept with indicators and sub-indicators in section 4.2.2 and 4.2.3 of this report.

Finally, the mitigation pillar to address country wide GHG emissions would also be supported by GHG data from the proposed observation system. Countries will able to develop mitigation plans and to plan accordingly to avert risk. A factor that can prevent large losses to ongoing development.

4 Functions and services of the African GHG observation system

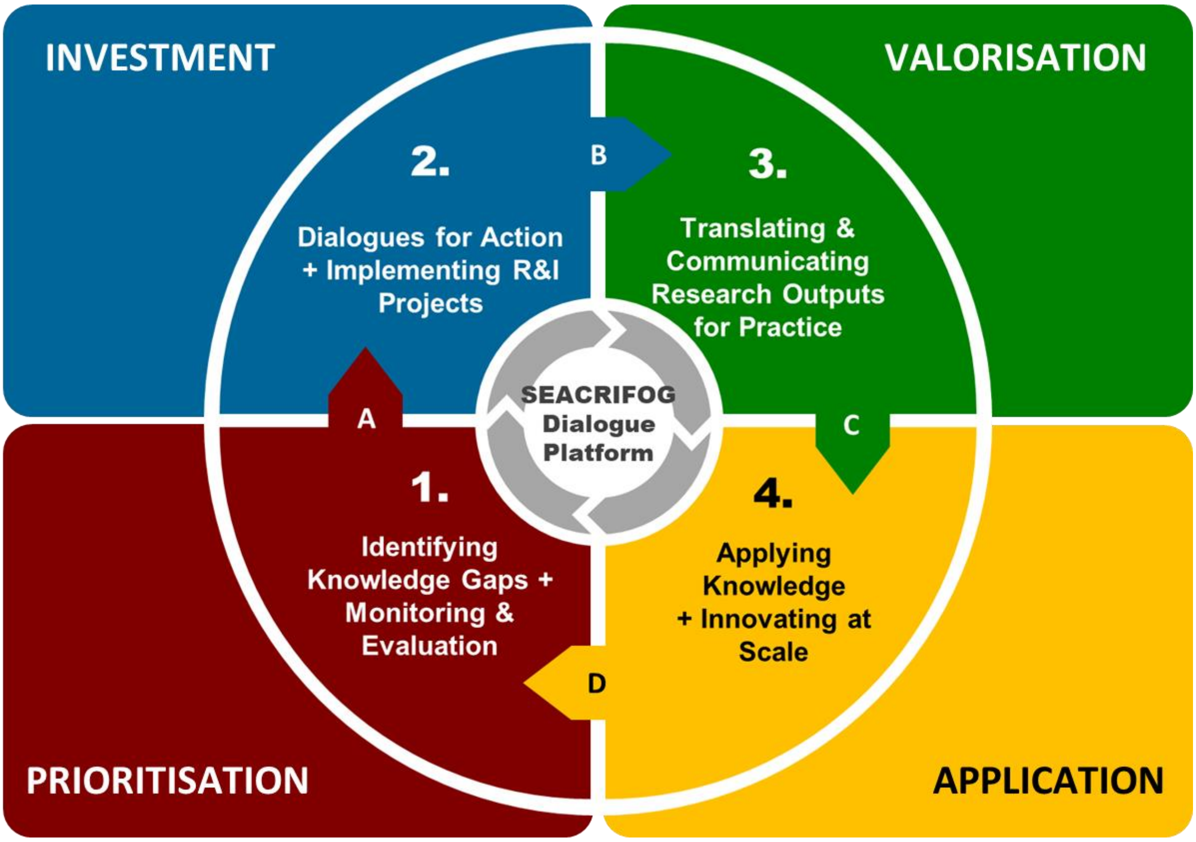

Figure 1, the Programme and Innovation Management Cycle (PIMC) applied by the LEAPAgri and LEAP4FNSSA projects which are working to evolve into a long-term collaboration platform from traditional European Union funding. The functions and services of the GHG observation system are considered in a PIMC for long term collaboration.

A global partnership study found that what was lacking in a set of reviewed international partnerships was demonstrable added value (Bezanson & Isenman, 2012). Institutional arrangements that would support added value are highly sought hence the consideration of service provision through the PIMC model to support integrated GHG observation for Africa. The guidelines and principles here highlight functions and services to implement the plan of the GHG observation system in a long-term collaboration perspective considering a Programme and Innovation Management Cycle (PIMC) to guide transparent institutional arrangements. The defined and integrated African GHG Observation System would support Measurement, Reporting and Verification (MRV) needs. The components considered to ensure transparent basic and special services are atmospheric measurement stations, ecosystem flux measurements, remote sensing and meteorological modelled products, agricultural campaigns, ocean measurements, total carbon column measurements, automated weather stations and national inventories capacity. Basic services according to the WMO community (WMO 2015) would address households and in this case, contribute to improved predictions from increased surface-based observations for better agricultural yield and resulting economic growth. Special service provision would address specialised data and publications for decision makers in national inventory development, responding to the United Nations Framework Convention on Climate Change (UNFCCC) and Paris Agreement.

The PIMC offers guidance by which institutions in a network could flexibly set functions to provide value addition through the pursuit of quality and services, and their wider reach. A good knowledge and communication framework in support of scientific valorisation is needed. Bottom-up engagement should be enhanced through such a knowledge and communication framework that prioritises end-user feedback. The partner requirements need must be taken into account in the design of each governance cycle so that the governance mechanisms support actual growth. From observations, to data, to knowledge for society, to engagement of users and feedback collection, the SEACRIFOG dialogue platform would enable interactions where quality, and impact are ongoingly pursued by different actors. The WMO in considerations for valuing its services recommended a value cycle approach that show the value chain of a service providing observation platform. It stresses user interaction on which the PIMC is based. It also stresses flexibility which allows for an exploration of what works. Figure 2 from the WMO value chain considerations highlights elements that must be considered for quality, relevance and impact.

