Greenhouse Gas Observation & Climate-Smart Agriculture

ICOS Integrated Carbon Observation System

SEACRIFOG Deliverable 7.2.

A co-financing concept for the establishment and long-term maintenance of adapted observation systems on food security and greenhouse gases

Mylène Ndisi[1], Lutz Merbold[2], Ville Kasurinen[1], Veronika Jorch[3], Karoliina Pilli-Sihvola[4], Emmanuel Salmon[1], Werner Kutsch[1]

[1] ICOS ERIC Head Office, Erik Palménin aukio 1, FI-00560 Helsinki, Finland

2 International Livestock Research Institute, Mazingira Centre, PO Box 30709, Nairobi 00100, Kenya

3 Thünen Institute of Climate-Smart Agriculture, Bundesallee 65, 38116 Braunschweig, Germany

4 University of Helsinki, Faculty of Agriculture and Forestry, Department of Economics and Management, P. O Box 27, 00014 University of Helsinki, Finland

Submitted: Helsinki, 30 June 2020

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730995

Contents

Executive Summary

Harmonised and comprehensive greenhouse gas exchange data and related scientific capacity for producing and communicating evidence-based knowledge are needed today even more urgently to support a green economy. This can be achieved through an understanding of agricultural systems within their natural and social eco-systems. This report is compiled at a time when the world finds itself at a major crossroads with decision makers bearing the responsibility of containing the COVID-19 virus while simultaneously minimising the negative effects of the confinement to the economy. Since negative economic effects are unavoidable, governments have also to decide how recovery programs after the confinement have to be designed. According to (Hepburn et al., 2020) the recovery programs have the possibility of "*setting the global economy on a pathway towards net-zero emissions or lock us into a fossil system from which it will be nearly impossible to escape*."

The COVID-19 pandemic has clearly shown the important role of science for societies to find an appropriate response to the crisis. Questions arise with regards to the role of climate change researchers, decision makers and producers like farmers and consumers in response to the impact of climate change. The global financial agenda at such a time of recovery from the pandemic, as sited by expert panellists in a COVID-19 action policy discussion[1], will probably shift towards the health and commercial sectors. However, climate change is not stopped by a pandemic and questions about food, nutrition security and climate-smart agriculture remain relevant to the global and particularly the African climate change adaptation and mitigation research agenda in the future. The agricultural and food security sector of Africa is very vulnerable to climatic stresses and climate change in the long term thus making climate change a priority today alongside global economic recovery efforts after the confinement.

According to Hepburn et al. 2020, economic recovery policies could have highly positive impact and long-term benefit if decision makers consider at this crucial moment (among other components): clean technologies research and development or rural support scheme spending for sustainable agriculture, education and training funding. The global data need is one that is reiterated to be urgent and one that is required to fill knowledge gaps that impede knowledge-based decision making by governing bodies against weather and climate impact challenges (IPCC, 2018; WMO, 2019).The proposed greenhouse gas (GHG) observation system offers evidence and solutions that are complimentary to the aforementioned policy action synergies through its research and innovation and capacity building agendas. It will provide data for sustainable decision making in the parts of the world that are most vulnerable to climate change. It is time that the much-needed technology for an African GHG observation system and the related scientific and societal implementation capacities are financed.

[1] Mistra Geopolitics project of the Stockholm Environment Institute on the geopolitics of COVID-19 and climate change-April 2020.

1 Introduction

A concept for an African GHG observation system to provide data for much-needed climate products and services has been thoroughly developed over the past three years in the framework of the SEACRIFOG project. In this deliverable we propose a funding concept for the system, which is currently planned over an initial period of 30 years to fill an existing gap of data that is needed to strengthen local, regional and global sustainable development. In this funding concept for the GHG observation system, we present:

1) An investment proposition of 500 M€ over 30 years, for an integrated African GHG in situ observation system including meteorological observations, campaign products, ecosystem flux measurements of energy and matter, atmospheric GHG and air pollutant measurements, national GHG inventories, Total Column Carbon Observation Network (TCCON) sites and automated weather stations spanning the African continent and a scientific capacity to derive knowledge from scientific analyses of in situ and remote sensing products. Roughly half of the suggested budget is foreseen for the respective observational capacity while the other half shall be an investment for personnel that provides the technical and scientific capacity to analyse the data and transfer knowledge to societies. The concept is thoroughly built on other deliverables of the SEACRIFOG project that have provided insights on already existing elements of the envisaged system and have provided scientific analyses on how a comprehensive system should look like.

2) In the funders section, we give overviews and explain complementarity of the system's agenda with potential funders priorities. Given the research and innovation agendas of the system, potential funders would be from both the public and private sectors and focusing on funding climate change adaptation and mitigation activities. National governments, central banks, private and development banks, and multilateral development organisations who need risk management to assure their activities, are prone to build technical, scientific and institutional capacity and are therefore potential funders as well. Local ownership is important for Africa for its sustainable societal growth; member country contributions for the system would be needed to cultivate local participation. Kenyan Cabinet Secretary for Foreign Affairs, in an open session organised by the Stockholm Forum for Peace and Development 2020 stressed the importance of local participation in Africa's growth efforts[2].

3) Lastly, we present the expected benefit to society through the lenses of a cost-benefit analysis. We present impact pathways towards defined research, innovation and capacity building agendas in an external socio-political and economic environment. A return on investment concept note is described with an example of a World Meteorological Organization (WMO) valuation of investment in certain Data Processing and Forecasting Systems (DPFS) through a Korean Meteorological Administration (KMA) socio-economic benefit study[3].

[2] SIPRI Virtual Stockholm Forum on Peace and Development 2020: Open Session on Climate Change; the other crisis.

[3] Valuing Investments in Data Processing and Forecasting Systems, Bulletin no: Vol 62 (1) – 2013.

We hope to bring this funding concept to the attention of several private, public and development cooperation climate financers namely: 1) The United Nations (UN) with a commitment to developing financing for the world global climate agenda. 2) The World Bank (WB) Climate Change Fund Management Unit. 3) The European Union (EU) and African Union (AU) structural funds. 4) The Nordic Climate Facility (NCF) for the Nordic Development Fund (NDF). 5) The WMO System Observations Financing Facility[4]. 6) Development banks[5] and their Climate Investment Funds (CIF). 7) African and other national governments.

2 Methodology

Task 7.2. is concluded with a consolidation of a network of potential funding organisations as well as a cost overview for the proposed observation system from the D3.2[6] project report. The costing exercise has shown that an adapted observation system for GHGs and climate pollutants (with a focus on climate-smart agriculture, CSA) will require substantial 30 M€ investment in the first 3 year phase. In addition, we assume that the costs to build up and maintain the necessary scientific capacity is accounting for half the total 500 M€ budget over a 30-year sustained period. This document presents a funding concept with a demonstration of return on investment to inform potential investors. New partnerships between academia, other users, and funding bodies are being sought for innovative financing which is a much-needed strategy for global impact of environmental research. A network of funding organizations is planned to be engaged through meetings of the SEACRIFOG Dialogue Platform (SDP), in continuous dialogue with other actors to foster impact of the system to society. Subtask 7.2.3 intending the design of a co-financing concept is what constitutes this deliverable. This investment plan will be a first step towards innovative financing.