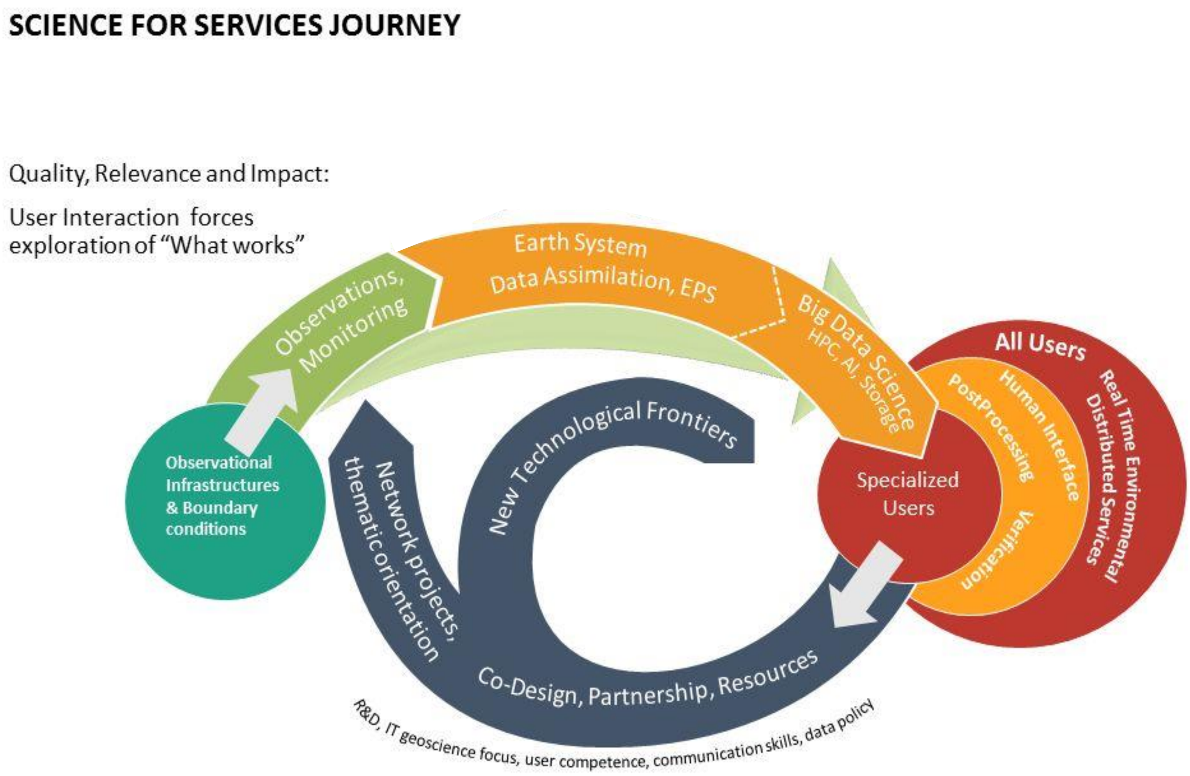

Figure 2, Value chain cycle considered by the WMO in its provision of integrated and seamless global data and processing and forecasting services from Ruti et al. (BAMS, 2019), from the Seamless GDPFS implementation plan.

These considerations become relevant in timelines, with set goals for anticipated action by African, European and other global users: researchers, funders, decision makers and entrepreneurs and/or farmers. In the value chain cycle, observations are made, data assimilation occurs and resulting knowledge is made relevant for end users. Institutional arrangements considered in the following sections guide 1) agenda setting in a prioritisation function, 2) investment/funding dialogues 3) data and knowledge valorisation tools and lastly, 4) societal innovation and livelihood improvement.

4.1 The SEACRIFOG Dialogue Platform

At the core of the implementation plan is a platform where functions and services of an African GHG infrastructure can be coordinated to allow for all actors to collaborate while maintaining flexibility and autonomy. This platform would be the nucleus for dialogue and for coordination, ensuring that partners inclusively take responsibility and participate in 1) setting priorities and a monitoring concept according to needs, 2) constituting funding alliances for research and human and institutional capacity building activities, 3) valorising and communication results back to end users, 4) and ensuring societal application through service delivery and innovation. The governance structures must enable change where needed hence the relevance of continuous monitoring and evaluation throughout these functions, elaborated in section 4.2.3. The SEACRIFOG Dialogue Platform would facilitate these research and innovation and capacity building activities, including holding partners accountable for responsibilities through legal statutes and institutions; a necessity according to a study reviewed by Ouma-Mugabe et al. 2018, for the governance of different forms of partnership. This implies legal statutes. An ongoing doctoral project is using a comparative approach to test these governance principles for African and European research and innovation cooperation in research where the question of inclusiveness often arises alongside funding needs and partnership capacity expectations.

4.2 Prioritisation: Situational analysis, impact analysis and M&E concept

1^st^ YEAR - 5^TH^ YEAR

This phase takes 3-5 years in a planned 30-year lifetime. It should engage all actors: researchers, funders, decision makers and end users.

The prioritisation phase proposes a starting point for research and innovation activities and allows for regular reflection on processes of research and innovation and capacity building. This stage proposes reflections on key areas: 1) the situational analysis, 2) a monitoring and evaluation (M&E) concept and 3) impact pathways for future impact analysis. After a situational analysis is carried out to find need. An M&E concept based on pathways with expected output, outcome and impact provide a foundation for future impact analysis. Lastly, agendas are set for research and human and institutional capacity building activities. It is important to have a clear idea of end users as proposed by this function. These are propositions from the Theory of Change and Impact Pathways (TCIP) in figure 3 below, that constitutes a first phase in the PIMC long-term perspective.

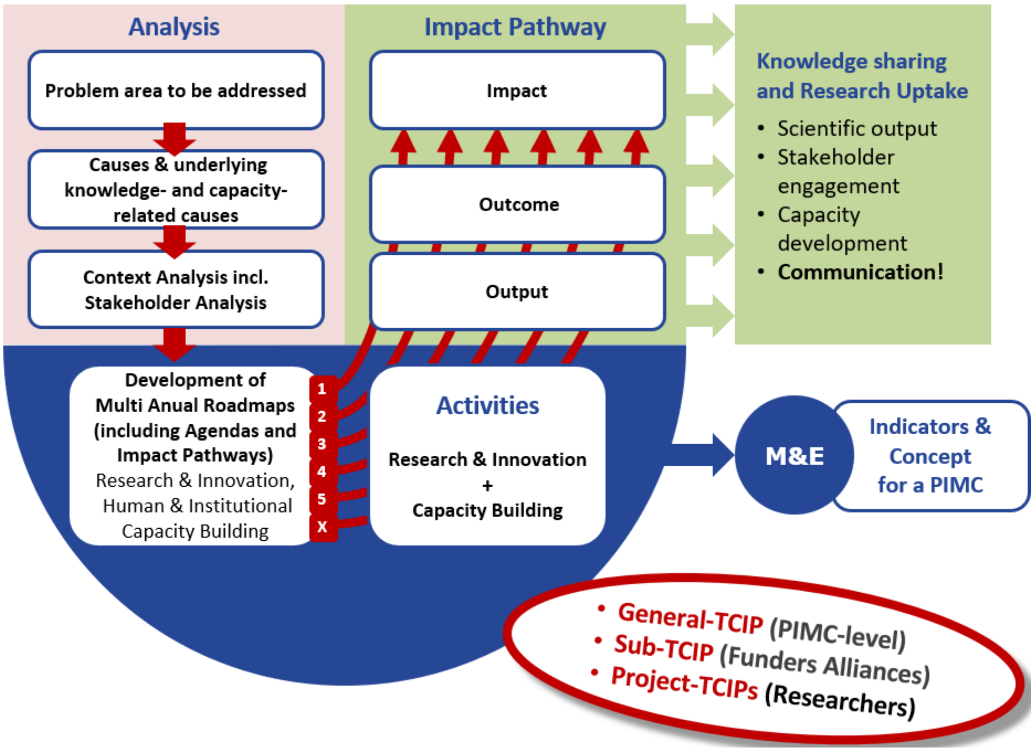

Figure 3, Theory of Change and Impact Pathways (TCIP) instrument developed in AU-EU cooperation projects for food and nutrition security and sustainable agriculture.

4.2.1 Situational analysis of SEACRIFOG

The situational analysis at the beginning of the SEACRIFOG project whose goal was to design a concept for an African GHG system, included both bottom-up and top-down approaches to identify environmental variables to be observed. An initial list of essential variables, was compiled by SEACRIFOG consortium experts according to global essential variables and then a bottom-up approach was used in a survey among 40 European and African researchers with expertise in atmospheric, oceanic and terrestrial domain (Beck et al. 2019) to find 58 essential variables relevant and feasible to continental climate forcing observation and agriculture needs. This was an important step in inclusive agenda setting.

The project has achieved significant ground laying with regards to setting a research and innovation, and human and institutional capacity building agenda through the WP1, D1.1 user need identification exercise in stakeholder workshops and report for a representative African research infrastructure (Lopez et al. 2018). WP2 D2.1 Eastern African study reviewed agricultural production systems in relation to climate change (Hunt et al. 2019). WP3 D3.1 and D3.2 reports looked at technical and cost considerations for GHG exchange observation system and personnel. WP4 reported on harmonization considerations for data quality including more location specific data (Beck et al 2019, Nickless et al. submitted 2019, Lopez et al. 2020). Essential variables concluded together with other data products and existing sites and networks are available in the SEACRIFOG collaborative tool. WP5 reported on interoperability and principles for data sharing in data policy considerations. WP6 focused on capacity building with regards to ocean observations, and WP7 on guiding policy frameworks and high-level contacts for the future infrastructure. A link to completed and upcoming publications is available. Below is a short project review with regards to these initially set goals which was in the end a prioritization phase in the PIMC.

SEACRIFOG project results review

We briefly review here the goals at project proposal writing that the output from the project fulfilled. The pursuit of an infrastructure for GHG observations with food and nutrition security relevance has resulted in a couple of achievements namely: the development of a data infrastructure prototype, the SEACRIFOG collaborative tool, according to essential variables identified, an observation system design with possible locations for the infrastructure and their cost, a network of relevant institutions including possible funders for the development of these agendas, and a human and institutional capacity need and cost. The goal for building a strong and independent African scientific community is key to contribute in processes of Measuring, Reporting and Verification (MRV) for national inventories to the UNFCCC and the Paris Agreement apart from impacting CSA to increase productivity while managing GHG emissions. The last results in blue are ongoing and will be operational during the lifetime of the proposed research infrastructure.

Table 1, SEACRIFOG project overview of results.

Project R&I and capacity building needs at onset		**Results**
1. Relevance of RI to global as well as local initiatives	✓	Essential variables that considered WMO/GCOS frameworks and local demands through stakeholder consultations
2. Feasible, cost-effective and up-to date observation system	✓	Consideration of existing technology during costing exercise and essential variable identification
3. Integrated observation system for GHG observations and CSA	✓	Considerations of technical infrastructure for weather, atmospheric GHG concentration, GHG fluxes from land, ocean and coastal regions in interaction with food security aspects
4. Uncertainty reduction in GHG emission data by science guided locations for stations, fulfilling safety requirements and national demands	✓	Design study to find optimal locations (Nickless et al. submitted 2019)
5. Data infrastructure provided by and integrated to African institutions	✓	Currently the SEACRIFOG collaborative tool with available data products is hosted at SAEON. Interoperability with other CSA databases is a possibility in future funded programmes
6. Strong independent African scientific community	✓	Trainings carried out, however long-term curricula about GHG observations, data management and communication should be established first in the infrastructure and at universities for institutionalised capacity building
7. African ownership in a successful collaboration	✓	Establishment of African ministerial, pan-African and global funding networks through the SDP ongoing

4.2.2 Impact Pathways

After a short review of the achievements of the SEACRIFOG project in light of initial goals in the earlier section, we place them here in the context of possible pathways to their achievement. First in the pathway are expected research and innovation *outputs*. Then expected *outcomes* are next; resulting change in behaviour and relations of the actors are reflected upon and set according to expected *impact* for socio-economic and political change in the long-term. Table 2 shows reflections on pathways from the project results/output to the desired impact. In blue are expected future outcomes and impact. This has been developed further after a first discussion in the earlier D7.2 funding concept for the proposed infrastructure, where concepts of valuation of the proposed infrastructure were introduced through a TCIP to give potential funders a view of the expected return on investment of the RI.

Table 2, elaborated impact pathways.

Stages of the impact pathway	R&I agenda: Land use change, climate smart agriculture, carbon cycle and greenhouse gas observations	Human and institutional capacity building
Output	1. Data policy considerations for infrastructure: collaborative tool and brokering registry (conceptual design of data infrastructure) a. 58 Essential variables to the research agenda identified (Lopez et al. 2018, Beck et al. 2019) b. Inventory of existing and planned observation infrastructures, observational data availability assessment (Lopez et al. 2018) c. Inventory of 140 methodological protocols and assessment of applicability (Lopez et al.2019) d. Data requirements for essential variables in terms of space and temporal resolution (Beck et al. 2019) e. Inventory of relevant available datasets 2. Design study for optimised atmospheric observation site locations (Nickless et.al submitted 2019) 3. 1st meeting of the SEACRIFOG dialogue platform a. Project results presentation to potential African and European partners b. Valuations from a socio-economic benefit assessment concept note c. Long-term cooperation sustainability plan	1. Trainings on how to collect, store and process, share data: a. Training workshop on analytical oceanography and data management, Bergen Norway April 2019 b. Eddy covariance flux measurements winter school 2019
Outcome	**Researchers, policy and decision makers and end users use data and communicate with each other:** **1. Emission factor improvement** **2. Improvement of national GHG inventories** **3. Global stock take: technical assessment/analysis and policy information** **4. GHG observation System improvement**	**Institutionalising training of personnel (network and data managers, atmospheric, oceanic and ecosystem scientists, modellers, policy and risk analysts, MRV capacity)**
Impact[6]	**1. Reduced GHG emissions** **2. Risk management, improved planning and resilience for agriculture** **3. Increased agricultural productivity and land use management**	**Maintenance of the capacity building system is secured and it becomes a standard operation in the system. Climate modelling, policy and risk analysis and data**

[6] These are impact pathways in a long-term view, a later impact analysis will depend on the definition of indicators in a monitoring and evaluation concept.

	4. Improved communication between scientists and end-users of knowledge **5. More societal acceptance of science as well as of investments into R&I and capacity building activities** **6. Successful collaboration and African ownership**	**management, MRV capacity is present**

4.2.3 Monitoring and evaluation concept

The monitoring and evaluation concept is developed for the continuous assessment of activities in pathways above in order to follow through output, outcomes and impacts based on earlier set expectations or goals. Indicators are set before in order to measure and monitor effectiveness and efficiency progress.

4.2.3.1 General indicators for proposed GHG system

Below are proposed indicators that would be used to monitor the proposed long-term impact from the impact pathways in Table 2 above. And they should be agreed upon by both African and European concerned actors, the same way that the pathways must be set communally, for the next research and innovation and capacity building activities. They stream from the United Nations Sustainable Development Goal (SDG) indicators for climate change impact and for hunger alleviation, to national adaptation and mitigation needs to the proposed programme goals.

4.2.3.1.1 Link to Sustainable Developments Goal indicators

Science Technology and Innovation elements have been noted to be embedded in all SDGs (AUDA-NEPAD 2019). More relevant to the proposed GHG system is environmental sustainability that is also embedded in all SDGs (Maathai, 2009). The goals of the proposed system and the subsequent indicators and sub-indicators will have to consider the SDGs. Table 3 lists SDG indicators related to two goals (United Nations, 2020) and compares them to the proposed GHG observation system goals to the far right in blue.

Table 3, adapted from the indicator framework, for the goals 2 and 13 of the 2030 agenda for Sustainable Development Goals[7].