We begin by assessing the capacity to build an African GHG observation system. Partners have done preliminary work in the form of literature review as well as gathered information from project meetings and through one-to-one networking with stakeholders. Work was guided by existing global framework recommendations by the WMO, Global Climate Observing System (GCOS) and the Global Ocean Observation System (GOOS), and with relevance to local and regional needs. This has been in a bid to find common Research and Innovation (R&I) agendas; D2.1 (Hunt et al., 2019) for the agriculture and food security agenda was an output of this exercise. For data, relevant essential variables and methodological protocols were selected, and can be found in the SEACRIFOG collaborative tool[7] along with other relevant information on networks and metadata (Lopez-Ballesteros, 2020; Beck et al., 2019; López-Ballesteros et al., 2018). Data policy considerations can be found in work package (WP) 5 project reports on the website. Human and institutional capacity building through trainings and workshops was also developed. Finally, optimised site locations for the most uncertainty reduction in GHG observations were a main result of a first phase of technical harmonisation for the research agenda. Output can be found alongside other in situ network considerations in WP3 project reports and (Nickless et al. 2019 submitted).

---

[4] The goal is to achieve developing countries' compliance with the Global Basic Observing Network (GBON) by 2025. It was envisioned to announce the facility with initial contribution pledges at the COP 26 in December 2020.

[5] The African Development bank, The Asian Development Bank, European Bank for reconstruction and development, Inter-American Development Bank, World Bank Group.

[6] SEACRIFOG reports.

[7] SEACRIFOG collaborative tool access from the project webpage.

3 Funding strategy

3.1 Investment proposition of the African GHG observation system

The investment needs for an African GHG observation system have been found to be complimentary to WMO system considerations for an adequate basic observation system for climate, weather and water services and products. The WMO considered modern technological infrastructure, scientific expertise in data science, automated systems for acquiring observations, data management facilities for storage, retrieval, processing, quality control and data integration and visualization systems as crucial to this system. They also identified a gap in climate relevant data from the global South[8]. The components that SEACRIFOG partners have considered for a comprehensive GHG observation system would provide global requirements like those of WMO's Global Basic Observation Network (GBON)[9] requirements to equip the developing world with climate observational climate data. The components are described briefly below with their cost, but can be found comprehensively in the WP3 reports.

3.1.1 Human and institutional capacity development

The development of human and institutional capacity remains a main agenda with roughly half of the 500 M€ infrastructure budget allocated to it as compared to other operations in figure 1. Economic recovery and development goals in the year 2020 onwards in Africa and globally have to focus on equipping local society with technical and scientific capacity. Not only will individuals be addressed by such an initiative but also institutions and the larger society through this agenda. The in situ component of the system has been allocated a total personnel budget of 38 M€ over 30 years while the data and modelling personnel budget came to about 189 M€ over 30 years and was foreseen to be incremental as technical capacity grows. The in situ personnel costs remain steady with a consequential initial investment and with upgrades in every phase depending on the site. Local ownership of science will be largely boosted through the data and network managers, modelling scientists, risk analysts and other personnel that will be trained alongside the system's be assured as trainings themselves are no indicator for impact; for a change in practise. This will go far in empowering the people for the development agenda of the continent.

[8] Systematic Observation Facility, Initial Concept, October 2019.

[9] WMO Network meant to improve the availability of the most essential surface-based data internationally for weather, climate and water services and products, with a main goal of supporting developing countries.

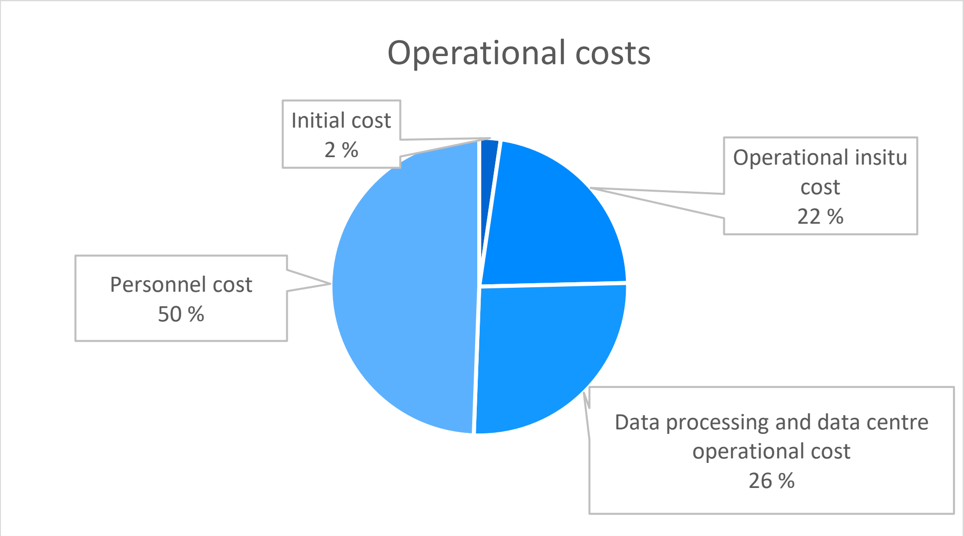

Figure 1: Human and institutional capacity building cost 50% of budget.

3.1.2 Research and Innovation development

The R&I agenda development are envisaged through a **data component** and an **in situ observation component**. The total estimated cost of 500 M€ over 30 years includes an estimated 163 M€ for the in situ component including personnel, 284 M€ for an integrated data and modelling centre including personnel and an incremental cost consideration of about 50 M€ for human capacity as well as for modular extensions like eventual development for aerosol measurements. Table 1 below and figure 2 thereafter give an overview of component costs.

Table 1: The levelised cost per year of initial, operational and data processing activities calculated over 30 years. The table is adapted from D3.2.

Element	Initial cost	Operational cost	Data processing cost	FTE[10]	Levelised cost over 30 years	%
	(M€)	**(M€ yr^{-1})**	**(M€ yr^{-1})**	**(M€ yr^{-1})**	**(M€ yr^{-1})**	
Remote sensing	0.15	0.00	1.43	3.15	4.58	32 %
Modelled products	0.15	0.00	1.43	3.15	4.58	32 %
Atmospheric measurement site	5.50	0.80	0.11	0.33	1.42	10 %
Ecosystem fluxes	6.35	0.50	0.20	0.63	1.54	11 %
Automated weather stations	2.70	0.60	0.40	0.15	1.24	9 %
Campaigns	0.00	0.45	0.00	0.00	0.45	3 %
National inventories	0.00	0.05	0.00	0.00	0.05	0 %
TCCON sites	0.60	0.20	0.10	0.15	0.32	2 %
Total	**15.45**	**2.60**	**3.66**	**7.56**	**14.19**	**100 %**

- **Africa-wide remotely-sensed products:** These are data generated by satellites and other technologies such as drones and cameras. In relevance to the infrastructure, they could help map asset specific information like individual farmers fields at very fine resolutions. But the

[10] Full Time Equivalent calculated as working person months.

computation, transmission and storage costs would be much higher than coarser products. ICOS and project partners considered a levelised cost per year of 4.58 M€ over the 30 years.

- **Model-assimilated meteorological products:** These are observation products from processes and phenomena pertaining to the atmosphere that incorporate computations and focus on weather predictions. With similar characteristics to the remotely-sensed products from space agencies, the advantage here is a significant network of meteorological agencies already exist on the African continent. Again, here the budget was of 4.58 M€ yearly levelised cost due to the high cost of data processing for fine products.

- **Site-based atmospheric composition measurements:** The objective here is to establish a continental network of tall towers and mountain stations for GHG concentration data in the atmosphere to be collected. Inverse modelling will be applied to describe continental sources and sinks which integrate natural and anthropogenic fluxes. GHGs (carbon dioxide CO_2, methane CH_4 and nitrous oxide N_2O) and other trace gases indirectly involved in climate forcing will be measured. The budget for 10 stations (apart from the 6 existing), research found will half uncertainty of measurements (Nickless et al. submitted). An annual levelised cost of 1.42 M€ was considered.

- **Site-based ecosystem flux measurements:** These are for direct observations of sources and sinks fluxes between land surfaces and the atmosphere. The continental network needs to cover the scope of ecosystems in Africa including agriculture. Agriculture, Forestry and Other Land use (AFOLU) and natural ecosystem GHGs however cannot be measured by this method alone over the African ecosystem due to the magnitude of investment that would be needed. The cost-effective measure here was a strategy to model emissions, driven and constrained by remotely-sensed and meteorological products. This way the sites develop, calibrate and validate models. The budget for 20 sites (apart from 18 existing sites) over 30 years was estimated at a levelised annual cost of 1.54 M€.

- **Site-based automated weather stations:** Meteorological and hydrological models as well as GHG estimation models in agriculture and forestry depend on a dense network of weather stations. The advantage of an automated station is that it would ensure consistency and continuity at a lower cost. A budget for a further 100 stations was considered as well as a maintenance budget for 300 existing stations at a levelised cost of 1.24 M€.

- **Campaign-based calibration products:** Three essential variables require focused campaign values for more reliable models to be constructed: species traits, crop yields and land use. A 30-year cost of 14 M€ was considered at a levelised cost of 0.45 M€.

- **National GHG inventories:** The budget here considered the necessity to sustain the responsible institutions to enable capacity for the submission of GHG inventories by African governments under the United Nations Framework Convention on Climate Change (UNFCCC). A levelised cost of 0.05 M€ was considered for capacity building and reiteration before institutions can self-sustainably report GHG inventories.

- **Site-based TCCON measurements:** A TCCON network will use sunlight directed into a spectrometer to measure the absorption of sunlight by atmospheric GHG and other trace gases. This provides a weighted column of integral GHGs to complement atmospheric in situ measurements. Data from these sites is requested by atmospheric modelers in order to validate their models. This network provides a link to GHG satellite data and provides a reference network for the calibration and validation. A budget of 5 sites was estimated at 10 M€ for 30 years at a levelised cost of 0.32 M€.

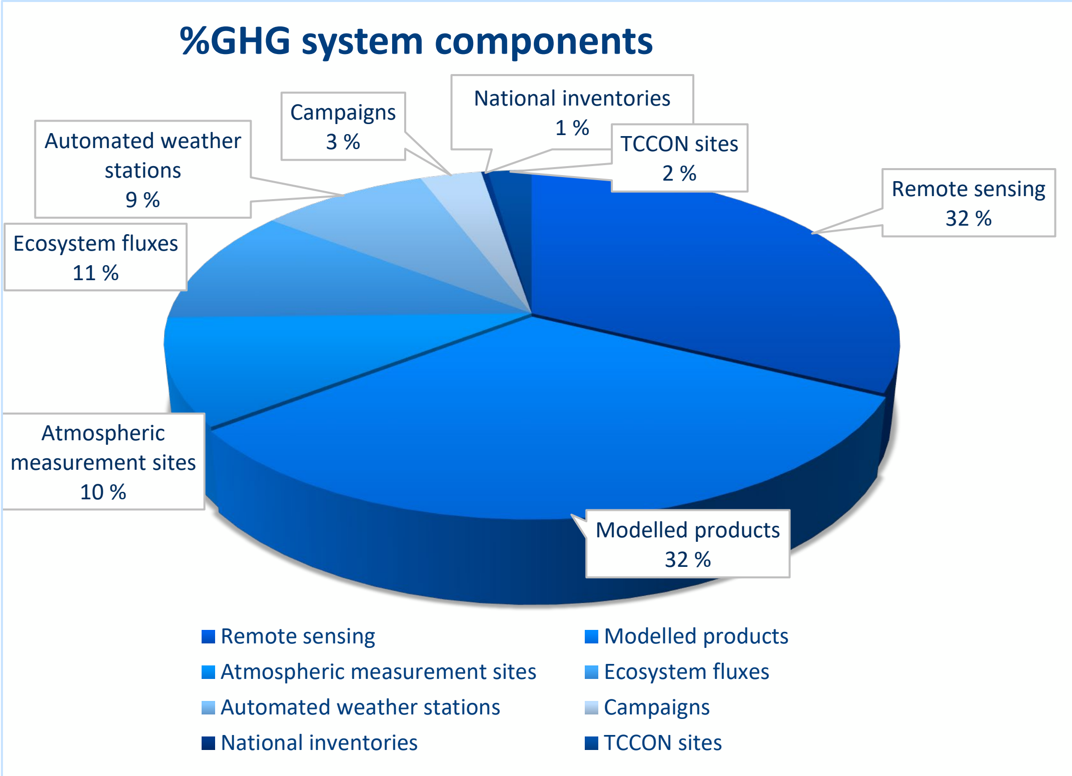

Figure 2. Levelised cost of GHG system components.

3.2 The co-financing concept

A co-financing concept will engage key stakeholders for traditional funding as well as innovative financing for additional funds, for wholesome societal development. Innovative financing brings to the fore several elements namely; the diversity of funding streams, the multisector aspect that considers non-conventional climate financing like the private sector. The IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global GHG emission pathways, mentions innovative financing in its recommendations to strengthen multi-sector global response in the context of sustainable development (IPCC, 2018). The Secretary General of the WMO talked of coherent financing that is needed specifically to complete a system of global climate service investments on which national services rely. The WMO in its concept for GBON for climate related products, acknowledges the need for alternative innovative solutions that ensure country incentivization as well as longevity.

Climate finance is yet to diversify. Mitigation and adaptation finance are estimated at an 95:5 ratio according to research work by (Cui & Huang, 2018), while private sector finance according to (SEI, 2020) makes less than 1% of the overall adaptation funding. The financial sector for example is increasingly interested in investing in climate research services that advise their risk management, which later influences their investment choices in different financial products in the energy, agricultural, transport and other sectors[11]. As we propose a GHG infrastructure for Africa, it is especially required to line its services and products to national, local and to private sector needs. The reason for any innovative funding is that the sustainable value generated from such a system in partnership with the private sector is that the benefits would cut across more societal sectors, apart from serving public sector needs. We present main funding sectors, organisations of interest and their instruments which are quite numerous and will not be exhausted here.

3.3 Funding sectors

The funders portfolios presented range from conventional development organisations to public sector and private sector funding for climate adaptation and resilience.