"Goal 13. Take urgent action to combat climate change and its impacts		**Related proposed GHG observation system goals**
13.1 Strengthen resilience and adaptive capacity to climate related hazards and natural disasters in all countries	*13.1.1 Number of directly affected persons attributed to disasters per 100,000 population* *13.1.2 Number of countries that adopt and implement national disaster risk reduction strategies in line with the*	1) Provide relevant data by measurement of essential variable of human population 2) Provide data to support more national governments in adoption

[7] Adapted from the proposed indicator framework and goals and targets 2030.

	Sendai Framework for Disaster Risk Reduction 2015–2030 *13.1.3 Proportion of local governments that adopt and implement local disaster risk reduction strategies in line with national disaster risk reduction strategies*	and implementation of disaster risk reduction strategies
13.2 Integrate climate change measures into national policies, strategies and planning	*13.2.1 Number of countries with nationally determined contributions, long-term strategies, national adaptation plans, strategies as reported in adaptation communications and national communications* *13.2.2 Total greenhouse gas emissions per year*	1) Provide relevant data for NDCs in order to support Africa in their inventories, long-term strategies 2) Provide GHG trends, fluxes and concentration data
13.3 Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning	*13.3.1 Extent to which (i) global citizenship education and (ii) education for sustainable development are mainstreamed in (a) national education policies; (b) curricula; (c) teacher education; and (d) student assessment*	1) Provide human and institutional capacity building planned through personnel training
13.a Implement the commitment undertaken by developed country parties to the United Nations Framework Convention on Climate Change to a goal of mobilizing jointly $100 billion annually by 2020 from all sources to address the needs of developing countries in the context of meaningful mitigation actions and transparency on implementation and fully operationalize the Green Climate Fund through its capitalization as soon as possible	*13.a.1 Amounts provided and mobilized in United States dollars per year in relation to the continued existing collective mobilization goal of the $100 billion commitment through to 2025*	1) Implement these diversity funds in national inventory development
13.b Promote mechanisms for raising capacity for effective climate change-related planning and management in least developed countries and small island developing states, including focusing on women, youth and local and marginalized communities	*13.b.1 Number of least developed countries and small island developing states with nationally determined contributions, long-term strategies, national adaptation plans, strategies as reported in adaptation communications and national communications*	1) Support least developed countries in development of NDCs, NAPAs and NAMAs
Goal 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture		
2.3 By 2030, double the agricultural productivity and incomes of small-scale food producers, in particular women, indigenous peoples, family farmers,	*2.3.1 Volume of production per labour unit by classes of farming/ pastoral/ forestry enterprise size*	1) Measure variables and provide data to enable climate-smart agriculture (increased agricultural

pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value addition and non-farm employment	*2.3.2 Average income of small-scale food producers, by sex and indigenous status*	production, monitored GHG emissions and improved livelihoods)
2.4 By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality	*2.4.1 Proportion of agricultural area under productive and sustainable agriculture*	1) Maintain partnerships and networks in food and nutrition security and sustainable agriculture to support ecosystem friendly increased productivity 2) Data provision for risk management
2.a Increase investment, including through enhanced international cooperation, in rural infrastructure, agricultural research and extension services, technology development and plant and livestock gene banks in order to enhance agricultural productive capacity in developing countries, in particular least developed countries	*2.a.1 The agriculture orientation index for government expenditures* *2.a.2 Total official flows (official development assistance plus other official flows) to the agriculture sector"*	1) Seek multiple source investment including national involvement climate services related to agriculture and food security

4.2.3.1.2 GHG system indicators

Table 4, proposed general programme indicators for the proposed GHG observation infrastructure.

Impact	**Indicators**
1. Reduced GHG emissions	GHG observation data is provided (section 4.2.3.2 for sub-indicators)
2. Increased agricultural productivity and land use management	Availability of concepts for agricultural and pastoral land use management: Policies and measures to reduce biomass burning on grassland, soil management and improved livestock feeding (section 4.2.3.3 for sub-indicators)
3. Improved national planning and risk management	Government use of GHG data and recommendations from national greenhouse gas inventories for NDCs
4. Improved communication between scientists and end-users of knowledge	Higher communication and data exchange rate through the data infrastructure and through SDP dialogue sessions
5. More investments into R&I and capacity building activities, and societal acceptance of science	Higher rate of government investment in science and education, more public media presence about science

6. Successful collaboration and African ownership	PIMC long-term perspective applied in dialogues for agenda setting, inclusive and local funding, research activity, knowledge communication and monitoring and evaluation concepts
7. Strong independent African scientific community	Human and institutional capacity building through curricular development and personnel budget

4.2.3.2 Sub-indicators for GHG emission reduction

Sub-indicators are more specific to the GHG data provision general indicator. Here they are adapted from the 5.4 blueprint for an e-infrastructure, data policy 5.2, and could be relevant for the future impact analysis. They highlight measures that would ensure GHG data provision as well as harmonization and interoperability considerations in WP4.

Table 5, proposed sub-indicators for GHG emission data provision.

GHG emission reduction impact	**Sub-indicators**
1. Have a governance framework i.e. data policy, by-laws, constitution	General Assembly (GA) agreement on suggested data policy, constitution and by-laws
2. Have a funded observation and e-infrastructure	PIMC Model funders networks to mobilise investment through SDP or relevant coordination platform
3. Have protocols, metadata standards and data standards	Adoption of standards by GA through the SDP or relevant coordination platform
4. Advanced architecture of the SEACRIFOG Collaborative Tool	Higher communication and data exchange rate through data infrastructure, pre-processing, metadata management sites
5. Data management and access, with value addition in society	Use cases demonstrating access extended to end users and actual end use
6. Institutionalised capacity building.	Long term curricula about GHG observations, data management and communication and monitoring, reporting and verification capacity is present and later established at universities
7. Successful collaboration around GHG climate forcing data	Globally openly accessible, interoperable, usable data

4.2.3.3 Sub-indicators for agricultural productivity and land use management

These are adapted from conclusions of the Eastern African review of agricultural production systems in relation of food and nutrition security and climate change (Hunt at al. 2019), in relevance to the 58 essential variables selected (Beck et al. 2019).

Table 6, proposed sub-indicators for agricultural productivity and land use management, with reference to the Eastern African study and the SEACRIFOG 58 essential variables.

Climate-smart agriculture impact	**Indicators**
1. Animal and health productivity, climate-smart livestock approaches	GHG data to support: forage and fodder supplementation, diversification through production system transformations like from pastoral to agropastoral production,

	livestock distribution, commonly referenced technologies for climate-smart interventions (Hunt et al. 2019:44) where relevant
2. Land use/land use change management	GHG ground flux data to support pasture and rangeland projects for rehabilitation, data to support field manure management, GHG data on burnt area emissions
3. Crop productivity	Data for improved precipitation, soil moisture predictions, informed best crop cultivars from plant species traits, informed planting zones which are predicted to change, informed planting times and length of seasons
4. Improved livelihoods, economic development	Data on human population, evidence to encourage herd management, adoption of new livestock types, production system transformations

4.3 Investment: National funding at the core of diverse funding

1ST YEAR ***20TH YEAR***

The whole 30-year timeline of the research infrastructure needs resources. The goal of this is to acquire funding from multiple sources in different phases up to the 20th year if a one-off investment is not attained. The costing exercise concluded an initial investment need of 30 M€ in the first 3 years. In this phase, funders and researchers are the main actors.