Public Sector: For the public sector, it is assumed that financially stronger countries have an elevated climate research budget disbursed through national as well as international research funding frameworks, and that Africa's public sector is grappling with different priorities due to very different economic realities. The national requirements for commitment under the UNFCCC consider the Gross Domestic Product of countries in relation to emissions and intends to protect economic development of the country (Höhne et al., 2003; Richards, 2001) in this case a mostly positive aspect for developing countries. Governments in Africa have increasingly and accordingly adopted national plans and strategies with regards to climate change and mitigation. Their commitment to funding climate change research could be sought and in return the GHG system support their engagement to UNFCCC reporting. Concerted effort is needed between governments to increase public sector funding of climate research.

Private Sector: Private climate financing envisages to create low carbon economies and sustainable development; through funding of initiatives that are climate friendly. Paradoxically, even though climate research's main goal is a carbon neutral world, funding from the private sector still often excludes research funding due to an often-lacking element of business generation. Private sector finance for climate adaptation is rare, but increasingly explored (Clark et al., 2018) as a vehicle for climate finance, like though green bonds. A challenge for the African GHG observation system eligibility to this type of climate finance is that research and capacity building are considered to be soft components and they are not prioritised high in the bonds investment agenda which favours hard components which relate to societal technology and infrastructure building (SEI, 2020).

If some of the private sector investor guidelines are reviewed and the system's observation infrastructure are categorised as hard components (defined in SEI 2020 as technology and infrastructure), then private sector finance requirements would be fulfilled by the observation system (not obliging business generation as a criterion, but rather incentivizing innovation in research), in return for data services that are relevant to investor needs. It is notable today that both hard and soft components (capacity building, research…) are increasingly seen as necessary investment targets to avoid creating more problems of imbalance by focusing only on hard components (SEI 2020; The Gold Standard Foundation 2017).

Nevertheless, there is incentive to fund environmental research through the financial sector in general. The incentive is that data from the African GHG observation system could inform investors'

---

[11] Climate data and climate services for the finance sector webinar, April 2020.

risk management plans. Commercial institutions or big companies such as banks and insurance companies as well as telephone service providers are also target funders for climate change. Telephone towers can be used as rainfall observation systems to partner in signal decrease during rain research as is already being done in West Africa. Commercial institutions invest notably in climate services to inform their investment decisions about asset specific investments. The large scale of scope of the proposed GHG system could attract this kind of funding which would normally privilege large projects. A gap that is often a hinderance for the private sector investment in climate resilience and adaptation is the lack of empirical knowledge of the success rate of climate related projects and their value (Clark et al., 2018). By the cost-benefit analysis in chapter 4, this document tries to inform funders of the projected value of the initiative. Attention must be paid to the needs of the private sector.

Development cooperation sector: Multilateral organisations and national development cooperation agencies have financed climate change mitigation and adaptation. The UN and the International Fund for Agricultural Development, on an international scale. On national scales, these are the United States Agency for Development, the Finnish Development NGOs, the British Department for International Development, the French Agency for Development…, which are just but a few of examples that have invested in multilateral programmes for rural support action for sustainability and resilience against adverse effects of climate change. This type of funding has prioritised grants or loans with different development agendas. This funding is found to be highly politicised with bureaucracies from the different implementation rules each donor comes with as well as their uncoordinated effort over the African region. Diminishing returns have been found to be the trend of aid after a certain period of time (Collier 2007), keeping researchers alert high for mechanisms and environments under which to administer effective development cooperation which is important for global growth. Funding for an observation and data infrastructure that will implicate multi-country coordination for CSA will provide a way to centrally administer and coordinate development finance.

3.4 Funding organisations

We present funding organisations and their priorities as well as mechanisms. The national, international, public and private organisations, and multilateral organisations for development cooperation are increasingly financing climate change, some more than others. We hope to attract the attention of the target organisations below that we found key for the financing of the proposed GHG observation system's technical and capacity building agenda.

3.4.1 The United Nations

The 2009 Copenhagen summit proposed to establish the **Green Climate Fund**. The developed countries have since pledged to mobilise funds from public, private, bilateral and multilateral institutions for a target of $100 billion per year by 2020 to help developing countries meet reporting needs to the UNFCCC, however the fund faces upheaval with a lack of commitment, demonstrated by the United States of America which left behind an estimated burden of 14 % points to European countries (Cui & Huang, 2018). The funds are insufficient and characterised by a lot of political upheaval. Studies advise that funding strategies need to be developed to complement the surplus like equities and financial investment, apart from countries needing to commit by historical responsibility and economic capacity (Cui and Huang 2018; Dellink et al., 2009; Müller, Fankhauser, and Forstater, 2013; Cui & Gui, 2015; Cui et al., 2014). Furthermore, costs for writing a GCF grant application are estimated by the WB to be about 225 K€! Until this stability is attained, the GHG observation system may have to look at other sources for funding. **The Clean Development Mechanism** of the UNFCCC is an initiative that was devised to help emission reduction projects generate Certified Emission Reduction units which may be traded in emissions trading schemes. The proposed observation system could provide carbon emissions data in support of the energy and other sector reporting by national governments to the UNFCCC and this way, engage the national governments commitment and participation to the observation system though mutually agreed member partnership terms.

The Global Environment Facility was founded prior to the 1992 Rio Earth Summit and offers several funds. It is composed of UN agencies, development banks, national and as well as private sector organisations and a financial mechanism for 3 UN conventions including the UNFCCC. Relevant to the observation system is the **GEF Trust Fund**, established to help tackle environmental problems that are pressing. The trust fund has 39 donor countries who commit every four years. Ongoing is the GEF-7 up to the year 2022. The goal is to help developing and transitioning countries to meet requirements of international environmental conventions and it is administered by the WB. Other funds are the **Special Climate Change Fund** which focuses on adaptation and technology transfer for UNFCCC signatory countries in areas of health, agriculture, land use, water management and infrastructure development. **Least Developed Countries Fund** which focuses on the implementation of National Adaptation Programmes of Action, the **Capacity-building Initiative for Transparency** which focuses on strengthening institutional technical capacities for countries that are signatory to the UNFCCC and the **Adaptation Fund**. The Adaptation Fund's goal was to focus on concrete programmes in very vulnerable countries to build resilience and climate adaptation against adverse effects, its success has been its direct access policy, where national implementing entities have been able to focus on own national adaptation projects. Nationally Appropriate Mitigation Actions (NAMAS) are an additional instrument to encourage developing countries towards mitigation actions and sustainable development. They are largely financed by the NAMA Facility and half of the GCF budget intended for mitigation would be useful for this instrument.

3.4.2 The World Bank climate change management unit

The Forest Carbon Partnership Facility is a global partnership of governments, businesses, civil society, and indigenous peoples with a focus on sustainable forest and land use. Working with 47 developing countries across Africa, Asia, and Latin America and the Caribbean, along with donors and commitments totalling 1.3 B€. The **Biocarbon Fund Initiative for Sustainable Forest Landscapes** for sustainable forest and land use, it has a goal to reduce emissions from deforestation and forest degradation, and to test a system of REDD+ credits in order to popularise the development and implementation of sustainable land use activities as well as ensure smarter planning, policies and practice. **The Transformative Carbon Asset Facility** helps national decision makers shape environmental, energy, and climate change policy for social impact. The CIFs are also administered by the WB.

3.4.3 The African and European Union

We look at joint funding mechanisms relevant to climate change and the food and nutrition security agendas of the two continents. The Joint Africa-EU Strategy (JAES) emerged from the 2007 meeting of heads of state and government in Lisbon. The JAES provides a framework for AU-EU relations in science technology and innovation through the AU-EU High-Level Policy Dialogue (HLPD), whose discussions culminated in a **Food and Nutrition Security and Sustainable Agriculture (FNSSA)** partnership as well as a **Climate Change and Sustainable Energy (CCSE)** partnership. The observation system is relevant to both partnerships and could be part of a solution for the FNSSA partnership in its efforts to consolidate initiatives and projects in the area. To the CCSE partnership, it could be key in contributing to knowledge by developing products that could inform its climate-smart energy initiatives. A key need here is to harness existing collaboration for joint funding. The ERAfrica initiative was an ERANET co-fund example of a multilateral partnership that was successful at creating a multisectoral approach at funding, independently of the two commissions own funding. The **AU Commission grant** with financial support of the EU, has launched two calls for research proposals in the area of food and nutrition, in a bid to contribute to the FNSSA partnership.

3.4.4 The Nordic Development Fund

The Nordic Climate facility, financed by the NDF fund is headquartered in Helsinki, Finland. Special to this fund is the co-financing aspect where the project, led by a Nordic partner is implemented in a developing country. There is a co-financing requirement of at least 25% of the requested NCF grant as loan, equity and or grant, of that amount the lead applicant who is a Nordic partner provides at least 10% as loan or equity. The local partner must provide 5% as loan, equity and or grant. The remaining 10% can be distributed between project partners and other financiers, while the NCF provides the larger amount. Co-financing can be >25% and proposals providing more co-financing receive a higher score as illustrated in figure 3. The plan would be to submit a concept note for the observation system pilot stage for infrastructure preparation involving new partners for innovation, a key criterion, as well as consolidate existing partnerships. The fund requires that a project be society focused hence a clear need to develop the societal impact component. An innovation component with a one stop knowledge hub, that would consolidate initiatives in food and nutrition security is desirable. Such a co-financing method could be borrowed and applied in a sustainability plan for the future observation system to slowly involve private sector and governments in its financial governance strategies.

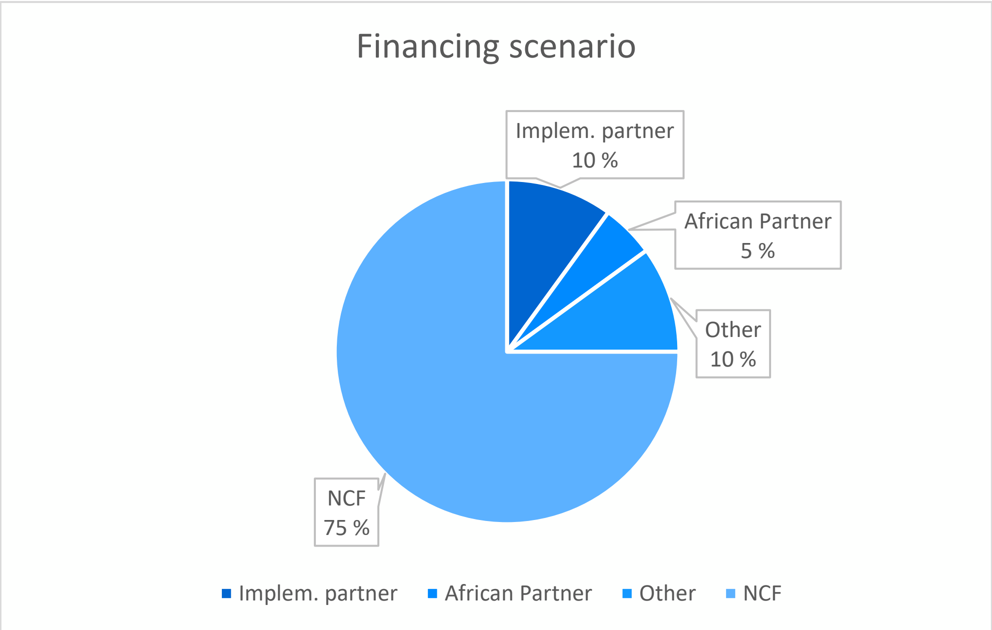

Figure 3. NDF financing scenario

3.4.5 The WMO System Observations Financing Facility

The proposed GHG observation system fulfils a direct need of the Systematic Observations Financing Facility, whose aim is to achieve developing countries' compliance with GBON by 2025. GBON needs countries to implement a minimal set of surface-based observations for numerical weather prediction and climate analysis. The WMO emphasised the need for finance that will value a coherent and long-term system that incentivizes country performance and sustainability. The African GHG system could not be more relevant to its target regions (Africa) and the global south that are largely lacking relevant observation data. The WMO intends for its systematic observations financing facility to find innovative solutions for finance that will, "*ensure coherence of hydromet development activities, provide long-term finance beyond time-bound projects, incentivizes country performance, and ensure sustainability of investments*" [12]. The GHG system should be a beneficiary as well as a main implementing organisation of its objectives.

3.4.6 African and other development banks

The African Development Bank has mobilised about 794 M€ from the **CIF** funds, with investment plans in 27 countries on the continent. It has leveraged an estimated 10 B€ from the public and private source financing and 1.7 M€ from the bank itself covering 26 projects across CIF. Programs include the **Forest Investment Programme (FIP)** which has supported projects addressing deforestation and forest degradation, while focusing on GHG reductions, for benefits such as environmental services, governance, and capacity building. 30.2 Mha of land is reported to be covered under sustainable management practices, more than the targeted 18.5 Mha[13]. GHG emissions reductions have been achieved at 12.3 tCO_2e about halfway the target for 8 countries, and 1.3 million people are reported to have received co-benefits, while FIP success in support to improve governance by strengthening decision making processes through participatory approaches remains unquantified. Secondly, the **Pilot Programme for Climate Resilience** has funded 7 projects for sustainable agriculture achieving 67% of the 185, 379 ha target of land area improved through sustainable land and water management practices (CIP, 2019). Other development banks include the Asian Development Bank, the European Bank for reconstruction and development, the Inter-American Development Bank and the WB Group.

3.4.7 African and other national governments

The observation system would support African national governments for their participation in carbon credit schemes by complementing their reporting, through improvement of their national inventories. Potential project partners who already measure industry emissions from energy consumption could have their activity complemented by in situ observations and monitoring and verification support capacity in the future. The GHG system would help to inform carbon budget offsets for the governments who in turn could submit commitment to the observation system as a function of offset industrial carbon budgets. The GHG structure could later negotiate member country funding with the station host countries bearing specific responsibility.

---

[12] Systematic Observation Facility, Initial Concept, October 2019.

[13] Climate Investment Fund programme results.