Funding is a main catalyst for the research and innovation and capacity building activities and national funding has been found to correlate to local research output. Considering that publications are a current success indicator for science, national funding by these findings is key. However, output itself does not account to quality but if coupled with openness, can account to higher impact through international collaboration (Wagner, 2018). Therefore, diverse investments coupling both national and global initiatives into research and innovation and capacity building activities is relevant.

This newly sought diverse funding for climate services should also involve the private and development aid sectors apart from the public sector. This call for diverse funding is however not oblivious of the challenges that arise in diverse funding scenarios of public funds, with regards to commercialisation and competition as seen in (WMO, 2015) National Meteorological and Hydrological (NMHS) service provision.

At this stage and function of the PIMC, actual research and capacity building activities should begin apart from dialogues for investment. Monitoring and evaluation at this stage is meant for funders to review progress of previous activities and to give feedback regarding the R&I and capacity building activities for funder interests to be included. This phase would organise socio-economic benefit studies to able to continually demonstrate value.

4.3.1 Perceived benefit

This call for investment is backed up by a demonstration of value for investing in long-term infrastructure. This was tackled in report D.7.2 section 4 with a socio-economic assessment that provided a benefit-cost analysis concept note. The above mentioned NMHS funders according to the WMO often need: 1) a demonstration of the importance of the proposed infrastructure and its services, 2) a demonstration of the services contribution to economic development, 3) a demonstration of clear funding needs and prioritisation, and 4) a clear support demonstrated to national services, as well as to the UNFCCC.

It was found from a comparison with the Korean Meteorological Administration service study by the WMO see D7.2, that an addition of the components considered by the proposed GHG system had resulted in their case in noticeable developments. More precision had been as a result of adding remote sensing and meteorological modelled products. Increased data processing capacity resulted in consistency. An optimised location study to complement existing atmospheric stations and additional ecosystem flux stations would add accuracy on top of attaining consistency in GHG observations in the SEACRIFOG case. A dense network of 100 automated weather stations added to existing ones and the planned maintenance of 300 stations in well-coordinated existing networks, would be expected to fill a gap of reliability, effectiveness and consistency. The campaigns would be relevant to location specific CSA and land-use measurements while capacity building would support national inventory reporting. The maintenance of the system as a whole would be relevant for measurement, verification and reliability of GHG data.

4.3.2 Cost of the GHG observation system

A concrete funding concept has highlighted the funding needs of the proposed GHG infrastructure in Africa; a research and innovation cost of 543 M€ over 30 years including a human and institutional capacity building cost at half the budget. These costs were estimated through project consortium and external consultation and they considered least cost but up to standard technology.

Table 7, estimated levelised cost of the proposed GHG infrastructure considering 30 years with FTE

GHG system component	Initial cost	Operational cost	Data processing costs	FTE	Depreciation cost	Levelised cost	
	M€	M€ yr-1	M€ yr-1	M€ yr-1	M€ yr-1	M€ yr-1	%
Ocean observations	1,96	0,67	0,01	0,1	0,33	1,18	7
Remote sensing products	0,15	0,00	1,43	3,15	0,03	4,61	25
Modelled products	0,15	0,00	1,43	3,15	0,03	4,61	25
Atmospheric measurement site	5,50	0,80	0,11	0,33	0,92	2,34	13
Ecosystem fluxes measurements	6,35	0,50	0,20	0,63	1,06	2,60	14
Automated weather stations	2,70	0,60	0,40	0,15	0,45	1,69	9
Campaigns	0,00	0,45	0,00	0,00	0,00	0,45	2
National inventories	0,00	0,05	0,00	0,00	0,00	0,05	0
TCCON sites	0,60	0,20	0,10	0,15	0,10	0,57	3
Totals	15,45	2,60	3,66	7,56	2,90	18,09	100
						542,76	

Possible funding scenarios including all sectors are presented in section 4.3.3 after initial costs for the atmospheric as well as other components were estimated. A design study using inversion techniques (Nickless et al. 2019 submitted) revealed appropriate locations in several African countries for the atmospheric stations for the most uncertainty reduction in GHG emission data. According to the design study, 10 atmospheric stations would be best stationed in countries mainly in tropical Africa. According to consortium estimations an additional 20 stations for ecosystem flux measurements was budgeted for. With 100 automated weather stations, 36 campaigns in different agricultural systems, 5 TCCON sites and 54 national inventories not excluding 8 fixed ocean observations and 4 ships of opportunity around the continent. Data processing and storing needs and costs were considered as well. Table 7 shows estimates of the initial, operational, data processing and full-time estimated costs. Depreciation costs have been considered to account for the needed replacement and upgrade costs every six years for the observation system. A levelised cost is used in estimation and it gives a total of 543 M€ for 30 years for the GHG observation system.

Potential funders whose interests would be met by the GHG infrastructure and their funding mechanisms were considered alongside a socio-economic assessment in the D7.2 concept. These potential funders and their mechanisms considered were both traditional and less conventional funders for climate change service provision. They were a mix of international organisations, bank institutions, both commercial and development institutions, with African and other governments providing core funding.

4.3.3 Is the key a common pot?

A common pot for research and innovation funding, has been sited severally as a best practise in AU-EU cooperation with examples of successful European Research Area-Africa (ERAfrica) and European and Developing Countries Clinical Trials Partnership (EDCTP) instruments (EC, 2014). Challenges are not lacking but the returns linked to African national participation seem to be worth the trouble of managing such partnerships over quite diverse social, political and economic landscapes. Funding propositions are made here based on demonstrated value for national and global service provision. The SEACRIFOG project has set the agenda and found a possible future value chain from observations to data, knowledge and to service provision. Environmental benefits attached to better national inventory monitoring, are expected to lead to economic benefit through agricultural production and social benefits stemming from evidence-based government investment in society. The costs have been estimated and the benefits also quantified qualitatively, including foreseen uncertainties to the service provision in the D7.2 report.

4.3.3.1 African national funding, R&D investment and GDP growth

A first proposition for funding is made here to African governments based on **membership with a contributing station, research program or data centre**. Added value to member countries includes human and institutional capacity building and direct economic return on investment. Contributions will be made based on the country's GNI or GDP, depending on the data available on past investment in research and development. As earlier introduced, national funding should be best at the core of diverse funding considerations because only then is local research output guaranteed. "*The past 30 years since 1980 has witnessed a stunning metamorphosis for science and technology as a class of activities—once considered marginal to economic growth, S&T has moved squarely into a central tenet of economic growth theories, right up there with "land, labour, and capital." This has occurred as economic growth has shifted toward a "knowledge economy" or knowledge-intensive* *growth" (Wagner, 2018).* This is a reason for governments to consider investments in R&D with a strong focus on international openness for impact and for value creation.

The higher rate of African ministerial and African institution participation sought in these dialogues for funding alongside other funding organisations including international organisations, is a strategy for African ownership as a key objective to empower societies for local development processes and initiatives. We illustrate Gross Domestic Expenditure (GERD) on research and development against total Gross Domestic Product (GDP). The data shows investment in R&D related to the total GDP using 2017 or latest data derived from the AOI report (AUDA-NEPAD 2019). Private non-profit expenditure on R&D was found to be lowest in the report compared to all other sectors while business expenditure on R&D was mainly focused on the sector's own knowledge development and came rarely from other sectors.