We look at the Square Kilometre Array (SKA)[14] as an example: South Africa together with Australia are host countries for the infrastructure, whose intention is to build the world's largest radio telescope. They have a country membership system, for now these are Western countries together with South Africa. However, other African partner countries namely: Botswana, Ghana, Kenya, Madagascar, Mauritius, Mozambique, Namibia and Zambia have committed to hosting the physical infrastructure. The infrastructure has had to ensure funding of 150 M€ for the Phase 1 of construction, and plans for 1.8 B€ from 2018-2027. Even though this is a much larger system in cost, there are similarities with the African GHG observation system. First is the data production from research, second is the location over the African continent hence the similar considerations for funding and governance frameworks. The SKA funding framework has considered the host countries to have a larger contribution engagement and for the rest of the member countries, contributions are based on the relative size of the astronomical communities. Other environmental research infrastructures in Europe are adapting this form of governance for several reasons, the main one being longevity.

Other national governments in focus here are the Finnish government whose year 2020 theme and priority for strategic research was 'Dealing with Climate Change-The Human Perspective'. It has its climate action support administered by the Ministry for Environment and well as that of Foreign Affairs. The German government administers climate finance through the Federal Ministry of Economic Cooperation and Development. The Federal Ministry of Education and Research is also well implicated as well as the German Federal Ministry of Economics and Technology. The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety has a funding instrument called international climate initiative.[15]

4 Socio-economic benefit assessment

A socio-economic benefit (SEB) valuation of products and services is of interest to this co-financing concept, in order to rally innovative funders and policy makers' support but also to inform the whole research and innovation community as well as other actors in society. Societally relevant systems should be accompanied by measures that ensure the implementation of R&I and capacity building agendas. Neo-institutional economists have developed theories that explain problem solving effort by institutions, guiding dynamics for diagnosis, analysis and prediction of outcome.

Different kinds of analysis can be used to evaluate the quality of services, user uptake and the benefits and the overall value of the infrastructure. According to the WMO report from 2015 (WMO, 2015) on valuing weather and climate services, these could be either social science methods or economic methods or both. The social analysis methods here explain the value of a proposed GHG observation system that cannot be expressed yet in monetary terms.

Ostrom's framework terms for institutional analysis, provide a basis for the understanding of the production of outcomes. As a remark, Ostrom does not specify the difference between output, outcome and impact. According to the theory of change and impact pathway (TCIP) instrument, the term output is used to mean research result, outcome connotates behavioural change brought

[14] Square Kilometre Array website.

[15] International Climate Initiative funding instrument website.

about by the results and finally, impact connotates a long-term effect of research. Coming back to Ostrom, if the 'action situation' is taken as the research activity, it could be framed by 'situational variables' which we can consider to be the essential variables in the case of the GHG system. The 'action situation' or research has actors whom according to Ostrom play a significant role as their strategic interaction, guided by rules and information, leads to certain outcomes. Actors weigh benefits and costs of their action. The outcomes are influenced by further evolution of actor relations guided by expectations of each other but also by feedback from contextual variables, in this case, CSA and food security related challenges. (Beckmann, Padmanabhan, 2009; Ostrom, 2009). Beyond Ostrom's framework, the development of the TCIP instrument could contribute to distinguish more precisely between output, outcomes and impact and to serve as a continuous reference point in the collaboration process. The stages in the development of the TCIP instrument are a) a participatory situation analysis, b) the development of common R&I and capacity building agendas and the definition of the desired impact pathways, which include the description of the desired outputs, outcomes and the impacts. The indicators for the common activities accompanying the monitoring and evaluation (M&E) process will have to be defined too.

Similar methods have been applied in the project as a first step to valuing services: 1) Identification and understanding of user needs, problems and perceptions. 2) Reviewing R&I and capacity building agendas which were defined at the beginning of the project. 3) Output, outcome and impact prediction through a TCIP and a benefit-cost concept note. Finally, a future governance concept need is highlighted to support the 30-year investment. A social analysis of benefit is important because some basic research knowledge can have impact that is not quantifiable in monetary terms with regards to societal benefit. Ex-ante and ex-post studies are both relevant to decisions of funding in the long term. At this stage, only ex-ante analysis (based on assumptions of value from historical data and experience) is possible for future potential value estimation of the GHG observation system.

4.1 Diagnosis: User needs identification

WP1 of the project, focused on the exercise of understanding and identifying user needs. This was done alongside essential variable identification in WP4. So that services could be tailored to user needs. The main results from the project were 48 essential variables relevant to the CSA agenda and the carbon cycle observation agenda. In addition, human and institutional capacity building was found to need further development. Furthermore, there is a need for a knowledge management and communication framework that guides strategic knowledge use. The SEACRIFOG collaborative tool, and a dialogue platform for engagement between researchers, policy makers and users are main outputs as ways in which to optimally use data and engage users.

In the D1.1 report, low data availability was a reoccurring finding. A scarcity of terrestrial in situ data products (with key variables missing) and low homogeneity of observations over existing ecosystems and biomes was found to be a hinderance to informed decision making. A data sharing need was highlighted in Africa; with a gap in interoperability and data formats which become a problem for farmer use. A problem of infrequent collection of data was sited, causing a lack in adequate spatial and temporal coverage. Uncertainty in crop yield models as well as precipitation and weather forecast observations was found to be a problem. Data management skills alongside technical equipment like high performance computers are needed. Capacity building therefore needs to be developed with services such as NDC reporting also in mind. Regarding the CSA agenda, land management was found to be needing data, local knowledge, equipment, observation infrastructure and computer software. Farmer cooperation was found to be necessary through information centres and platforms. Transport infrastructure was found necessary for sustained adoption of CSA practices. With regards to climate adaptation and mitigation, water management and irrigation, desertification control, adoption of alternative sources of energy, and sustainable adoption of CSA practises while considering the practicalities of implementation were found to be necessary. Future discussions around research and innovation agendas of the observation system should take into account these findings in order to adopt multiple approaches for further societal relevance.

4.2 Analysis of R&I and capacity building agendas

The value of an African GHG observation system includes better predictions of variables that will allow for increased agricultural productivity, reduced GHGs, improving planning by governments and capacity among other results. So far, the project has first output or results in support of the research and innovation and capacity building agendas and their development will be ongoing in the next programme's stages.

Table 2. The table outlines the R&I and capacity building agendas: land use management, climate-smart agriculture and greenhouse gas emissions observation and human and institutional capacity building agendas.

	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 **2.** 48 Essential variables to the research agenda **3.** 1st meeting of the SEACRIFOG dialogue platform **4.** Design study for optimised atmospheric observation site locations	Personnel training on how to collect, store and process, share data
Outcome	***See table 3 below***	***See table 3 below***
Impact	***See table 3 below***	***See table 3 below***

4.3 Output, outcome and impact prediction

4.3.1 Impact pathways

In the collaboration process of the GHG observation system, the application of a TCIP will serve as a constant reference point for the actors to reflect on their goals and activities through set pathways, to be able to finally carry out an impact analysis.

Table 3. R&I and capacity building in possible pathways to attain societal impact through climate data and knowledge products and services.

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 available through infrastructure: collaborative tool and brokering registry** **2. Other outputs…**	**Personnel training on how to collect, store and process, share data**
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)***
Impact[16]	***1. Reduced GHG emissions*** ***2. Risk management, improved planning and resilience for agriculture*** ***3. Increased agricultural productivity*** ***4. 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 management capacity is present***

Table 4. Future M&E analysis process could include the indicators listed. These should enable impact analysis.