Figure 4 illustrates a gross domestic expenditure on research and development (GERD). GERD investment as percentage of GDP for African countries is barely the 1% recommended by the AU Assembly of Heads of State, Kenya comes closest for 2017 or later data. Figure 5 illustrates public expenditure including government and higher education expenditure (PUBERD) and figure 6, business expenditure (BERD) with South Africa's business sector investing the most in the sector's own R&D. It is positive that some investment is being made in research and development and solutions can be found to harness this will and make the most of contributions, both monetary and in kind.

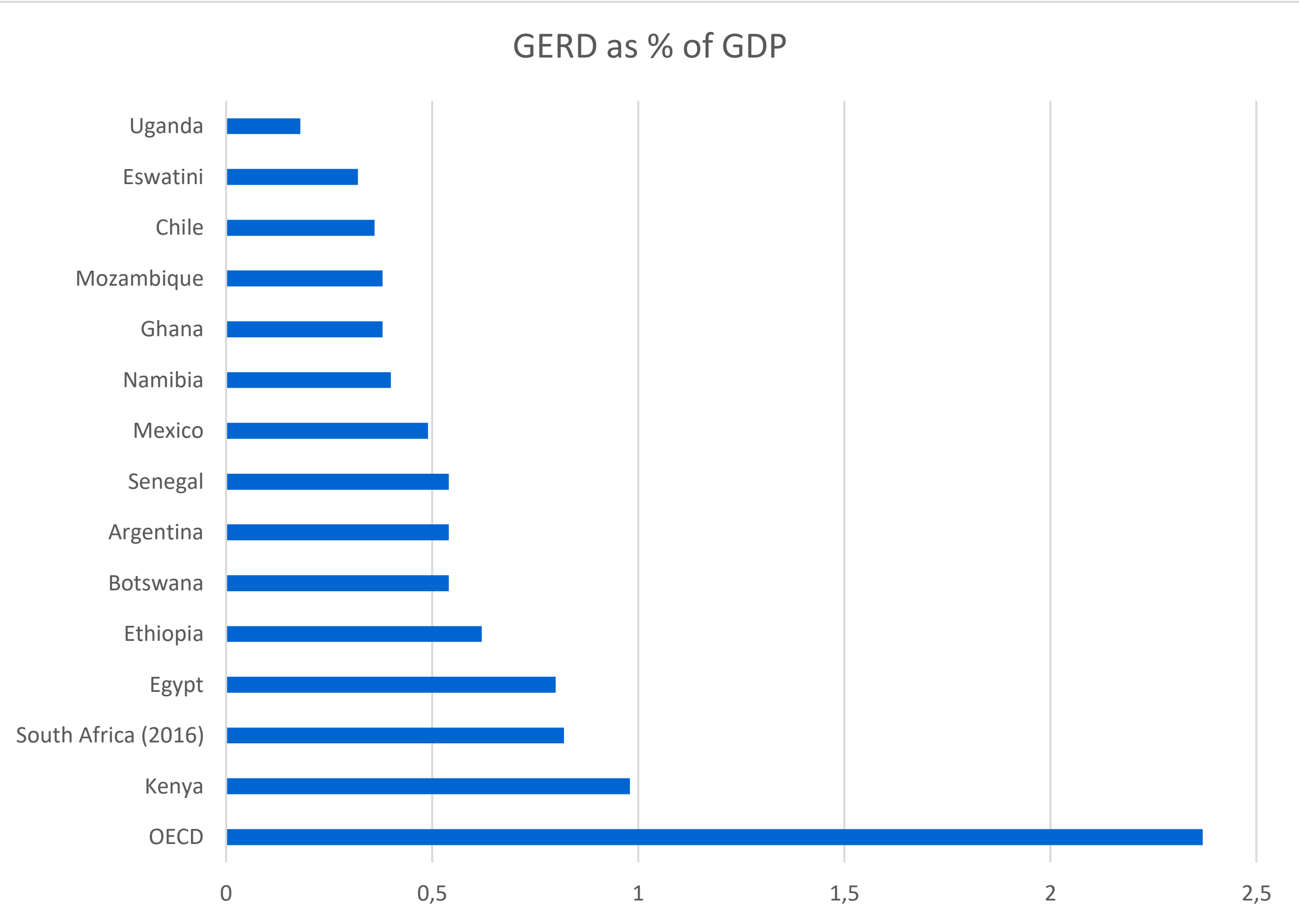

Figure 4, is Gross Domestic Expenditure on R&D for African countries compared to OECD countries and some other states from the tropical region as a % of GDP (AUDA-NEPAD 2019).

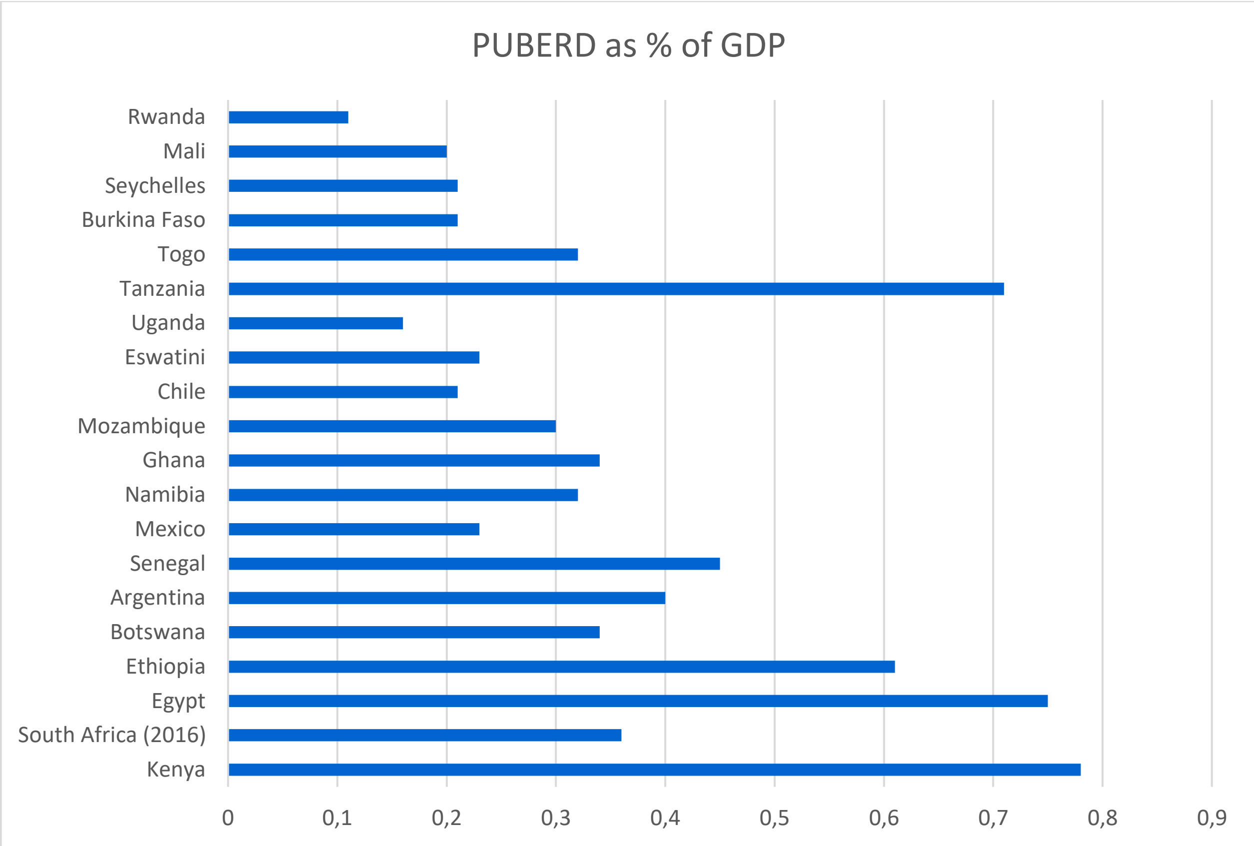

Figure 5, is the Public Expenditure (higher education and government expenditure) on R&D. Mali, Botswana, Ethiopia, and South Africa in figure 5 are some of the concluded locations by the design study for atmospheric towers in tropical Africa (AUDA-NEPAD 2019).