Impact	Examples of indicators
1. Reduced GHG emissions	GHG observation data
2. Improved national planning and risk management	Government use of GHG data and recommendations
3. Increased agricultural productivity	Data about agricultural productivity, like maize productivity per m^2
4. Land use management	Availability of concepts for agricultural and pastoral land use management
5. Improved communication between scientists and end-users of knowledge	Higher communication and data exchange rate
6. More societal acceptance of science as well as of investments into R&I and capacity building activities	Higher rate of government investment in science and education, more public media presence about science

[16] These are impact pathways in a long-term scale needing the definition of indicators for continuous monitoring and indicators.

7. Institutionalised capacity building	Long term curricula about GHG observations, data management and communication established at universities

4.3.2 Benefit-cost analysis (BCA) concept note

According to WMO 2015 valuation of climate services report, a benefit-cost analysis compares net-cost and net-benefit values to find best possible return on investment. An overview of possible value or benefit in this section helps therefore in the development process of the desired impact pathways following a TCIP. In a BCA, a discount rate is considered in monetary estimations, including accounts of non-quantifiable parameters, uncertainties and biases which are meant to assure an investor. In this section we show possible value of the cost of investment as net values would need further study to attain.

The IPCC has reiterated the need for uncertainty reduction in emission data. We consider therefore below a WMO valuation of investment through the Korean Meteorological Administration (KMA)[17] study on its weather services, that looked at investments in Data Processing and Forecasting Systems and valued them against economic gains. The valuation exercise in this chapter draws from a forecast and warning system, and other meteorological investment valuation (weather services), but it gives us a critical view of the added value of an in situ GHG observation system, in complementarity to existing services and products of meteorological and remote sensing technology on the African continent. It considered the following operational components for the valuation exercise: 1) Real time observing and data collection, 2) Routine global data and information exchange and 3) Data processing for meteorological analyses, weather predictions, forecast and warnings.

This report looks at operational components for the planned African GHG observation system in parallel: 1) An observation system for atmospheric, ecosystem and ocean components. 2) Data collection, storage and processing capacity. 3) Capacity building and 4) a knowledge management and communication framework (KMCF).

Korean Meteorological Administration study

A KMA study considered the value of a climate system to be relative to the nature of socio-economic activities, the environmental context and realities of the climate regime. *"It is interesting to note that observation has shown that developing countries only harness part of the full potential benefit from early warning systems. Low-income countries only gain 10 % of the maximum benefit, while the upper middle-income countries gain about 50 %"* (Hallegatte, 2012), WMO[18].

[17] The Korean Meteorological Administration, invested heavily in a Data Processing System and has valuing its products as a mandate to accompany the functionality of the system, in Bulletin no: Vol 62 (1) – 2013.

[18] WMO valuation of investments KMA study.

Technical performance was related in the KMA study to economic terms. They used standard verification measures under the WMO Commission for Basic Systems, converting verification results later to monetary terms which links research output to societal function. *Accuracy* was one of the verification measures considered by the KMA study apart from *reliability, consistency and precision* as well as *forecast lead-time*. The KMA study found benefits linked to accuracy, to be most evident in their contribution to the European Centre for Medium-Range Weather Forecasts, where the global model had improved greatly over decades in accuracy with a root mean square error reduction at 500hPa. This improvement in accuracy was traced back to *satellite data assimilation* to the Korean system, *physical parametrization and technology transfer and software upgrades* while having young scientists who were *trained* alongside. *High resolution modelling techniques* were attributed to this success. Increased *density* of the observation network was cited as having enabled better service provision to villages for example 5km mesh hourly forecasts became possible when resolution and accuracy of regional models were of high quality due to the numerical weather predictions.

Proposed observation system benefit-cost concept note

A further SEB study will be needed to develop this benefit-cost concept note along the lifetime of the proposed system. This section gives an overview of expected benefit of the current cost estimations. A benefit-cost analysis in future will compare net-cost and net-benefit values to find best possible return on investment. The benefit values have not been quantified at this stage.

Table 5. Overview of the benefits attached to each GHG observation system component investment.

Element	**Levelised cost over 30 years (M€ yr^{-1})**	***Benefit***
Remote sensing	4.58	*Finer products/precision, consistency from data processing capacity*
Modelled products	4.58	
Site-based atmospheric measurement site	1.42	*10 new stations complementing existing ones: Optimised location study done for accuracy, consistency in GHG observations*
Site-based ecosystem fluxes	1.54	*20 new stations complementing existing ones: For accuracy, consistency in GHG observations*
Site-based automated weather stations	1.24	*100 automated stations, maintenance of 300 existing: Dense, well-coordinated network for effectiveness, reliability, consistency*
Campaigns	0.45	*Location specific CSA and land-use needs*
National inventories	0.05	*Capacity building for consistent and reliable NDC reporting*
TCCON sites	0.32	*Verification, reliability, accuracy*
Totals	**14.19**	***Capacity building considered in each cost (half of budget) for local ownership.**

An annual budget for remote sensing products of 4.58 M€ and meteorological modelled data processing at the same cost are foreseen to produce *finer products* that cost so much more to process than the coarse remote sensing products. These components are key for a holistic observation system to complement existing data and services investment already on the continent. The result of adding in situ measurements is *accuracy* in GHG measurements for temperature predictions as well as for other variables, that would impact predictions for agricultural land use management and food and nutrition security positively.

Regarding *network density*, effectiveness was considered as a criterion as well to foresee a network of 100 automated weather stations, with a budget for maintenance of 300 existing weather stations over 30 years, at a levelised annual cost of 1.24 M€. They would complement the existing Trans-African Hydro Meteorological Observatory (TAHMO) network which has 20k weather stations installed in schools. They include lesson plans for teachers as well as links to international links to other schools for partnership in learning. The much-needed change is to have an integrated system and not more dispersed infrastructure. A first 10 atmospheric measurement stations were concluded to be necessary by employing a Bayesian inverse model in research for the most *optimized locations* so that meaningful investment is done (Nickless et al, submitted), in addition to existing 6 stations. Some of these stations are already active and the goal would be to equip them, a levelised cost of 1.42 M€ was set. Ecosystem flux measurements were concluded to be complemented by an additional 20 stations at an annual levelised budget of 1.54 M€. 5 TCCON sites and agricultural campaigns for agricultural systems were also budgeted for. *Human and institutional capacity development* for final institutionalisation of necessary skill and for local ownership is important and is the reason why half of the component budget has been considered for this. The goal is to train young scientists to accompany infrastructure through its capacity growth. These elements of the GHG system should fulfil not only *accuracy* requirements, but also *reliability, consistency, precision and real time* needs if compared with the success elements of the KMA study. A cost-saving measure was taken for the GHG system, so that economies of scale are achieved was to consider *least cost technologies for less operational costs* as years go by.

4.3.3 Uncertainties

This report at this stage highlights some expected uncertainties. Capacity building and the trap of losing skilled personnel is one. Additionally, the current network dispersion and lack of integration will need a lot of work done on integration and common data provision. And in society, the human behaviour aspect is a hinderance to realities of climate predictions for agriculture.

4.4 Governance concept

A few questions could be asked at a planning stage of such a size of investment with regards to its governance system and the outputs, outcomes and impacts of applying one over another. This valuation, which is part of the aforementioned ongoing doctoral research on a prospective model for inclusive AU-EU R&I cooperation, should provide understanding and inform research governance for the adoption of a suitable governance system for AU-EU cooperation in R&I activities in GHG exchange observation and Agriculture and Food and Nutrition Security. A transaction cost approach has been considered by neo-institutional economic frameworks to assure outcome efficiency by a reduction of the cost, allowing for a socio-economic approach to the study of organisation. This approach to valuing the institution proposes that the value of an organisational structure focus on a basic unit of analysis which could have a higher cost under certain circumstances but lower in others. Efficiency by an organisation structure is equated to lower transaction costs[19]. The lack of which might not be worth the investment of funding bodies. Recommendations with regards to climate finance urged the formation of convening bodies for cost

[19] The cost here is seen to cause loss, and to reduce efficiency for the desired result due to organisational structural function.

effectiveness of projects in order to avoid resource redundancies (Clark et al., 2018). A proposition therefore in the case of research cooperation is that this reduction of cost could be as a result of efficient cooperation through dialogue. As partners are strategically in contact with the AU and the EU at continental level, the plan is to engage governments actively as well. This must stream down to subnational governance systems where there would be contact between science and the citizens. Facilitating action between international or regional bodies, and local government as well as farmers' organisations is key for the achievement of intended goals.

5 Conclusion

Innovative financing that would allow for multiple sources of climate finance is most likely suited to accompany concerted effort in facing global challenges. The conclusion of the SEACRIFOG project under difficult socio-economic circumstances leaves us voicing the need for global action, to consider carefully climate finance at the core of the efforts towards societal recovery. This by funding a pan-African greenhouse gas observation system with a research and innovation agenda of climate-smart agriculture and food security as well as the carbon cycle observations. Core to this call is funding of a consequential initiative to equip the African continent in its human and institutional capacity development because any global development or growth must be steered jointly. An operational society that owns its growth, manifested as intrinsic motivation that stems from an understanding and a capacity to tackle challenges is the end goal of the proposed system.

Bibliography

Beck, J., López-Ballesteros, A., Hugo, W., Scholes, R., Saunders, M., & Helmschrot, J. (2019). Development of a climate forcing observation system for Africa: Data-related considerations. *Data Science Journal*, *18*(1), 1–11. https://doi.org/10.5334/dsj-2019-042

Beckmann, Volker, Padmanabhan, M. (Ed). (2009). *Institutions and sustainability: political economy of agriculture and the environment-Essays in Honor of Konrad Hagedorn*.

CIP. (2019). *The future is now.* Washington DC: 2020 Climate Investment Funds, The World Bank group.

Clark, R., Reed, J., & Sunderland, T. (2018). Bridging funding gaps for climate and sustainable development: Pitfalls, progress and potential of private finance. *Land Use Policy*, *71*(November 2017), 335–346. https://doi.org/10.1016/j.landusepol.2017.12.013

Cui, L., & Huang, Y. (2018). Exploring the Schemes for Green Climate Fund Financing: International Lessons. *World Development*, *101*, 173–187. https://doi.org/10.1016/j.worlddev.2017.08.009

Hepburn, C., Callaghan, B. O., Stern, N., & Zenghelis, D. (2020). *Will COVID-19 fiscal recovery packages accelerate or retard progress on climate change ? 36*(20), 1–48.

Höhne, N., Harnisch, J., Phylipsen, D., Blok, K., & Galleguillos, C. (2003). *Evolution of commitments under the UNFCCC: Involving newly industrialized economies and developing countries*. *January*.

Hunt, S., Eshete, G., Tadesse, M., & Eshetu, Z. (2019). *Review of agricultural production systems in eastern Africa in relation to food and nutrition security and climate change*. *December*.

Lopez-Ballesteros, A. (2020). *Harmonised observations of climate forcing across Africa: an assessment of esxisitng approaches and their applicability*. 11–14.

López-Ballesteros, A., Beck, J., Bombelli, A., Grieco, E., Lorencová, E. K., Merbold, L., Brümmer, C., Hugo, W., Scholes, R., Vačkář, D., Vermeulen, A., Acosta, M., Butterbach-Bahl, K., Helmschrot, J., Kim, D. G., Jones, M., Jorch, V., Pavelka, M., Skjelvan, I., & Saunders, M. (2018). Towards a feasible and representative pan-African research infrastructure network for GHG observations. *Environmental Research Letters*, *13*(8). https://doi.org/10.1088/1748-9326/aad66c

Masson-Delomotte, V.; Zhai, P.; Pörtner, H.-O; Roberts, D.; Skea, J.; Shukla, P.R.; Pirani, A.; Moufouma-Okia, W.; Péan, C.; Pidcock, R.; Connors, S.; Matthews, J.B.R.; Chen, Y.; Zhou, X.; Gomis, M.I.; Lonnoy, E.; Maycock, T.; Tignor, M.; Waterfield, T. (eds);. (2018). *IPCC Summary for Policymakers. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts.* In Press.

Ostrom, E. (2009). A general framework for analyzing sustainability of social-ecological systems. *Science*, *325*(5939), 419–422. https://doi.org/10.1126/science.1172133

Richards, M. (2001). *A review of the effectiveness of developing country participation in the Climate Change convention negotitions*. *December*.

SEI. (2020). *Green bonds: a mechanism for bridging the adaptation gap?* Stockholm: Stockholm Environment Institute.

Williamson, O. E. (1981). Economics of Organisation: The transaction Cost Approach. *Vol. 87, No. 3 (Nov., 1981), pp. 548-577*.

WMO. (2015). Valuing Weather and Climate : Economic Assessment of Meteorological and Hydrological Services. In *World Meteorological Organization* (Vol. 09, Issue 1153). https://doi.org/10.4236/acs.2019.92014

List of Abbreviations

AFOLU	Agriculture, Forestry and Other Land use
AU	African Union
CCSE	Climate Change and Sustainable Energy
CH_4	Methane
CIF	Climate Investment Funds
CO_2	Carbon dioxide
COVID-19	Coronavirus disease
CSA	Climate-Smart Agriculture
DPFS	Data Processing and Forecasting Systems
EU	European Union
FIP	Forest Investment Programme
FNSSA	Food and Nutrition Security and Sustainable Agriculture
GBON	Global Basic Observation Network
GCF	Green Climate Fund
GCOS	Global Climate observation system
GEF	The Global Environment Facility
GHG	Greenhouse Gas
GOOS	Global Ocean Observation System
HLPD	High-Level Policy Dialogue
hPa	Hectopascal
IPCC	Intergovernmental Panel on Climate Change
JAES	Joint Africa-EU Strategy
KMA	Korean Meteorological Administration
Mha	Million hectares
N_2O	Nitrous oxide
NAMAS	Nationally Appropriate Mitigation Actions
NAPAS	National Adaptation Programmes of Action
NCF	The Nordic Climate Facility
NCF	Nordic Climate Facility
NDC	Nationally Determined Contributions
NDF	Nordic Development Fund
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
SKA	Square Kilometre Array
SKA	Square Kilometre Array
TCCON	Total Column Carbon Observation Network
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
WMO	World Meteorological Organization
WP	Work Package