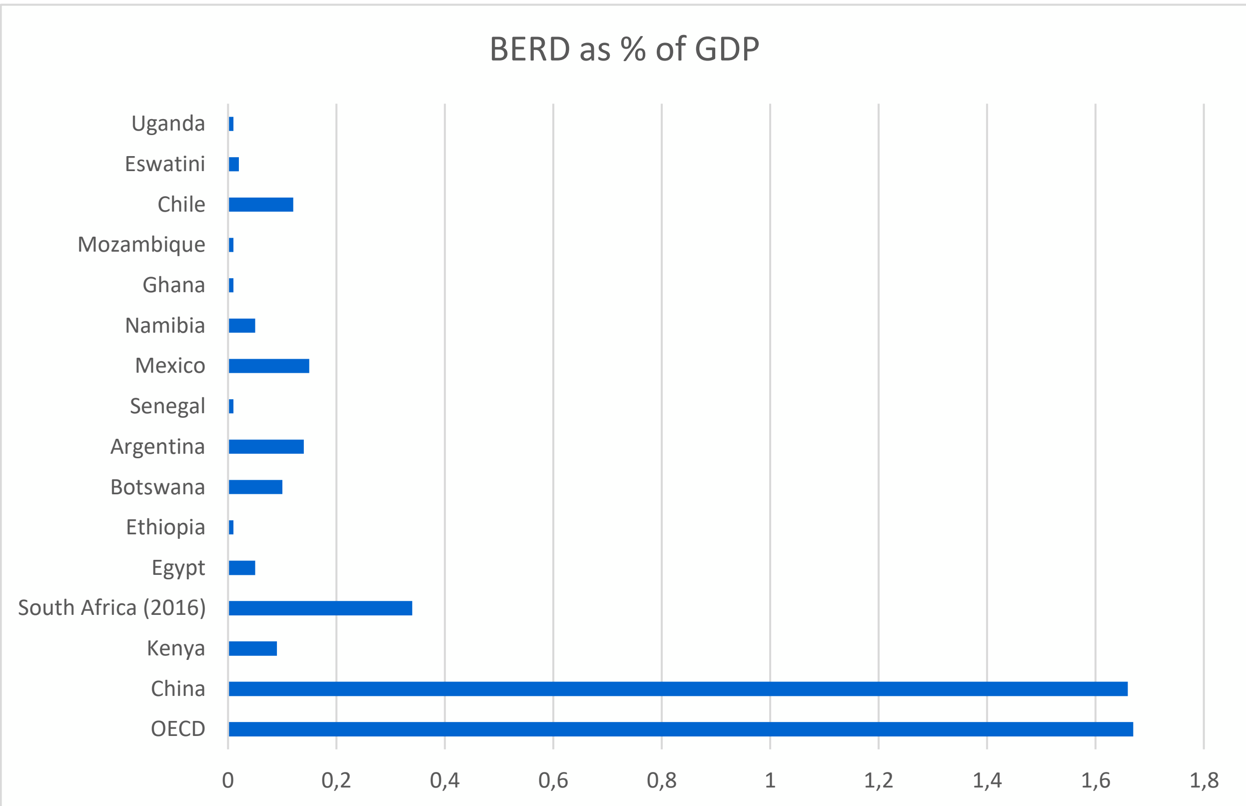

Figure 6, Business Expenditure on R&D as % of GDP (AUDA-NEPAD 2019).

4.3.3.2 Associated states and institutions funding

A possibility is provided for national governments and international organisations **membership without a station but a research programme or a data centre.** 1) This is based on the value that is proposed nationally as well as globally to support national inventories and national climate adaptation and mitigation plans. 2) Specialised data products and knowledge will be consequential in informing risk aversion and investment plans leading to 3) direct return on investment.

This membership option would be any of the 82 EU-AU member states who already recognize the food and nutrition security and sustainable agriculture (FNSSA) and the Climate Change and Sustainable Energy working groups (CCSE), of the High-Level Policy Dialogue (HLPD) in the context of the Joint Africa Europe Strategy (JAES). For the states´ participation, contributions will also consider past investment in research and development alongside current capacity.

Europe has a clear national engagement solicitation even while the European Commission strongly supports cross-national engagement in research through various funding schemes such as the former Framework Programmes, Horizon 2020, the upcoming Horizon Europe, the Joint Programme Initiatives, European Research Area Networks (ERANet), leading to fully operational legal forms supported by nation states; the European Research Infrastructure (ERICs) consortia. A result of national and international funding from EU support it seems, is a balance of competitiveness and collaboration that only goes further to benefit national states as reiterated in the (European Research Infrastructure Consortium (ERIC) Forum September 2020. Could organs of the African Union like African Observatory of Science Technology and Innovation (AOSTI) play such a supporting role in the African case?

This membership would be open to institutions directly without involvement of the government including international organizations like the UN organs. It would include willing, external research and private institutions where government relations may be complicated. And it would allow for transnational relations depending on nations statutory agreements. The international private sector for example, could be involved through station access fees as they visit certain stations either virtually, remotely or physically.

4.3.3.3 Host funding

Thirdly, a proposition for funding is made to the **nations that would host the service infrastructure and/or secretariat** in Africa. This would be the scientific data processing service for the infrastructure generating knowledge for further service development. The secretariat presumably coordinating the functions of the SEACRIFOG Dialogue Platform under legal responsibility could be hosted at the same institution or elsewhere depending on capacity. The added value here for the host countries is: 1) human and institutional capacity building apart form a 2) direct return on investment. Contributions will consider financial resource capacity as well.

4.4 Valorisation: Data into science

5TH YEAR ***30TH YEAR***

This phase depends on available results, 5-10 years or earlier depending on the type of data. It involves researchers, and end users: decision makers, farmers and or entrepreneurs.

The monitoring and evaluation tools including indicators are applied here to analyse the research output and outcome available from the previous timeline of the cycle. This phase obliges experts to identify external knowledge generated and then to translate data into recommendations considering these. Dialogues in this phase pursue data availability, findability, accessibility, interoperability and reusability. In the case of the GHG system for climate data, dialogue sessions could be programmed after the first 5-10 years. A knowledge and communication framework should guide dialogues that would communicate knowledge to decision makers and to other end users, and to define and plan for elaborated ways to receive feedback from end-users, which is incorporated to recommendations.

The WMO in its weather and climate services valuation report considered all their users who *"conceive, create, develop, disseminate, translate, exchange, promote, receive, interpret, utilize and benefit from one or more products or services... in their roles of communication, perception and interpretation, decision making behaviour, and actions taken which, in turn, lead to outcomes and ultimately value."* This phase might have to be programmed to run throughout the lifetime of the infrastructure according to need, and output as it becomes available. Service provision options are considered below. Finally, this phase should maintain monitoring and evaluation exercises, by reflecting on the relevance of the knowledge to the general and sub-TCIPs.

4.4.1 Data for scientists

Data and service access would be made possible through virtual, remote and physical means. It has been seen to be of enormous support to scientific growth since services that would not be available locally are made available through these research infrastructures. In Europe physical access has been mainly free to the user and institutions have been supported by the EU to provide such services. As a strategy for funding, African states could either participate in common pot type of funding as seen in section 4.3.3 for physical access or provide payable physical access to users like the private sector. Virtual and remote access are globally being developed through open science principles and it would be of service to society to keep this free of charge with the right attributions, guided by a data policy.

4.4.2 Information system

Data converted to knowledge and recommendations to farmers and national inventories to the UNFCCC as well as to national governments is the end goal here. The data and/or knowledge would immediately find relevance and feed into existing information systems locally to farmers, and globally to decision makers. Guiding adaptation and mitigation action against climate change.

SEACRIFOG has gained visibility in an already larger network of relevant actors, who are working towards climate knowledge provision for improved livelihoods through the agricultural sector and other national planning development needs. Stakeholder relations have attracted attention of the World Meteorological Organisation due to the similarities in the goals of the proposed GHG system and its relevance to not only the Integrated Global Greenhouse Gas Information System (IG3IS) of the WMO Information Systems (WIS) but the Global Data Processing and Forecasting System (GDPFS) and the WMO Integrated Global Observation system (WIGOS). These three arms have a clear goal to support developing countries in their observational infrastructure for earth system observation for environmental information. The WMO Systematic Observations Financing facility was specifically proposed by the WMO requiring developing countries to establish a minimal set of surface-based observations in sustainable long-term systems for numerical weather and climate services. In compliance to the global basic observation system by 2025. The concept for a GHG Observation System for Africa could be developed through this financing facility as both seek funding models that engage the country participation.

At a continental level, Africa-Europe cooperation for food and nutrition security and sustainable agriculture and GHG mitigation and adaptation has been pursued for evidence-based knowledge. The African Observatory of Science Technology and Innovation (AOSTI), African Union Development Agency-New Partnership for Africa's Development (AUDA-NEPAD), the African Science Technology Indicator Initiative (ASTII) are only but a few institutions at the African level through which GHG data provision can be established with the country ministries.

With regards to food and nutrition security, the AU-EU High Level Policy Dialogue provides a platform for the two continents to exchange knowledge. The target is to have sub-national, national, regional and AU-EU level of engagement in knowledge management. Global partnership possibilities with the earlier mentioned GRA in GHG data provision for Africa are being explored. Similarities were found in knowledge and gap studies carried out separately by both the SEACRIFOG project and the GRA and future synergies for data products and the knowledge generated are in progress.

4.4.3 Eventual quality reference framework

If set up accordingly, the infrastructure could evolve into a quality reference framework providing consistent data to fill the GHG data gap in the tropics. This would require an implementation and maintenance of high-performance computers, maintaining consistent cross-validation schemes of the same data. ICOS together with other initiatives like AmeriFlux, FLUXCOM, and the National Oceanic and Atmospheric Administration (NOAA) are setting the pace for accurate quality assurance and control processing of data.

4.5 Application: Improved livelihoods

5TH YEAR ***30TH YEAR***

Innovation and practical use of data is relevant alongside the data valorisation efforts (5-10 years). Actors here are societal end users and researchers.

In this phase, effort is made to apply knowledge and innovate at the societal scale. Impacting the behaviour of users is a whole other dynamic. The WMO valuation of services realised that many other factors are at stake when it comes to changing user behaviour. And they recognise a need to integrate the social sciences for impact to be possible. The report sited how well communication is done as factor that could guide impact, the decision maker characteristics like prior knowledge as well as their environment (community norms) and resources. Investment in weather and climate services has been understood to have a higher return on investment according to the WMO but studies still need to be done to understand the value on human well-being. There is a large task for social sciences in completing the value chain for impact.

In this phase, local centres for dialogue and communication would be established, linked to political institutions for local initiatives but also global initiatives like the sustainable development goals.

The set indicators from the M&E concept can be used to reflect on relevant data and what kind of recommendations to give to suit a societal challenge. Currently 54 countries are noted by the African Development bank NDC hub to have submitted their INDCs and are working on developing NDCs. The relevance of the proposed infrastructure is to support national inventory development. In line with the most relevant SDGs, no. 2 on zero hunger, no. 13 on climate action, but also no. 7 on affordable and clean energy and no. 3 on good health and well-being. The system will be key to influencing CSA practices aiming at increased productivity while controlling GHG emissions. See Table 3 for a link to SDG relevance. Innovation hubs or technology transfer centres or laboratories could be a result of this phase. A reflection on general TCIPs is recommended at the end of this stage, with a situational analysis, giving way to the next phase of prioritisation. Improvements to the system are possible with these considerations for the next research and innovation and capacity building agendas.

5 Conclusion

A clear need has been established for an African GHG observation system's data in relation to climate-smart agriculture. Propositions for this infrastructure have carefully considered the relevance, feasibility and cost aspects for technical harmonisation and interoperability of data and for human and institutional capacity building. Significant results have been achieved with a special focus on attaining increased food production without increasing greenhouse gases. Governance mechanisms which would highly determine feasibility and robustness of the proposed infrastructure over 30 years would need to allow for diverse groups to equally contribute to research output, outcome and impact with the goal that African countries and actors are fully participating in their own research and innovation developments through funding and other in-kind contributions.

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List of Abbreviations

AOI	African Outlook Innovation
AOSTI	African Observatory for SCIENCE Technology and Innovation
ASTII	African Science Technology Indicator Initiative
AUDA-NEPAD	African Union Development Agency- New partnership for Africa's Development.
BERD	Business Expenditure on Research and Development
CGE	Consultative group of experts
CGIAR	Consultative Group on International Agricultural Research
CH_4	Methane
CO_2	Carbon dioxide
CSA	Climate-Smart Agriculture
D	Deliverable
EDCTP	European and Developing Countries Clinical Trials Partnership
ERANET, ERAfrica	European Research Area Network-Africa
ERIC	European Research Infrastructure Consortium
EU	European Union
FNSSA	Food and Nutrition Security and Sustainable Agriculture
GA	General Assembly
GBON	Global Basic Observation System
GDP	Gross Domestic Product
GERD	Gross Domestic Expenditure on Research and Development
GDPFS	Global Data Processing and Forecasting System
GHG	Greenhouse Gas
AU-EU HLPD	African Union, European Union High Level Policy Dialogue
IPCC	Intergovernmental Panel on Climate Change
MRV	Measuring, Reporting and Verification
N_2O	Nitrous oxide
NDC	Nationally Determined Contributions
NOAA	National Oceanic and Atmospheric Administration
PIMC	Project and innovation Management Cycle
PUBERD	Public Expenditure on Research and Development
R&D	Research and Development
R&I	Research and Innovation
SDP	SEACRIFOG Dialogue Platform
SEACRIFOG	Supporting EU-African Cooperation on Research Infrastructures for Food Security and Greenhouse Gas Observations
SEB	Socio-Economic Benefit
SEI	Stockholm Environment Institute
TCIP	Theory of Change and Impact Pathways
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States agency for International Development
WMO	World Meteorological Organisation
WIGOS	WMO Integrated Global Observation System
WIS	WMO Information System
WP	Work Package

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